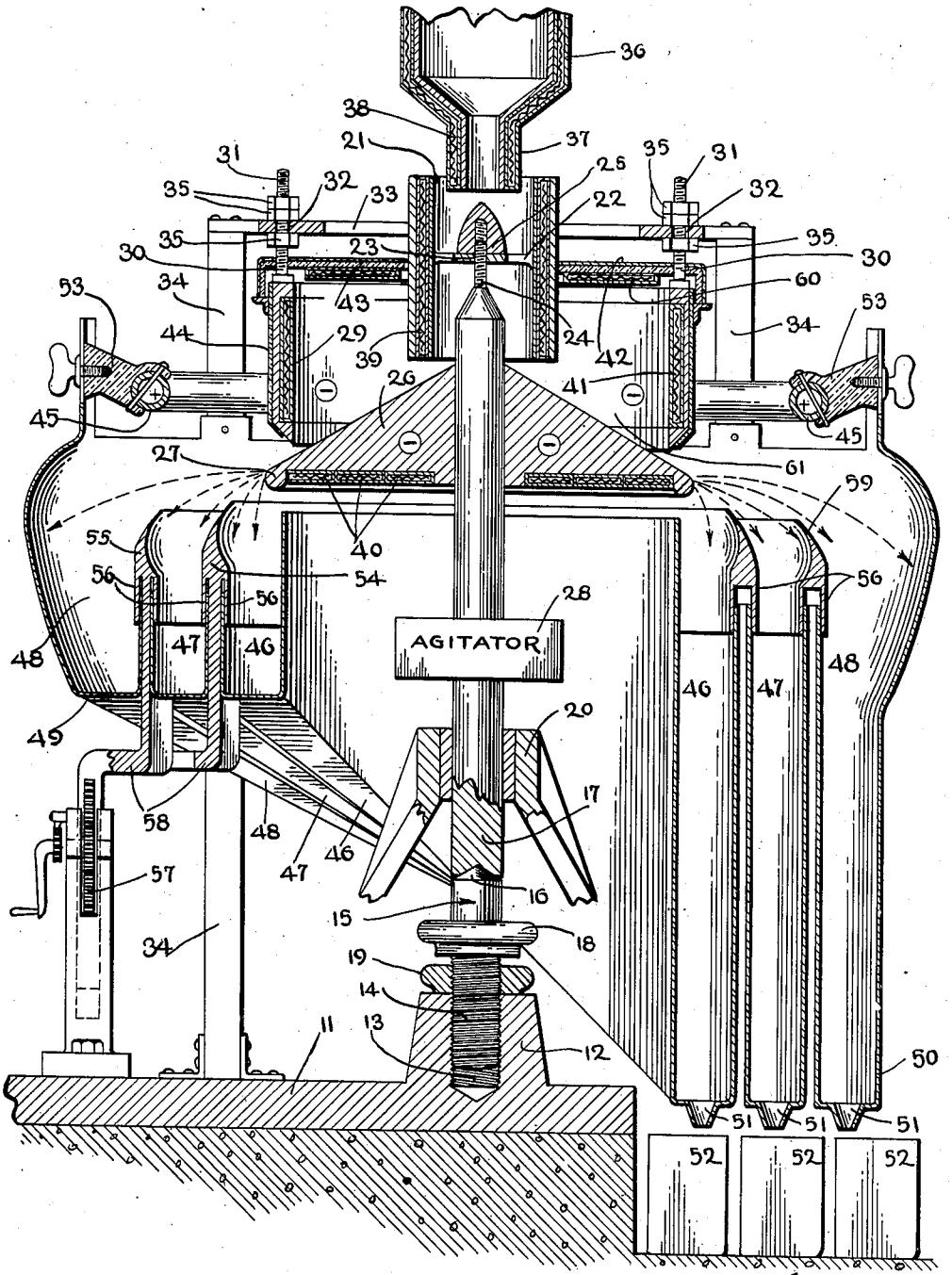
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PROCESS OF CLASSIFICATION AND SEPARATION OF MATERIAL PARTICLES

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PROCESS OF CLASSIFICATION AND SEPARATION OF MATERIAL PARTICLES

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28 Claims. (Cl. 209—127)

This application is a continuation of my copending application 755,694, filed December 3, 1934.

My invention relates to classification and separation of material particles, and the principal object of my invention is the provision of an improved process of classification and separation of material particles. My invention finds one application in the manufacture of refractory heat-conducting electrical insulating material, as for use in electrical resistance heating elements wherein the resistor is refractory embedded, but my invention is not limited to this particular application.

In the manufacture of refractory electrical insulating material I have found that the commingling of particles of different electrical resistivity is likely to reduce the electrical resistivity of the aggregate below the average value, and that the removal of the particles of lower electrical resistivity results not only in increase in resistivity of the residue, but in decrease in variation in resistivity between different portions or specimens of the residue, and for these and other reasons I deem it important in the manufacture of refractory electrical insulating material that the particles of lower resistivity be removed.

At least as respects the materials with which I have operated, in general those particles that are particularly susceptible to electromagnetic influence are of relatively low electrical resistivity, but the reverse does not obtain, that is, only part of the particles of relatively low electrical resistivity are particularly susceptible to magnetic influence, and accordingly, I have not found it possible to attain any such elimination of the particles of relatively low resistivity as I consider satisfactory, merely by magnetic classification and separation.

At the same time, inasmuch as all or almost all of the particles segregated by magnetic classification and separation are particles of relatively low electrical resistivity that need to be eliminated, so that magnetic classification and separation eliminates few if any particles that are desirable in such refractory electrical insulating material, in practicing my invention with relation to refractory electrical insulating material I may employ magnetic classification and separation as a preliminary step, to remove a considerable part of the undesirable particles in this way.

In an endeavor to remove the remaining particles of relatively low resistivity I have subjected the residue from the magnetic classification and separation to electrostatic classification and separation. Speaking generally, the susceptibility of a particle to electrostatic influence is proportional to the electrostatic capacity of the particle, and electrostatic capacity is greater in particles of relatively higher conductivity and less in particles of relatively lower conductivity, or applied to the material on which I have operated, greater in particles of relatively lower resistivity and less in particles of relatively higher resistivity. Therefore it would be expected that electrostatic classification and separation would eliminate a considerable portion of the remaining particles of relatively low resistivity.

In carrying out this electrostatic classification and separation I have warmed the material sufficiently to drive off mechanically associated moisture, for example, up to temperatures of approximately 250° F., and in this way have eliminated erratic variations and uncertainties that otherwise would be occasioned by the presence of such moisture, and with this precaution I have found that this low-temperature electrostatic classification and separation is moderately beneficial, for instance in material employed in heating elements wherein the material may be brought to temperatures of say up to perhaps 1300° F. I have found, however, that by superheating the material, for example, to approximately 800° F., and conducting an electrostatic classification and separation while the material is at this super-temperature, I attain marked improvement over the results attained by only the cold electrostatic classification and separation.

I have found that the various kinds of particles generally possess different resistivities at the temperature of the cold electrostatic classification, but that at this cold temperature the resistivity of each of the different kinds of particles is so extremely high that the differences are relatively small. I have found also that each kind of particles has a different and usually lower resistivity at high temperatures, and further, that the various kinds of particles have different rates of change in resistivity with change in temperature. In fact, I have found that these conditions obtain even among different particles of the same kind, due apparently to slight variations in physical or chemical structure, or to other reasons not so definitely ascertainable.

Under the circumstances I believe the improvement resulting from thermo-electrostatic classification and separation may be ascribed in part to the fact that the particles are subjected to the treatment at a temperature at which the resis-

tivities have decreased sufficiently that differences in electrostatic susceptibility have become sufficiently pronounced to permit accurate separation based thereon, and accordingly, that the use of elevated temperatures is beneficial in itself. However, undoubtedly a very substantial part of the improvement results from effecting the classification and separation at a temperature so approximating the temperature at which the material is to be employed that the classification and separation actually segregates those particles that will have low resistivity at the temperature at which the material is to be employed.

Obviously, under these circumstances successive electrostatic classification and separation at different temperatures is of increased advantage as segregating those particles possessing lower resistivity either cold or hot. Also, in this respect I have found that by successive electrostatic classification and separation at different temperatures, I may effect separations not possible at either temperature.

For example, with three values of particles, one of relatively high resistivity both hot and super-hot, a second of relatively high resistivity hot but of relatively low resistivity super-hot, and a third of relatively low resistivity both hot and super-hot, I may segregate the third value by hot electrostatic classification and separation, and then may segregate the second by subjecting the residue of the hot electrostatic classification and separation to super-hot electrostatic classification and separation, leaving the first also segregated as the residue of the super-hot electrostatic classification and separation. I have found, therefore, that by reason of the differences in rate of change of resistivity, by successive electrostatic classification and separation at different temperatures, I may segregate particles not capable of segregation at either temperature, or for that matter, at any single temperature.

Owing to the wide variety of materials to which my process is applicable it is impossible to set exact temperatures, electrical potentials, or other conditions, for general application, but the treatment of an ore of zircon ($ZrSiO_4$) may be taken by way of example.

A residue of such ore analyzing ZrO_2 60% or higher and SiO_2 40% or lower possesses a relatively high fusing point, a relatively high electrical resistivity, and a relatively low rate of decrease in resistivity at least up to temperatures of approximately 1300° F., and at the same time possesses moderately high heat conductivity, and accordingly such residue is peculiarly adapted for use as a refractory material for embedding the resistors of electrical resistance heating elements operating at temperatures now employed. However, such residue does not occur pure, but in an ore containing in addition to the grosser impurities such other minerals as ilmenite ($FeTiO_3$), magnetite (Fe_3O_4), rutile (TiO_2), and sometimes monazite (a mixture containing cerium oxide up to 28%, didymium oxide up to 15%, lanthanum oxide up to 13%, phosphoric acid up to 26%, alumina up to 5.5%, and titanic acid up to 3%), and these other minerals being largely either detrimental or positively objectionable for this particular purpose, in general need to be eliminated.

To segregate the zirconium-silicon oxides I preferably first treat the zircon ore by preliminary processes to remove the grosser impurities and leave the zirconium-silicon oxides admixed substantially only with these other minerals, principally ilmenite, rutile, magnetite, and sometimes monazite.

The iron-bearing minerals either are or may be made susceptible to magnetic influence, accordingly I prefer to eliminate the magnetite and ilmenite by magnetic classification and separation. However, the rutile and monazite are relatively less susceptible to magnetic influence, and also, at low temperatures rutile and monazite are not of sufficiently different electrical resistivity than the zirconium-silicon oxides and can be separated from the zirconium-silicon oxides by any usual cold electrostatic classification and separation only by repeated passes through an electrostatic field of relatively high potential, and then only in part.

I have found, however, that while the resistivity of the zirconium- silicon oxides remains relatively high up to approximately 1300° F., the resistivity of rutile is sharply decreased at temperatures of approximately 600° F., and accordingly, that I can very easily segregate and eliminate the rutile by electrostatic classification and separation at a temperature somewhat in excess of 600° F., for example, 800° F., Also, that I may eliminate the monazite in the same way, at a temperature depending on the composition.

Specifically, I have found that such zircon ore subjected only to preliminary treatment and magnetic classification and separation may have resistivities of, for example, at 1100° F., 20.0 megohms, at 1200° F., 14.0 megohms, and at 1300° F., 6.5 megohms, while the same material subjected also to cold electrostatic classification and separation will be only of slightly increased resistivity, for example, at 1100° F., 24.3 megohms, at 1200° F., 15.0 megohms, and at 1300° F., 7.2 megohms, but that treatment of the same material by electrostatic classification and separation at approximately 800° F. renders the material of markedly increased resistivity, for example, at 1100° F., in excess of 50.0 megohms, at 1200° F., 21.7 megohms, and at 1300° F., 10.0 megohms.

On the other hand, if the same material is heated to and tested at a temperature of approximately 1600° F., the results may be reversed. The material subjected only to preliminary treatment and magnetic classification and separation may have a resistivity of say 0.93 megohm, the material subjected also to cold electrostatic classification and separation a resistivity of only 0.64 megohm, and the material subjected also to electrostatic classification and separation at approximately 800° F., a resistivity of only 0.43 megohm.

It appears, then, that while thermo-electrostatic classification and separation is advantageous in itself, as acting at a temperature at which the differences in resistivity generally have become more pronounced, and that while successive electrostatic classification and separation at different temperatures is advantageous and can be employed to segregate particles not otherwise separable, nevertheless, in treating to secure a residue of maximum electrical resistivity, the electrostatic classification and separation, or the successive electrostatic classifications and separations, desirably should include the range of temperature to which the refractory is to be subjected, including if possible the maximum temperature to which the refractory is to be subjected, at least to an extent to include whatever decisive critical points may be within the range.

Specifically, material intended to be used at 1600° F. should be subjected to electrostatic classification and separation at a temperature sufficiently approximating 1600° F. that no decisive critical point lies between.

My process, therefore, contemplates thermo-electrostatic classification and separation at elevated temperatures at which the differences in electrostatic susceptibilities of the particles are sufficiently pronounced to form a suitable basis for electrostatic classification and separation, rather than at the low temperatures required merely for drying the material, at which the electrostatic susceptibilities of the particles are too slight and/or the differences in electrostatic susceptibility relatively insufficient.

My process also contemplates successive electrostatic classifications and separations at different temperatures, higher or lower, to eliminate particles having low resistivity at any of the selected temperatures, and the selection of the temperatures to approximate as largely as practicable the range of temperatures within which the material is to be employed.

My process contemplates also electrostatic classification and separation at an elevated temperature sufficiently close to the temperature at which the material is to be used that the selection is effective for the temperature of use.

Additionally, my invention comprises the use of electrostatic classification and separation at one or more elevated temperatures selected to effect the particular segregation sought to be effected, based on difference in rate of change of resistivity with change in temperature.

However, once a material is separated into its constituents, obviously the constituents may be employed for any and all purposes for which they may be suitable, accordingly my process is valuable not only in the production of material for purposes where the degree of electrical resistivity or conductivity is important in itself, but also in the production of materials for other purposes. It is applicable likewise to the production of material that is electrically conductive and to the production of material that is electrically resistant or electrically insulating, to the production of material that is heat-insulating and to the production of material that is heat-conducting, and to the production of non-refractory material and to the production of refractory material.

Also, while my invention is particularly valuable as applied to the production of materials for uses where electrical resistivity or conductivity is directly important, it also is applicable with particular facility in the production of materials in respect of which the fundamental criterion is a property that bears some direct relation to electrostatic susceptibility or electrical resistivity or conductivity. For example, while not all materials that suffer a rapid lowering of resistivity with increase in temperature are fusible at relatively low temperature, most if not all mineral materials suffer a heavy decrease in electrical resistivity as the fusing point is approached, accordingly I may classify not only on the basis of electrostatic capacity or electrical resistivity, but by reason of this relationship, indirectly with reference to the temperature of fusion. The invention therefore is extremely valuable both for direct classification on the basis of electrostatic susceptibility or electrical resistivity and for indirect classification on the basis of fusing point, and therefore contributes both to the electrical art and to the refractory and ceramic arts, particularly in connection with super-refractories and super-insulators, and in an especially particular sense, in connection with the manufacture of refractory insulators normally operating at more or less elevated temperatures.

In performing my process, particularly as applied to free flowing material, I may conveniently employ apparatus such as is disclosed in the accompanying drawing, in which the single figure is a general vertical sectional view.

The illustrated apparatus comprises a base 11 provided with a central boss 12 having an axial screw-threaded aperture 13 in which is received the screw-threaded lower end 14 of a supporting stud 15 provided with an alined upper end terminating in a concentric cone 16 on which seats the conically recessed lower end of a coaxial shaft 17. The shaft 17 may be raised and lowered by rotation of the stud 15, as by means of the hand-wheel 18, and the stud may be locked in any adjusted position by means of the hand lock-nut 19, thus locking the shaft 17 in corresponding vertical-adjusted position. The shaft 17 is supported laterally by a bearing bracket 20 suitably mounted on the base 11.

Mounted on the upper end of the shaft 17 is a feed duct 21 provided internally with a spider 22 having a central screw-threaded aperture 23 cooperatively receiving a reduced screw-threaded extension 24 of the shaft 17, whereby the feed duct 21 is supported on the shaft 17, but vertically adjustable by rotation relative to the shaft 17. Available to lock the feed duct 21 in any adjusted position is a lock-nut 25 formed conical on its upper side to minimize lodgment of material thereon.

Also mounted on the upper end of the shaft 17, but below the feed duct 21, is a distributing cone 26 arranged to receive material from the feed duct 21 and discharge such material over its periphery 27 in an annular stream. Permissibly the cone 26 may be of such inclination that the material will discharge therefrom by gravity, but herein I have shown the cone 26 as of lower inrate of discharge, merely by change in rate or inclination, and the shaft 17 as provided with agitating means 28, operative to agitate the shaft 17 and cone 26 to effect discharge of the material from the cone 26, and for free-flowing particles I prefer this arrangement, both because it provides greater uniformity of discharge and also because it permits convenient adjustment of the tensity of agitation of the shaft 17 and cone 26.

The agitator 28 may be an electro-magnetic vibrator agitating the shaft 17 and cone 26 either axially of the shaft 17 or about the axis of the shaft 17, or may be an electric motor rotating the shaft 17 and cone 26 and acting in conjunction with cooperating surfaces that produce concurrent vibration of the shaft 17 and cone 26, or the agitator 28 may be of any other construction that may be found desirable for any particular reason or for any particular material or use. A movement about the axis of the shaft 17 in some instances has the advantage of breaking any wedging of material particles between the cone 26 and any other part, such as the gate 29 hereinafter described, but any such movement needs to be agitation as distinguished from rotation at any speed that will impart to the particles any measurable centrifugal force or otherwise will interfere with the desired condition of the particles leaving the periphery of the cone 26 in a uniform stream and with a minimum velocity

incapable of introducing any variable into the operation of the apparatus.

Above the cone 26, slightly inwardly of the periphery 27, is an annular gate 29 provided to afford additional control of the discharge from the cone 26 and mounted vertically-adjustable by means of a plurality of rods 30 secured to the upper face of the gate 29 and provided with screw-threaded upper ends 31 passing through plain apertures 32 in a spider 33 supported by a frame 34 secured to and rising from the base 11, the gate 30 being secured in vertically adjusted position by nuts 35 screw-threadedly engaging the screw-threaded upper ends 31 of the rods 30 and abutting the upper and lower faces of the spider 33.

Positioned above the feed duct 21 is a furnace 36 provided with a discharge spout 37 extending into the feed duct 21 to be self-stopping, that is, when material builds up in the feed duct 21 to adjacent the level of the end of the discharge spout 37 the material in the feed duct 21 will automatically block the discharge spout 37 and prevent further discharge of material into the feed duct 21 until the level of the material in the feed duct 21 has been suitably lowered.

The furnace 36 may be heated in any suitable manner, depending largely on the temperature desired and the sources available, and preferably is provided with temperature control and automatic temperature limitation; herein I have illustrated a furnace for moderate temperatures, and have shown the furnace heated by electric resistance heating elements 38 energized from a suitable supply. Also, I have shown the feed duct 21 heated by similar elements 39, the cone 26 by other elements 40, and the gate 29 by further elements 41, and have shown the upper end of the gate 29 closed by a cover 42 mounted on the feed tube 21 and heated by a further heating element 60, all to maintain the material at the desired temperature in the hopper 61 formed by the cone 26, gate 29, and cover 42, the various heating elements to this end being under suitable control.

In operation, the material is heated in the furnace 36, passes from the furnace 36 through the spout 37 into the feed duct 21, and from the feed duct 21 onto the cone 26 down and from the periphery 27 of which it travels under the impetus of the agitation effected by the agitator 28, falling from the cone periphery 27 in an annular stream preferably of uniform and minimum velocity. The flow from the furnace 36 into the feed duct 21 is regulated by the blocking of the furnace nozzle 37 when the level of the material in the feed duct 21 rises above a predetermined maximum, while the rate of flow from the feed duct 21 onto the cone 26 is regulated by the vertical position of the vertically adjustable feed duct 21 and to some extent by the rate and intensity of action of the agitator 28. Likewise, the rate of flow from the cone periphery 27 is regulated by the vertical position of the vertically adjustable gate 29 and by the rate and intensity of action of the agitator 28. Desirably the parts are adjusted so that the material flows from the cone periphery 27 in a uniform thin annular stream at minimum velocity.

During the entire flow the material is maintained at elevated temperature by the controlled heat from the feed duct 21 and from the oven 61 formed by the cone 26, the gate 29, and the cover 42, and for this purpose the cover 42 may be provided on its inner surface with a heat-insulating surfacing 43, and likewise, the gate 29 may be provided on its exterior surface with an electrical-insulating heat-insulating covering 44.

Spaced from the cone periphery 27, adjustable relative thereto, is an annular electrode 45 supported indirectly by the base 11, but suitably insulated from the other parts of the machine, and connected to this electrode 45 is the positive terminal of a variable-potential unidirectional electric circuit of, for example, from 1000 to 50,000 volts, the negative terminal of which is connected to the remainder of the machine, and particularly to the cone 26 and the gate 29.

The material in passing over the cone 26 will acquire a negative charge, varying in intensity with each particle according to the electrostatic capacity of the particle, and when the particle leaves the cone periphery 27 the particle will be deflected outwardly by the annular positive electrode 45 according to the strength of the negative charge the particle has acquired. Some particles will acquire little or no charge, will be influenced little or not at all, and will drop into the inner annular receptacle 46. Other particles will acquire an intermediate charge, will be influenced intermediately, and will fall in an intermediate annular receptacle 47. Still other particles will acquire a strong charge, will be influenced strongly, and will fall in an outer annular receptacle 48.

Each of the receptacles 46—47—48 is of progressively increasing depth from a shallow place 49 in both directions to a diametrically opposite deep place 50 at which the receptacle is provided with a suitable discharge spout 51 through which the material from that receptacle is discharged, as into a suitable container 52. The receptacles 46—47—48 are supported on the frame 34, and the outer wall of the outer receptacle 48 is extended upwardly and carries a plurality of brackets 53 formed of insulating material and mounted in the annular electrode 45.

As will be appreciated, the relative elevations of the cone 26 and of the electrode 45 may be adjusted by raising or lowering the electrode 45, or by raising or lowering the cone 26 by raising or lowering the shaft 17 by means of the hand-nut 18, and the electrode 45 may be replaced by an electrode of any other diameter, all to properly adjust the position, shape, and intensity, of the electrostatic field.

It is desirable, however, that provision be made whereby the division of the material between the receptacles 46—47—48 may be varied, and for this purpose the divisions between the receptacles 46 and 47, and between the receptacles 47 and 48, are constituted by annular members 54 and 55 provided with sharp upper edges 59 and with depending skirts 56 embracing the respective receptacle edges but mounted on the frame 34 independently of the receptacles and vertically movable relative thereto. For this purpose the frame 34 is provided with two raising and lowering mechanisms 57 operating two brackets 58 to which the two members 54 and 55 are secured. It will be appreciated that the higher the member 54 or 55 the greater the deflection required for the particle to pass over the member, and accordingly, that changes in the division of the material may readily be accomplished by raising or lowering the members 54 and 55.

It also will be appreciated that the particular apparatus herein disclosed eliminates any variation by reason of centrifugal action, since with any indicated construction of the agitator 28, the

material falls from the cone periphery 27 with minimum velocity, without in any sense being thrown. The various parts of the apparatus subjected to heat are made of materials suitably heat-resistant. Also, the division of the particles may be into three parts as indicated, or into any other number of parts as may be desired, either more or less, and the number of receptacles 46—47—48, annular members 54 and 55, supporting brackets 58, and raising and lowering mechanisms 57, will be increased or decreased accordingly.

On the other hand, it will be appreciated also that my processes are in no way limited to the particular apparatus herein disclosed, and that while I regard this apparatus as particularly satisfactory for the practice of my processes, nevertheless the processes can be practiced with any other apparatus suitable for the purpose, for example, the apparatus shown in my co-pending application Serial Number 149,806, filed June 23, 1937.

As used herein, the term refractory material generally designates compounds and in any event does not include metals. The term zirconium-silicon oxides includes the combination or combinations commonly designated zirconium silicate. The term nature refers to the qualities or characteristics of a particle which distinguish that particle from any other particle, and whether the particles are of different species or kinds or of the same species or kind. The term normal temperatures designates ordinary temperatures, for example, in the neighborhood of 70° F. Reference to driving off mechanically associated moisture, and the term dry condition, refer to a condition in which mechanically associated moisture is not present in any amount sufficient to control or change the essential result of the separation. Also, in any instance there may be present particles other than those particularly considered, and the classification and separation may place such other particles with one part of the particles particularly considered, or divided between two or more such parts, or separately from any such parts. And in general, it is to be understood that my invention is not limited to the specific embodiments hereinabove disclosed, and that the above disclosure is illustrative only, for the purpose of explaining my invention and not for the purpose of defining it.

I claim:

1. The process of classifying a mixture of material particles which, after mechanically associated moisture has been removed by subjection of such particles to a drying temperature, have intrinsic electrical characteristics at such temperature, which comprises: superheating the dried mixture of said particles to a super-temperature above such drying temperature, said super-temperature approximating the fusing temperature of a selected class of said particles, to occasion a substantial change in an electrical characteristic of said particles, and, by causing said superheated mixture to move with respect to an electrostatic field, effecting a separation from said mixture of said selected class of particles which is determined by the difference in such electrical characteristic as possessed by said selected class of particles and by the other particles of said mixture at said super-temperature.

2. The process of classifying a mixture of dry particles of refractory materials of different natures, which comprises: superheating said mixture to a super-temperature, above the temperature required to dry said particles and maintain said particles dry, said super-temperature being determined by the fusing temperature of a selected class of said particles; and causing said superheated mixture to move with respect to an electrostatic field and effecting a separation from said mixture of said selected class of particles.

3. The process of fractionally classifying a mixture of dry material particles of different natures, which comprises: superheating said mixture to a super-temperature, above the temperature required to dry said particles and maintain said particles dry, at which super-temperature a substantial relative difference in the electrostatic susceptibility of a certain class of said particles with respect to another class of said particles exists, said super-temperature being determined by the differences in nature of said different classes and by the relatively dissimilar variability in response to temperature change of the electrostatic suspectibilities possessed by said different classes due to said differences in nature; and causing said superheated mixture to move with respect to an electrostatic field and effecting a separation of said classes on the basis of the difference in electrostatic susceptibility of said classes at said super-temperature; and heating a selected class of particles, resulting from said separation, to a temperature different from said super-temperature; and causing said so heated selected class to move with respect to an electrostatic field and effecting a further separation of the particles of said selected class on the basis of the difference in electrostatic susceptibility of sub-classes of particles of said selected class at said different temperature.

4. The process of fractionally classifying a mixture of dry particles of refractory materials of different natures, which comprises: superheating said mixture to a super-temperature, above the temperature required to dry said particles and maintain said particles dry, at which super-temperature a substantial relative difference in the electrostatic susceptibility of a certain class of said particles with respect to another class of said particles exists, said super-temperature being determined by the difference in nature of said different classes and by the relatively dissimilar variability in response to temperature change of the electrostatic susceptibilities possessed by said different classes due to said differences in nature; and causing said super-heated mixture to move with respect to an electrostatic field and effecting a separation of said classes on the basis of the difference in electrostatic susceptibility of said classes at said super-temperature; and heating a selected class of particles, resulting from said separation, to a temperature different from said super-temperature, and causing said so heated selected class to move with respect to an electrostatic field and effecting a further separation of the particles of said selected class on the basis of the difference in electrostatic susceptibility of sub-classes of particles of said selected class at said different temperature.

5. The process of effecting a desired separation of a mixture of dry material particles of different natures, comprising particles of refractory electrical insulating material, into a plurality of different portions, to obtain a desired refractory electrical insulating material, which comprises, heating said mixture to a selected super-temperature which is substantially above a drying temperature but below the temperature

at which the desired separation would be prevented by agglomeration of the particles by fusion, which in effect approximates the maximum temperature at which said refractory electrical insulating material is to be used, and at which the desired separation may be effected by reason of the difference in the motion response of the particles to an electrostatic field at that temperature, and subjecting said particles to the action of an electrostatic field while said particles are at said super-temperature, and effecting a separation of said particles at said super-temperature, by reason of said difference in said motion response at said super-temperature, to segregate said desired refractory electrical insulating material.

6. The process of effecting a desired separation of a mixture of dry material particles of different natures, into a plurality of different portions, which comprises, heating said mixture to a selected super-temperature which is substantially above a drying temperature but below the temperature at which the desired separation would be prevented by agglomeration of the particles by fusion, and at which the desired separation may be effected by reason of the difference in the motion response of the particles to an electrostatic field at that temperature, and subjecting said particles to the action of an electrostatic field while said particles are at said super-temperature, and effecting a separation of said particles at said super-temperature by reason of said difference in said motion response at said super-temperature, and then subjecting a separated part of said particles to the action of an electrostatic field while said part of said particles is at a selected temperature different from said selected super-temperature and at which a further separation may be effected by reason of the difference in the motion response of the particles of said part to an electrostatic field at that different temperature, and effecting a separation of said particles of said part at said different temperature, by reason of said difference in said motion response at said different temperature.

7. The process of effecting a desired separation of a mixture of dry material particles of different natures, into a plurality of different portions, which comprises, heating said mixture to a selected super-temperature which is substantially above a drying temperature but below the temperature at which the desired separation would be prevented by agglomeration of the particles by fusion, and at which the desired separation may be effected by reason of the difference in the motion reponse of the particles to an electrostatic field at that temperature, and subjecting said particles to the action of an electrostatic field while said particles are at said super-temperature, and effecting a separation of said particles at said super-temperature by reason of said difference in said motion response at said super-temperature, and then subjecting a separated part of said particles to the action of an electrostatic field while said part of said particles is at a different selected super-temperature, also above a drying temperature but below the temperature at which the desired separation would be prevented by agglomeration of the particles by fusion, but different from the first said selected super-temperature and at which a further separation may be effected by reason of the difference in the motion response of the particles of said part to an electrostatic field at that different super-temperature, and effecting a separation of said particles of said part at said different super-temperature, by reason of said difference in said motion response at said different super-temperature.

8. The method of effecting electrostatic separation of a mixture of dry material particles comprising refractory electrical insulating material, into at least two classes of particles, to obtain a desired electrical insulating material, comprising, differentially adjusting the electrostatic susceptibilities of said classes by bringing said mixture at least to a temperature which is substantially above a drying temperature and in effect approximates the maximum temperature at which said desired material is to be used, and at which there exists a substantial difference in electrostatic susceptibility between one part of the particles and another part of the particles, subjecting said mixture to an electrostatic field at said temperature, and effecting a separation of said classes by reason of the differentially adjusted electrostatic susceptibility existing at said temperature, to obtain said desired electrical insulating material.

9. In respect of a mixture of dry material particles, the process of effecting a separation of said particles, separating said particles into a plurality of portions, which comprises, heating said particles at least to a first temperature which is substantially above normal temperatures, and at which there exists a substantial difference in motion response to an electrostatic field, between one part of said particles and another part of said particles, by reason of which a desired separation of said particles may be effected, and while said particles are substantially at said first temperature, subjecting said particles to the action of an electrostatic field, and effecting a separation separating said particles into said portions, by reason of said difference in motion response, and then, in respect of a separated fraction of said particles, causing the particles of said fraction to be at a second temperature, substantially different from said first temperature, at which there exists a substantial difference in motion response to an electrostatic field, between one part of said particles of said fraction and another part of said particles of said fraction, by reason of which a desired separation of said particles of said fraction may be effected, and while said particles of said fraction are substantially at said second temperature, subjecting said particles of said fraction to the action of an electrostatic field, and effecting a separation of said particles of said fraction into a plurality of portions, by reason of said difference in motion response at said second temperature.

10. The process of separating into a plurality of portions, co-mingled particles of mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises, subjecting said particles to the action of an electrostatic field while said particles are of the same chemical constituencies as in dry condition at normal temperatures but are at a selected super-temperature above two hundred and fifty degrees Fahrenheit determined on the basis of differentiation in electrostatic susceptibility in response to change in temperature, and effecting a division of said particles into said portions, on the basis of the electrostatic susceptibilities at said super-temperature, while said particles are of said same chemical constituencies.

11. The process of separating into a plurality of

portions, co-mingled particles of refractory mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises, subjecting said particles to the action of an electrostatic field while said particles are of the same chemical constituencies as in dry condition at normal temperatures but are at a selected super-temperature above two hundred and fifty degrees Fahrenheit determined on the basis of differentiation in electrostatic susceptibility in response to change in temperature, and effecting a division of said particles into said portions, on the basis of the electrostatic susceptibilities at said super-temperature, while said particles are of said same chemical constituencies.

12. The process of separating into a plurality of portions, co-mingled particles of mineral oxides or oxide compounds the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises, subjecting said particles to the action of an electrostatic field while said particles are of the same chemical constituencies as in dry condition at normal temperatures but are at a selected super-temperature above two hundred and fifty degrees Fahrenheit determined on the basis of differentiation in electrostatic susceptibility in response to change in temperature, and effecting a division of said particles into said portions, on the basis of the electrostatic susceptibilities at said super-temperature, while said particles are of said same chemical constituencies.

13. The process of separating into a plurality of portions, co-mingled particles of zircon ore the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises, subjecting said particles to the action of an electrostatic field while said particles are of the same chemical constituencies as in dry condition at normal temperatures but are at a selected super-temperature above two hundred and fifty degrees Fahrenheit determined on the basis of differentiation in electrostatic susceptibility in response to change in temperature, and effecting a division of said particles into said portions, on the basis of the electrostatic susceptibilities at said super-temperature, while said particles are of said same chemical constituencies.

14. The process of separating into a plurality of portions, co-mingled particles of mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude and low, which comprises, subjecting said particles to the action of an electrostatic field while said particles are of the same chemical constituencies as in dry condition at normal temperatures but are at a selected super-temperature above two hundred and fifty degrees Fahrenheit determined on the basis of differentiation in electrostatic susceptbility in response to change in temperature, and effecting a division of said particles into said portions, on the basis of the electrostatic susceptibilities at said super-temperature, while said particles are of said same chemical constituencies.

15. The process of separating co-mingled particles of refractory mineral material, segregating particles suitable for use as electrical insulating material at elevated temperatures, which comprises, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at a selected super-temperature above two hundred and fifty degrees Fahrenheit and not less than the minimum temperature which in effect approximates the maximum temperature to which it is intended said insulating material will be subjected in use but at which the particles to be segregated are of the same chemical composition as in dry condition at normal temperatures, and effecting a division of said particles on the basis of the electrostatic susceptibilities at said super-temperature.

16. The process of separating co-mingled particles of refractory mineral material, segregating particles suitable for use as electrical insulating material at elevated temperatures, which comprises, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at a selected super-temperature at which said particles are of the same chemical compositions as in dry condition at normal temperatures but which is above two hundred and fifty degrees Fahrenheit and not less than the minimum temperature which in effect approximates the maximum temperature to which it is intended said insulating material will be subjected in use, and effecting a division of said particles on the basis of the electrostatic susceptibilities at said super-temperature.

17. The process of separating co-mingled particles of mineral material which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

18. The process of separating co-mingled particles of refractory mineral material which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities

whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

19. The process of separating co-mingled particles of mineral oxides or oxide compounds which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

20. The process of separating co-mingled particles of zircon ore which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and affecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

21. The process of separating co-mingled particles of mineral material which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at least one of which is substantially above two hundred and fifty degrees Fahrenheit, at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

22. The process of separating co-mingled particles of refractory mineral material which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at least one of which is above two hundred and fifty degrees Fahrenheit, at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

23. The process of separating co-mingled particles of zircon ore which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures at least one of which is substantially above two hundred and fifty degrees Fahrenheit, at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an

electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

24. The process of separating co-mingled particles of mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures each substantially different from normal temperatures, at each of which the chemical constituencies of the particles are the same as in dry condition at normal temperatures, but at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

25. The process of separating co-mingled particles of refractory mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures each substantially different from normal temperatures, at each of which the chemical constituencies of the particles are the same as in dry condition at normal temperatures, but at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

26. The process of separating co-mingled particles of zircon ore the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures each substantially different from normal temperatures, at each of which the chemical constituencies of the particles are the same as in dry condition at normal temperatures, but at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

27. The process of separating co-mingled particles of mineral material the electrostatic susceptibilities of which in dry condition at normal temperatures are of the same order of magnitude, which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures each substantially different from normal temperatures and at least one of which is substantially above two hundred and fifty degrees Fahrenheit, at each of which the chemical constituencies of the particles are the same as in dry condition at normal temperatures, but at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

28. The process of separating co-mingled particles of refractory mineral material the electrostatic susceptibilities of which in dry condition

at normal temperatures are of the same order of magnitude, which comprises successive fractionations by successive subjections to the action of electrostatic field at substantially different temperatures each substantially different from normal temperatures and at least one of which is substantially above two hundred and fifty degrees Fahrenheit, at each of which the chemical constituencies of the particles are the same as in dry condition at normal temperatures, but at each of which exist substantial differences in electrostatic susceptibilities in dry condition by reason of which part of the separation may be effected, said temperatures being determined on the basis of differentiation in electrostatic susceptibilities in response to change in temperature and the differences in electrostatic susceptibilities being materially different at the different temperatures, including, subjecting said particles in dry condition to the action of an electrostatic field while said particles are at one such temperature, and effecting a division of said particles on the basis of the electrostatic susceptibilities thereof at that temperature, and then subjecting a fraction of said particles the electrostatic susceptibilities whereof in dry condition at said one temperature were of the same order of magnitude, in dry condition to the action of an electrostatic field while those particles are of the same chemical constituencies as when previously subjected but are at another such temperature, and effecting a division of those particles on the basis of the electrostatic susceptibilities thereof at that temperature.

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