United States Patent Office 2,997,171 Patented Aug. 22, 1961

2,997,171

METHOD FOR BENEFICIATING POTASH MATERIALS

Gene L. Samsel, Northbrook, Ill., assignor to International Minerals & Chemical Corporation, a corporation of New York

No Drawing. Filed June 2, 1958, Ser. No. 738,988
18 Claims. (Cl. 209—4)

This invention relates to a method of beneficiating potash minerals. More particularly, it relates to a method of electrostatically separating dry particles of potash from the gangue of the ore. Still more particularly it relates to a method of electrostatically separating sylvite values from the halite values with which they are found associated, which method includes treating the ore with finely divided holid particles.

It has been long known that it is possible to beneficiate minerals by electrostatic methods. However, up to the present time, electrostatic methods have been successful from an economical and practical standpoint only in isolated instances.

Two general problems confront those interested in electrostatic methods of beneficiation. The first problem concerns the nature of the apparatus employed to create the electrostatic field. The second problem concerns the methods by which the feed material is advantageously rendered susceptible to the forces exterted in an electrostatic field.

At the present time, the most important methods that have been dealt with in this art are methods involving the phenomenon of "conductance" and the phenomenon of "contact electrification." These and other phenomena of minor importance are disclosed in vol. 32, No. 35, of Industrial and Engineering Chemistry, beginning at page 600.

As distinguished from methods utilizing the phenomenon of conductance, the present invention deals with methods utilizing the phenomenon of contact electrification and, in utilizing such phenomenon, subjects the particles of ore to be separated to an electric field. In apparatus utilizing the contact electrification phenomenon, the electric field is maintained by suitable juxtaposition of electrodes between which substantial differences of electric potential are maintained. Differential electrification of the particles having taken place prior to or at the time of their entry into the electric field and as a result of the phenomenon of contact electrification, the differentially charged particles are caused to be differentially displaced during their travel through the electric field in order that a suitable split may be accomplished in the lower part of the apparatus.

The differences between the "conductance" and "contact electrification" methods of charging and electrostatic separation are thus fundamental and the problems confronted are widely divergent. By the very nature of the different principle of operation involved in mechanisms utilizing these methods, those who employ conductance separation will face requirements and desiderata as to rate of feed and electrification thereof, as well as segregation mechanism that differ in kind and degree from those dealt with in contact electrification methods of separation of the kind herein utilized.

In the utilization of the contact electrification phenomenon followed by subjecting the charged particles to an electric field, problems arise with respect to conditions compatible with effective charge transfer between the particles, as well as conditions which favor the maintenance or even enhancement of the resulting charge. The above enumerated and other problems have caused a marked cleavage to exist between "conductance" and "contact electrification" methods of electrostatic separation.

Various methods of suitably charging particles to effect electrostatic separation of different components are known and include not only the imparting of charges to the particles by means of effecting intimate frictional contact thereof with a source of free electrons, such as a donor plate, but also include the differential charging of the particles as a result of exchange of electrons therebetween upon the effecting of contact between particles of different components of the feed material.

It will be clear from even a cursory review of the literature that the behavior of various ores is, in large measure, unpredictable in electrostatic separation methods. In particular, it cannot be predicted what behavior results when these pure substances are contaminated by the presence of other substances or are present in mixtures of other substances. It has been found by extensive study upon different ores having naturally occurring slimes thereon that the electrostatic separation of particles of ores is inhibited by the presence of such slimes upon the surfaces of such particles. The term "slime" as used herein, includes very fine particles in the form of dusts and other solid bodies as conventionally used in the art and also includes films of solid materials whether or not present as discrete particles. In the present process, slimes, if present on only a small portion of the surfaces of all ore particles treated, sometimes are not detrimental. However, if slimes appreciably cover the surface of the particles to be separated, they generally exhibit troublesome and deleterious effects, which effects must be overcome to obtain a successful beneficiation of the types of ore herein described.

Another factor of importance that determines the behavior of ore particles in electrostatic separations of the freely falling type is the character of the surface of the ore particles. While the exact effect of this factor is not known at the present time, it has been established that variations in this factor as between different ores reflect varying results in the electric separation in which the particles are charged by the contact electrification phenomenon. Thus, each different type of ore presents special problems which must be solved in order to achieve good separations. Accordingly, this invention is restricted specifically to the separation of potash ores.

It has been found that the presence of slimes on the ore particles is detrimental to the obtention of good electrostatic separation. It has also been found that one method of avoiding the deleterious effects of slimes is to remove them by washing. However, in some cases the removal of slimes by washing is either incomplete, impracticable, prohibitively expensive, or otherwise undesirable. For example, in the case of potash ores, washing with water or brine can result in the solution of part of the ore particles which, in itself, is wateful of ore values. Again, washing with water may result in transfer of one of the ore components to the surface of the particles of another component, thus contaminating the natural surfaces of the minerals in the ore. Instead of water, other liquids can be used for washing the ore, but the cost of such washing is oftentimes prohibitive.

Accordingly, it is an object of the present invention to provide a method of beneficiating potash minerals.

It is another object of this invention to provide a method of electrostatically separating dry particles of potash from the gangue of the ore.

It is a further object of the invention to provide a method of electrostatically separating sylvite values from a sylvite ore containing slimes.

It is a specific object of the invention to provide a

method of electrostatically beneficiating a potash ore containing sulfates, such as a langbeinite ore.

It is an additional object of the present invention to provide a method of electrostatically separating sylvite values from a sylvite ore containing slimes, which method includes treating the ore with finely divided solid particles.

These and other objects and advantages of the present invention will be apparent to those skilled in the art from the description of the invention.

In U.S. Patent 2,762,505, granted to James E. Lawver, an electrodynamic method for beneficiating sylvinite ore is described. In the method set forth by Lawver, a potash ore is treated first with a long chain aliphatic amine and then with a monohydric alcohol prior to the electrodynamic separation. While the process as set forth by Lawver is commercially practical, efforts have been made to find different processes for beneficiating potash ore.

In general it is desirable that a new beneficiation process be simpler to operate, cheaper, and/or provide a higher yield and higher purity of product.

In accordance with the present invention, it has been discovered that eminently satisfactory dry beneficiation of potash ores and minerals can be achieved electrostatically by means of a series of critical and interdependent process steps. The process of the invention requires treatment of the mineral feed with finely divided solid particles and also provides a different electrification of the particular components in the feed whereby a commercially attractive electrostatic beneficiation and separation of the constituents of a potash ore are achieved.

In accordance with the discovery of this invention, good electrostatic separation of potash ores may be obtained without removal of slimes from the surface of the ore particles. In carrying out the instant process to obtain potassium containing products, it is preferred that the potash bearing material, such as a slime bearing sylvite ore of relatively low sylvite content, is subjected to a preliminary heat treatment of the proper magnitude. The ore is also treated with a finely divided material. The treated ore is then subjected to a differential electrification and passed through an electric field to effect beneficiation of the ore.

Potash ores which may be beneficiated by this method are the natural ores such as sylvinite consisting of a mixture of sylvite and halite with small amounts of other minerals; sylvinite ore containing carnallite; mixed ore consisting of magnesium sulfate-potassium sulfate complex, sylvite and halite; langbeinite ore, consisting of a magnesium sulfate-potassium sulfate complex, and sylvite, and the like, as well as other potash ores which may contain varying amounts of one or more minerals such as anhydrite, kainite, leonite, magnesium sulfate, polyhalite, syngenite, etc. in addition to sylvite; natural salt mixtures and salt mixtures crystallized from naturally occurring brines as well as artificially created brine solutions. It is also possible to beneficiate potash concentrates obtained in beneficiation processes such as flotation, tabling, electric separation, etc. and these concentrates are intended to be included in the term "ore."

In this novel method, potash ore, for example, as received from the mine, is comminuted to economical liberation size to produce a granular feed material. This granular material is sized to produce a granular feed of a particle size less than about 4 mesh and preferably a feed consisting of −8 mesh +200 mesh particles and still more preferably a feed consisting of −14 mesh +150 mesh particles. The liberation size depends to some extent upon the specific ore. Some potash ores from Canadian deposits are substantially liberated at about 4 mesh while potash ores mined in the vicinity of Carlsbad, New Mexico, are substantially liberated at −14 mesh. The comminution of the ore may be carried out in a single stage or several stages of comminuting equipment. When the ore is comminuted to the mesh size indicated above, the potassium values of the ore are substantially liberated from the gangue and the ore is ready for treatment in accordance with this invention.

Sized granular material is then heated. In the process described in Lawver Patent 2,805,768, the potash ore is heated to temperatures of from 600° F. to the melting point of the ore. While such high temperatures may be used in the present process, good separations are obtained at lower temperatures. The ore is preferably heated to a temperature above 150° F. and more preferably within the range from about 250° F. to about 350° F. After the granular material is heated it is cooled to a temperature in the range of from about 350° F. to about 125° F. and preferably in the range of from about 250° F. to about 150° F. and is then subjected to the differential electrification. Most potash ores are beneficially separated at temperatures within these limits. However, the treated potash ore need not be cooled below 350° F., since separation of treated potash ore has been achieved when the ore was above this temperature.

Before being differentially charged, however, the granular material is treated with a finely divided solid material. At the present time it is not known exactly why the process of the invention is successful in obtaining good separation of potash ore values. However, it is known that the heating of the ore and the treating with finely divided solid material results in conditioning the ore so that it responds to the attractive and repulsive forces operating in an electrostatic field.

The treatment of the ore particles with a finely divided material is performed before the differential electrification of the granular material and preferably is added before the material has cooled below 150° F. The treatment with finely divided material may be performed before the granular material is heated, while it is being heated, or after it has cooled; however, it is preferred that it be performed after the ore has been heated to its highest temperature and before it has cooled below 150° F. Treating the ore with finely divided solid materials at these conditions has produced good results.

The method of this invention is based upon the discovery that potash ores which are not subject to any appreciable upgrading by passage through an electrostatic field may be upgraded when they are treated with a finely divided solid material. The treatment with finely divided solid material is, of course, with finely divided solids in addition to those which may originally be present in the ore. That is, the finely divided solid material is not indigenous to the ore, but it is extraneous to the principal components found in the ore.

The solid materials which are preferred are those which have a work function different from the principal components of the ore which it is desired to separate. By the terminology "work function different from the principal components of the ore" is meant the characteristic of exchanging electrons with the ore component whereby one or more of the ore components exhibits a definite charge. Materials which receive electrons are generally referred to as having a higher work function than the donor material.

As set forth, the finely divided solid material used is one which is extraneous to the principal components of the ore. For example, sylvinite ore contains as the principal components, sylvite, halite, sulfates, and slimes. The finely divided solid material to use in the process of this invention is one which is extraneous of these components, that is, the material used is other than sylvite, halite, sulfates, or slimes. It is, of course, recognized that most ores will contain small amounts or traces of other materials; however, it is not intended to exclude those materials which may be present in small or trace amounts. For example, alumina may be found in some potash ores in small amounts, for example, in an amount of less than about 0.1% by weight. Alumina, however, may be used

in the process of this invention since it is extraneous to the principal components of the ore. It is not intended to limit the invention to any theory, but the invention includes equivalent applications by which ore components exhibiting insufficient charge for effecting separation are, by contact with finely divided material, caused to show a response to eletrostatic fields warranting additional passes for further ore concentration.

Solid materials which are preferred for use in the present invention are the solid inorganic oxides and/or solid inorganic hydroxides of the alkaline earth metals, alkali metals and aluminum. The oxides and/or hydroxides of aluminum, magnesium and calcium are specifically preferred. Activated alumina is also preferred. Although oxides and hydroxides are preferred, other compounds such as carbonates, nitrates, etc. may be used. Of these, the carbonates of aluminum, magnesium and calcium are preferred. Starches, glues, and other such proteinaceous materials in a solid, finely divided form may also be used. The solid material which may also be used includes materials containing these substances and further, two or more materials may be used.

The solid material must be in a finely divided form for use in the process of this invention. For best results, the solid material must have an average particle size appreciably smaller than the average particle size of the component of the ore which it is desired to separate from the gangue. Generally speaking, the solid material is used as a fine powder or dust in which the average size of the particles is many times smaller than the average size of the ore particles. The average size of the particles of the solid material is preferably —50 and more preferably —100 mesh. When processing ore of a —8 mesh size, —200 mesh size solid material is preferably used and —300 mesh size material is still more preferred since —300 mesh size material has produced good results.

The solid finely divided material is intimately mixed with the ore particles in any suitable type of mixing equipment. When the solid finely divided material is a free flowing dust or powder it may be sprayed onto the ore particles. The solid finely divided material may also be applied as a suspension in a suitable carrying medium. It is preferred, however, that the method of application used does not tend to agglomerate the ore particles. The mixing may be either in the presence or absence of an electric field.

At first it was not clearly understood where the finely divided solid material went when it was added to the granular material. That is, it was not known whether the finely divided solids contacted one constituent of the material in preference to the others, or whether it contacted the constituents somewhat equally, etc. It has now been observed, however, that the finely divided solid material is preferentially directed to the slimes, i.e. the slimes appear to have a high affinity for the finely divided solid material. In a sylvinite ore, it has been observed that the finely divided solid material selectively coats the slime particles and slime areas on the surfaces of the particles, regardless of whether they are sylvite or halite particles. In order for effective coating of the slime particle, the finely divided solid must be of a very small particle size. For best results it is, therefore, preferred that the finely divided solid be of a smaller size than the average size of the slime particles in the ore.

It has further been observed that it is only necessary to add a sufficient amount of the finely divided solid material to satisfy the requirement of the slimes. When the amount of slimes is low, the amount of finely divided solids to effect good electrostatic separation of the ore is small; and as the amount of slimes increases, the amount of finely divided solids increases. Therefore, it is indicated that only very small amounts of finely divided solid material need be used, i.e. amounts only sufficient to coat the slime particles without altering the surfaces of the other particles in the granular mixture. Larger amounts may, of course, be used. However it is not economically practical to use an amount greater than needed to effect optimum separation in the electrostatic separation.

Generally, the amount of finely divided solids used will be within the range from about 0.01 to about 10.0 pounds of finely divided solids per ton of material and preferably within the range of from about 0.1 to about 5.0 pounds of finely divided solids per ton of material.

Charging, in accordance with the invention, is attained through the medium of contact electrification. Contact electrification results from the movement of matter in response to such stimuli as differences in escape rate of positive or negative charges, or transfer of electrons or ions across an interface due to differences in energy levels and the like. It has been determined that real crystals never attain the static perfection of an ideal crystal lattice and that a real crystal may have distorted surfaces, displaced ions or atoms, interstitial sites and surface sites, and charge displacement due to separated anion-cation pairs of abnormal ionized atoms and trapped electrons. It is postulated that these traps are capable of acting as donors and acceptors of electrons and frequently it is these traps that are probably the controlling influences in contact electrification of minerals.

Particles of dissimilar materials, if the surfaces thereof do not exhibit differential electrification upon subjection to contact electrification operations, such as agitation, often can be caused to exhibit differential electrification by thermal, chemical, or electromagnetic methods. The differential charge may be acquired, for example, by rupture of an electrical double layer, by mechanical means, as, for example, from interparticle contact and separation or by transfer of electrons from a source external to the particles or any combination of these methods.

Basically, the desired contact electrification depends on temperature, impurity content, and mechanical history of the various surfaces involved. Therefore, it is necessary to determine the precise conditions requisite to optimum selective charging. Under certain conditions the surfaces of the mineral species are such that it is possible to electrify by mineral-metal contact electrification. For example, if such contact causes high electrification with one mineral species and very low electrification with a second mineral species, a selective separation is possible. By way of specific example, quartz-metal contact electrification will result in a relatively high surface charge density on the quartz compared to the corresponding surface charge density on Florida phosphate after phosphate-metal contact electrification. However, even with these materials it is more desirable to employ quartz-phosphate contact electrification since this charging mechanism results in a surface charge density of opposite polarity on the two mineral species to be separated. A more complete discussion of charging mechanisms may be found in Fraas et al., Industrial and Engineering Chemistry, vol. 32, pp. 601–602 (1940).

Following the preliminary heating, treating with the finely divided solid material and differential electrification, the granular material is passed into the electrostatic field. The material just prior to its entry into the electrostatic field should be at a temperature in the range from about 100° F. to about 350° F. and preferably from about 150° F. to 300° F.; however, as hereinbefore set forth, higher temperatures may be used. Entry of the granular material into the electrostatic field at temperatures within this range is preferred since numerous observations have shown that good separations of potash ores are achieved in this temperature range.

Where ore particles are subjected to a series of separations, the feed to subsequent stages often exhibits progressively reduced response to the electrostatic fields. This reduced response is probably due to loss or leakage of charges from the granular particles or coating of the charged granular particles with fines, although it is not

intended that the invention be limited to this theory. Such weak responding concentrates may in one form of treatment be restored or induced to activity by passage through an impactor to create new surfaces and again recharging by frictional or other methods that give rise to differential electrification, which recharging may include a reheating in accordance with the treatment hereinabove described. The ore particles may also be retreated with finely divided solid material between stages or at any other suitable point in the process.

The strength of the electrostatic field which will effectively alter the path of ore particles depends on the mass of the particles and the total surface charge on the particle. The field gradient or strength may vary from about 1,000 volts to about 5,000 volts per inch of distance between electrodes in separating material of relatively fine particle size and from about 3,000 volts to about 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 by means of a direct current potential source substantially free of ripple. A steady supply of direct current may also be obtained with less expensive filtering apparatus by the use of such equipment as a rectified radio frequency power supply.

When sufficiently high benefication is not accomplished in a single stage of electrostatic separation, the usual procedure is to separate a concentrate in a first or so-called rougher stage and to upgrade the concentrate by treatment in two or more so-called cleaner electrostatic separation stages. In some instances reheating of the ore has been found to be beneficial in order to make products of acceptable commercial grade, i.e., consistently to obtain about 55% K_2O products, and such reheating is indispensable in the production of 60+% K_2O products.

By commercial grade is meant 50% or better K_2O content material (higher than 80% potassium chloride). Some product is sold as 50% K_2O granular muriate and appreciable quantities are sold as 60% K_2O content muriate (about 95% potassium chloride content).

When the material to be separated passes through a series of electrostatic fields, the preferred mode of operation provides for the collection of three fractions from each electrostatic field. How these fractions are further treated depends upon whether the emphasis is on a recovery of a relatively pure tail, a relatively pure concentrate, or both. For example, if emphasis is on the concentrate fraction, the operation of the first or rougher separation stage may be such that a throwaway tail is taken in this very first step. Under such circumstances the middling fraction is treated in one or more scavenger sections, in which event the tail product from the scavenger section is likewise a throwaway material and the desired component concentrates of the scavenger section are recycled to a point where the composition of the material corresponds roughly to the composition of the feed material to a separation unit. In another mode of operation the rougher concentrate and rougher tail are not final products, and then each will be subjected to one or more stages of separation to segregate, for example, sylvite from halite. In most instances a middling fraction is recycled either to the feed unit in which it is prepared, or to a point where the composition of the middling corresponds roughly to the composition of the feed material to a separation unit. Thus, it can be seen that there are many variations, when there are four or more separation stages, upon the exact processing order.

In order to give a fuller understanding of the invention, but with no intention to be limited thereto, the following specific examples are given:

EXAMPLE I

Various slime-containing potash ores mined in the vicinity of Carlsbad, New Mexico, were comminuted and screened to produce particles in the size range of about −14 mesh to +200 mesh. This comminuted material was dried at a temperature of approximately 300° F. The slime-bearing material, while at a temperature of about 200° F., was passed in a layer of about ¼ to ½ inch in depth down an inclined vibrating trough and then dropped as freely falling bodies through an electrostatic separator. The field was maintained at a field gradient of approximately 8,000 volts per inch. In several of the runs finely divided aluminum hydroxide of approximately −325 mesh was mixed with the ore in an amount of approximately 5 lbs. of aluminum hydroxide per ton of ore. The results of the single pass separations were as follows:

Table I

Feed	Addition	Assay	Recovery, Percent
Sylvinite Ore 16% K_2O	None	21.6% K_2O	36.7
	Aluminum Hydroxide.	58.5% K_2O	85.7
Mixed ore 21% KCl	None	41.0% KCl	41.3
	Aluminum Hydroxide.	54.5% KCl	64.5
40% Langbeinite Ore	None	63.0% Langbeinite.	41.7
40% Langbeinite Ore	Aluminum Hydroxide.	81.0% Langbeinite.	64.5

This example illustrates the advantages to be obtained by treating the feed to the separation process with finely divided material.

EXAMPLE II

Other potash ores were electrosatically separated as outlined in Example I, however, other finely divided solids were used to treat the ore prior to the drop through the electrostatic field.

The results of these runs are given below in Table II.

Table II

Ore	Finely Divided Solid	Concentrate	
		Assay	Recovery, Percent
Sylvinite Ore 18% K_2O	None	31.0% K_2O	22.0
	$Mg(OH)_2$ —200 mesh	42.0% K_2O	47.5
Sylvinite Ore, 18% K_2O.	Activated alumina —325 mesh.	40.0% K_2O	82.0
Sylvinite Flotation concentrate.	$CaCO_3$ —200 mesh	52.8% K_2O	20.0
Sylvinite Ore, 18% K_2O.	$Mg(CO_3)$ —200 mesh	40.4	64.0
Langbeinite Ore 48% Langbeinite	None	70.0% Langb	78.3
	Hydrated Lime —200 mesh.	84.0% Langb	87.0

EXAMPLE III

A sample of a sylvinite ore analyzing 17% K_2O mined in the vicinity of Carlsbad and comminuted and screened to produce a −20, +200 mesh fraction was divided into two portions. One portion was mixed with MgO of approximately +20 mesh in an amount of approximately 2.5 lbs. of MgO per ton of ore. This mixture was then beneficiated as outlined in Example I.

The other portion was mixed with MgO of approximately −200 mesh in an amount of 2.5 lbs. of MgO per ton of ore. This mixture was also beneficiated as outlined in Example I.

The results of these two runs are given below in Table III.

Table III

Feed	Addition	Concentrate	
		Assay, Percent K_2O	Recovery, Percent
25% K_2O Sylvinite	+20 mesh MgO	30.0	17.8
25% K_2O Sylvinite	−200 mesh MgO	44.2	44.5

The above example illustrates the benefits to be obtained when the solid material is in finely divided form.

The description of the invention utilized specific reference to certain process details; however, it is to be understood that such details are illustrative only and not by way of limitation. Other modifications and equivalents of the invention will be apparent to those skilled in the art from the foregoing description.

Having now fully described and illustrated the invention, what is desired to be secured and claimed by Letters Patent is set forth in the appended claims.

I claim:

1. A method of beneficiating a slime bearing potash-containing material which comprises heating potash-containing particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, treating the particles with finely divided solid material extraneous to the principal components of the potash-containing material and having a work function different from the mineral component being concentrated and an average particle size smaller than the average size of the potash-containing material, inducing the treated particles to accept differential electrical charges subjecting the charged particles to an electrostatic field, and recovering a concentrate.

2. A method of beneficiating a slime bearing potash-containing material which comprises heating potash-containing particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, treating the particles with finely divided solid material extraneous to the principal components of the potash-containing material and having a work function different from the mineral component being concentrated and an average particle size smaller than the average size of the potash-containing material, in an amount of from about 0.01 to about 10.0 pounds of finely divided solids per ton of potash-containing material, inducing the treated particles to accept differential electrical charges subjecting the charged particles to an electrostatic field, and recovering a concentrate.

3. A method of beneficiating a slime bearing potash-containing material which comprises heating potash-containing particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, treating the particles with finely divided solid material extraneous to the principal components of the potash-containing material and having a work function different from the mineral component being concentrated and an average particle size smaller than the average size of the potash-containing material, in an amount of from about 0.1 to about 5.0 pounds of finely divided solids per ton of potash-containing material, inducing the treated particles to accept differential electrical charges subjecting the charged particles to an electrostatic field, and recovering a concentrate.

4. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, treating the ore particles with finely divided solid material extraneous to the principal component of the ore and having an average particle size smaller than the average size of the potash-containing material and a work function different from the mineral component being concentrated, inducing the treated particles to accept differential electrical charges, subjecting the charged particles to an electrostatic field and recovering a concentrate.

5. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, mixing the ore particles with finely divided aluminum hydroxide having an average particle size smaller than the average size of the particles of the ore, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

6. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, mixing the ore particles with finely divided activated alumina having an average particle size smaller than the average size of the particles of the ore, inducing the particles in the mixture to accept differential electrical charge, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

7. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles while in a state of subdivision sufficient to substantially completely liberate the desired components from the gangue, mixing the ore particles with finely divided slaked lime having an average particle size smaller than the average size of the particles of the ore, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

8. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and the melting point of the ore, mixing the ore particles with a predetermined amount of −200 mesh size solid material extraneous to the principal components of the ore and having a work function different from the mineral component being concentrated, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

9. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles of a size in the range between about 8 mesh and about 200 mesh, in an amount of from about 0.1 to about 5.0 pounds of finely divided solids per ton of potash-containing material, to a temperature between about 150° F. and the melting point of the ore, mixing the ore particles with a predetermined amount of −200 mesh size solid material extraneous to the principal components of the ore and having a work function different from the mineral component being concentrated, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

10. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and the melting point of the ore, mixing the ore particles with a predetermined amount of −200 mesh size aluminum hydroxide, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

11. A method of beneficiating a slime-bearing potash ore which comprises heating slime-bearing potash ore

particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and the melting point of the ore, mixing the ore particles with a predetermined amount of —200 mesh size slaked lime, inducing the particles in the mixture to accept differential electrical charges, subjecting the charged particles to an electrostatic field, and recovering a potash concentrate.

12. A method of beneficiating a slime-bearing sylvinite ore which comprises heating the slime-bearing sylvinite ore particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and about 350° F., mixing the heated ore with a —200 mesh size solid material extraneous to the principal components of the ore and having a work function different from the mineral component being concentrated, inducing the particles in the mixture to accept differential electrical charges while at a temperature above 150° F. and thereafter subjecting the charged particles while at a temperature above 150° F. as freely falling bodies to an electrostatic field to beneficiate the ore without substantially altering the charge on the particles while in the field, and recovering a sylvite concentrate.

13. A method of beneficiating a slime-bearing mixed ore which comprises heating slime-bearing mixed ore particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and about 350° F., mixing the heated ore with a —200 mesh size solid material extraneous to the principal components of the ore and having a work function different from the mineral component being concentrated, inducing the particles in the mixture to accept differential electrical charges while at a temperature above 150° F., thereafter subjecting the charged particles while at a temperature above 150° F., as freely falling bodies to an electrostatic field to beneficiate the ore without substantially altering the charge on the particles while in the field, and recovering a potash concentrate.

14. A method of beneficiating a slime-bearing langbeinite ore which comprises heating slime-bearing langbeinite ore particles of a size in the range between about 8 mesh and about 200 mesh to a temperature between about 150° F. and about 350° F., mixing the heated ore with a —200 mesh size solid material extraneous to the principal components of the ore and having a work function different from the mineral component being concentrated, inducing the particles in the mixture to accept differential electrical charges while at a temperature above 150° F., and thereafter subjecting the charged particles while at a temperature above 150° F., as freely falling bodies to an electrostatic field to beneficiate the ore without substantially altering the charge on the particles while in the field, and recovering a langbeinite concentrate.

15. The method as in claim 12 wherein the —200 mesh size solid material is aluminum hydroxide.

16. The method as in claim 12 wherein the —200 mesh size solid material is activated alumina.

17. The method as in claim 12 wherein the —200 mesh size solid material is magnesium hydroxide.

18. The method as in claim 12 wherein the —200 mesh size solid material is slaked lime.

References Cited in the file of this patent

UNITED STATES PATENTS

959,646	Swart	May 31, 1910
2,197,865	Johnson	Apr. 23, 1940
2,757,796	Shoeld et al.	Aug. 7, 1956
2,805,770	Lawver	Sept. 10, 1957