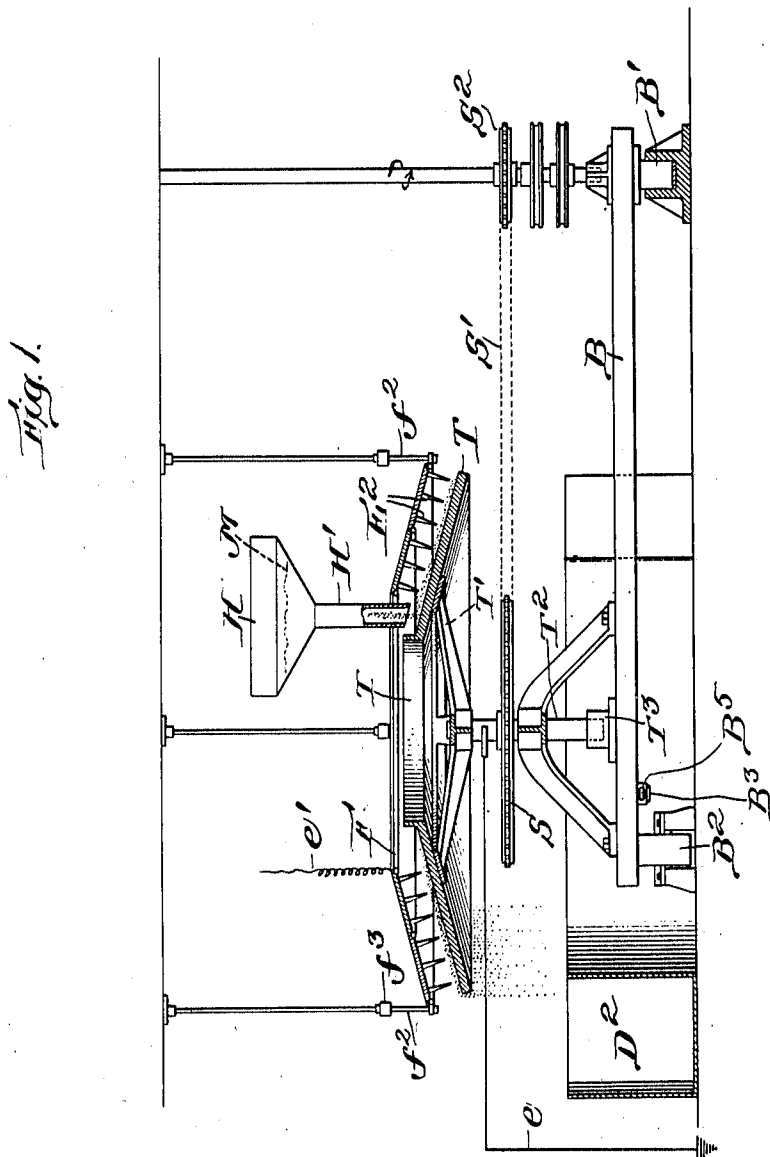


970,001.

3 SHEETS--SHEET 1.



Witnesses:
Charles D. Wickers
Josephine A. Ryan

Inventor:
Henry G. Truitt
by Robert Roberts & Co. Attys.

H. A. WENTWORTH.
 PROCESS OF ELECTRICAL SEPARATION.
 APPLICATION FILED FEB. 17, 1908.

970,001.

Patented Sept. 13, 1910.

3 SHEETS—SHEET 2.

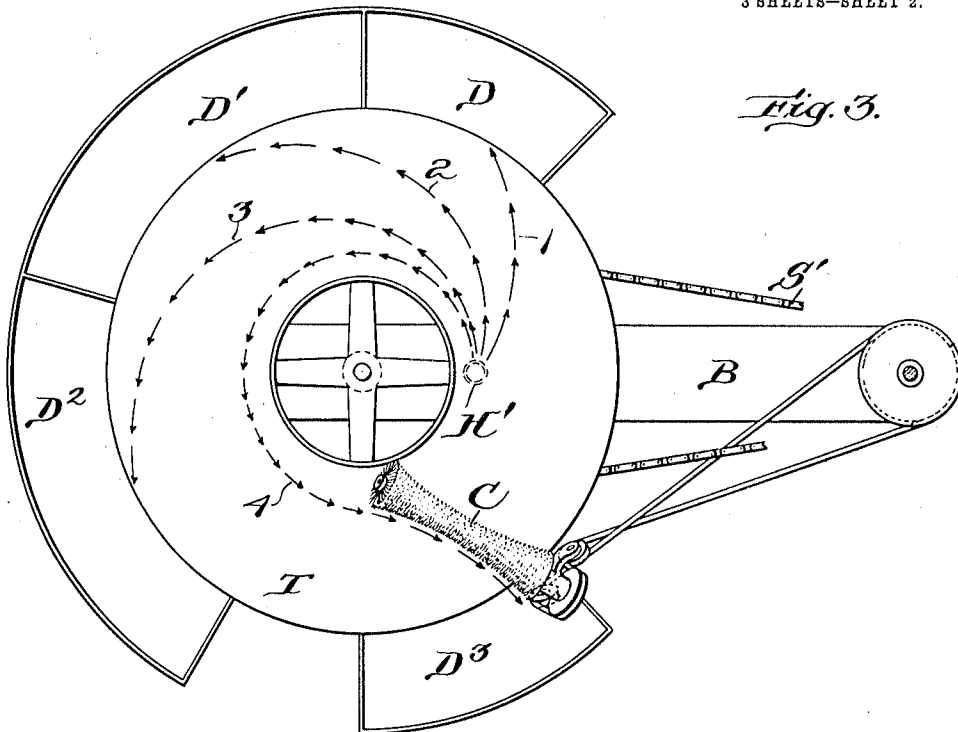


Fig. 3.

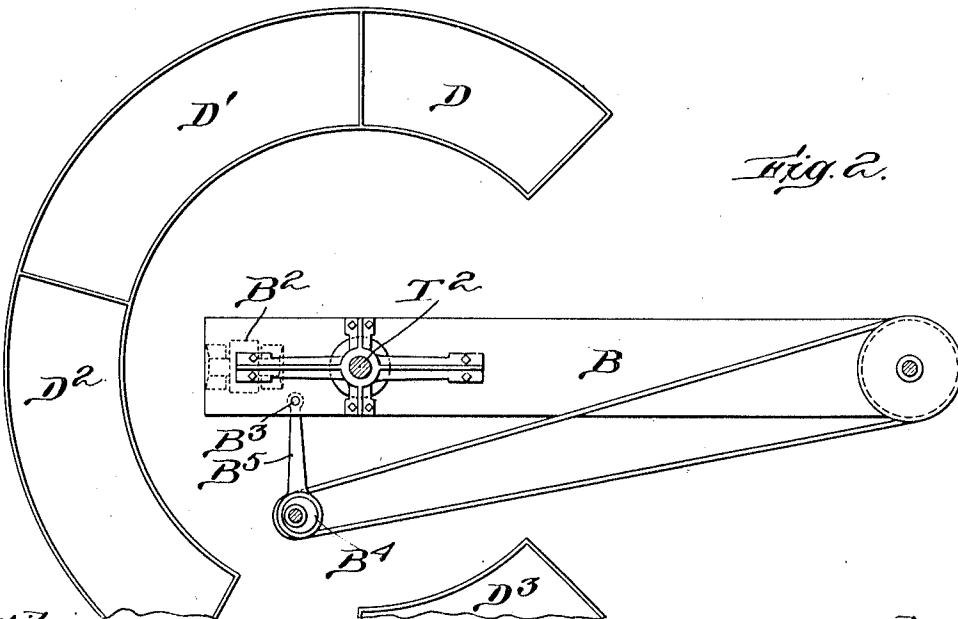


Fig. 2.

Witnesses:
 Charles S. Woodberry
 Josephine H. Ryan

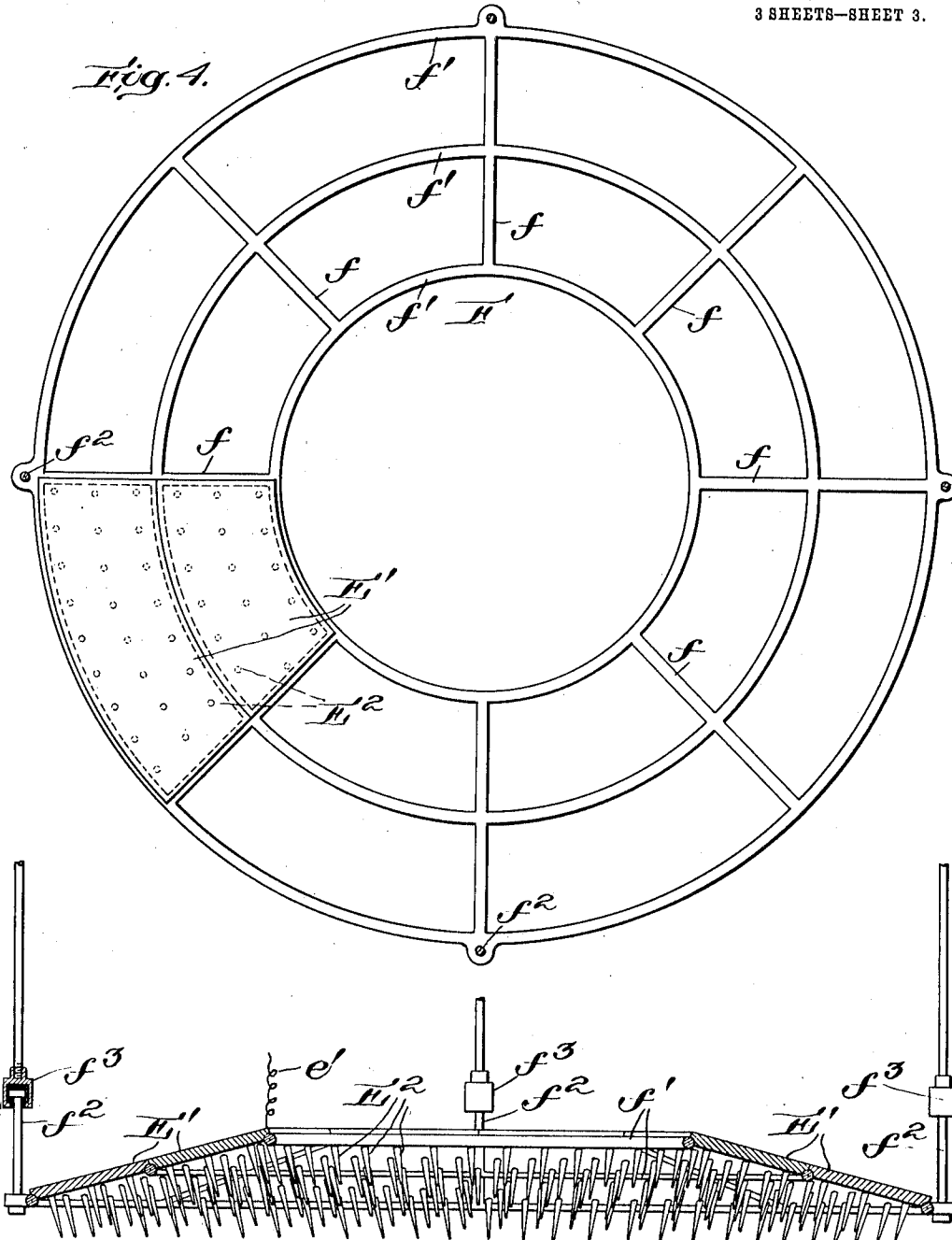
Inventor:
 Henry A. Wentworth
 by Robert Roberts & Chasman
 Attys.

H. A. WENTWORTH.
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Patented Sept. 13, 1910.

3 SHEETS—SHEET 3.



Witnesses:
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Fig. 5.

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UNITED STATES PATENT OFFICE.

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MAINE.

PROCESS OF ELECTRICAL SEPARATION.

970,001.

Specification of Letters Patent. Patented Sept. 13, 1910.

Application filed February 17, 1908. Serial No. 416,269.

To all whom it may concern:

Be it known that I, HENRY AZOR WENTWORTH, a citizen of the United States, and resident of Lynn, in the county of Essex and State of Massachusetts, have invented new and useful Improvements in Processes of Electrical Separation, of which the following is a specification.

My invention relates to the separation of differentiated ingredients of granulated or otherwise comminuted solid matter such as metal-bearing ores and the rock or earth with which they are associated in nature and from which the ores may be mechanically dissociated by crushing, grinding or other modes of mechanical comminution. The separation of the ores from the gangue or, in other words, the concentration into heads, middlings and tailings of the differentiated ingredients of such comminuted masses of material has been effected under favorable conditions by many now well known modes; in all cases I believe that the fundamental principle of separation or concentration consists in subjecting the differentiated particles of such a mass to a common force or influence to which different classes of particles in the mass are responsive in different degrees so that one class of particles is, under the conditions imposed, distinguished from another class by a difference in mobility; this difference in mobility is then utilized to lead the several classes of particles through different paths to different receptacles. Modes of electric or electrostatic separation fall within this generalization; the influence or force applied being electrical and depending for its operation either upon the repulsion of one charge of electricity for a charge of like character or the mutual attraction of unlike charges of electricity or on both these electrical phenomena in conjunction or succession. Particles of different materials, as they differ in their electro-conductivity, respond in divers ways to the directional tendencies of the electrical charges which reside upon them or upon bodies in their immediate neighborhood, and as there is nearly always a difference in electro-conductivity between the several ingredients of a mixed mass of ore and gangue, electrical separation finds responsive materials in a very wide range of natural products. Whether the separation

of the ingredients of the mass may be effected by the emphatic and visible repulsion of relatively good conductive particles from an electrified surface or the retention by attraction of relatively poor conductors which carry a charge opposite in sign to that of the electrified body, the better conductors being liberated from the electrified body by a feeble electro repulsion assisted or supplemented by gravitation, the separative process depends upon the relative conductivity of the several particles. The measure of this conductivity is the degree of persistence with which a particle retains an electric charge or, conversely, the degree of facility of promptness with which it transfers its electric charge to a conductive surface with which it comes in contact. Or, to state the case in converse terms the measure of conductivity is the degree of readiness or reluctance with which a particle acquires electric charge by contact with an electrified body, the differences in degree being measurable by the time required for a particle to alter its electrical condition. The significance of this time element as a measure of conductivity is set forth in United States Patent to Philip H. Wynne, No. 805,694, dated November 28, 1905. These differences in conductivity may be well demonstrated by an experiment such as follows:

Charge a gold leaf electroscope so that its leaves diverge, taking care to observe such precaution as to insulation and dryness of atmosphere that leakage from the electroscope is negligible. Then take samples of such characteristic substances as iron pyrite, Wisconsin blende, and quartz, each piece being, say, as large as a walnut. If the piece of pyrite, held in the hand, be touched to the contact piece of the electroscope, the diverging leaves instantly collapse upon each other, showing that the charge has been quickly transferred from the electroscope over the surface (or through the body) of the fragment of pyrite. Recharge the electroscope and repeat the experiment using the fragment of blende. The gold leaves will be seen to close deliberately upon each other. Re-charge the electroscope and apply the fragment of quartz. The gold leaves remain distended indefinitely. The difference manifested by

these three substances in the above experiment afford a correct measure of their respective conductivities and disclose the reason for the different behavior of the same materials in an electrostatic or other electrical separator. If a mixture of these three materials properly comminuted be distributed over a conducting surface and this surface be charged electrically, the pyrite particles which receive this charge instantly leave the surface, provided the charge is sufficiently intense to overcome the gravitative tendency of the pyrite particles. If the surface be a cylinder rotating so that under ordinary conditions the particles would slide off, the pyrite will be repelled (provided the charge be sufficiently intense) with such emphasis that the pyrite particles describe an easily discernible trajectory; the particles of blende will be freed from the surface at a lower point in its movement and may appear only to fall off, but the quartz particles will be carried still farther and under proper electrical conditions will even remain clinging to the conductive surface against gravitative tendencies and must be forcibly removed. Thus, if the apparatus be so constructed that a spray discharge or ionized jet be thrown upon a portion of the surface which conveys the material, such a jet or spray will carry to and deposit upon the particles, electric charges or electrons opposite in sign to the charge of the conveying surface. The superior conductivity of pyrite transfers this charge instantly to the conveying surface and by the same conductivity the pyrite receives from the conveying surface a charge similar in sign to that which the surface carries and is eventually liberated or repelled from that surface with emphasis proportionate to the intensity of charge. A pyrite particle may be so vigorously repelled as to leave the surface in spite of the opposing tendencies produced by the reception of fresh spray discharge or it may leave the surface and return thereto upon receiving a fresh spray discharge which is then attracted by the charge on the surface. But the instant the particles of pyrite leave the region affected by spray discharge, the repulsive effect due to contact with the conveying surface, manifests itself so that the particle will leave the electrode by a trajectory more or less pronounced, according to the intensity of charge and the directional resultant between the force of electrical repulsion and gravity. Under these conditions a particle of blende having received its deposit of spray discharge, surrenders that charge with greater deliberation to the conveying surface and with equal deliberation receives a counter charge from the surface so that its time of liberation from the surface is later than that of the pyrite.

The quartz, having received the spray discharge, retains its charge in spite of contact with the conveying surface and clings thereto until removed by some mechanical or electrical device for the purpose.

While many commercially practicable separations are accomplished by the electrical method above illustrated there are, nevertheless, combinations of material wherein the ingredients present less clearly marked differences in conductivity and where therefore the separation of one class of particles from another is more or less imperfect. Differences in size or shape of particles of the same material may and sometimes do produce differences in electrical behavior so that separations are effected where none are desired and combinations encountered where separation is intended. Such difficulties as these are I believe in large measure increased by the circumstance that in electrical separators which employ a rotating drum electrode, gravitative action interferes with and qualifies the separative electrical action; whether this qualification of the electrical condition is detrimental or not depends largely upon the character of the heterogeneous material under treatment. With some materials the gravitative action is a valuable adjunct to electrical action whereas with others the two stimuli to mobility of particles act at cross-purposes, judged from the point of view of the person who desires to make an effective separation of ingredients. Gravitative action on the particles under treatment affects or overpowers the electrical action as the size of the particles themselves increases so that with electrical separators as heretofore constructed it has been found necessary to comminute the material down to at least ten mesh and in many cases this comminution has to be carried much farther. When the material is very finely comminuted a considerable amount of very fine dust is produced and much of this is lost in the air. The expense of the mechanical reduction of materials increases greatly with the fineness of the product and one of the objects of my invention is to effect a separation by electrical means without necessitating the extreme comminution of material heretofore resorted to as a necessity of the situation. It stands to reason that crushing or grinding should be carried only to the point necessary to free the several ingredient substances from each other and that no further comminution should be indulged in unless the necessity of the situation demands it.

By my invention presently to be described, gravitative force as an element in the operation may be reduced to any minimum desired, leaving the electrical factors free to work out a separation of the materials with only such qualification by gravitative force as may be thought advantageous.

In the drawings hereto annexed there is illustrated an apparatus by which my process may be carried into effect:

Figure 1 represents a separator, this being shown in vertical section; Fig. 2 is a plan view of the lower part of the separator shown in Fig. 1, some portions of the apparatus being shown as broken away to give a better view of others; Fig. 3 is a plan view and diagram of the separating table; Fig. 4 is a plan view of an electrode, and Fig. 5 is a cross section of the electrode shown in Fig. 4.

Referring to Fig. 1, H is a hopper from which leads the spout H' through which the material M is delivered to the table T. The table T is shown as cone-shaped. The angle of inclination of the cone surface may be determined to suit the nature of the material employed, and the conditions under which separation has to take place. The conical table T is mounted upon a spider T' which is keyed to the vertical shaft T² this shaft rotating on a step bearing T³. A sprocket wheel S carrying a sprocket chain S¹ serves to impart a rotary movement to the table T. The separating table T with its carrying and operating mechanism is mounted upon the frame B which is pivoted in a step at B' and supported at the other end upon a roller B² or other adequate support. An eccentric rod B³ joined to the pin B³ and actuated by the eccentric B⁴ serves to impart a vibratory movement to the frame B and the table carried thereby. Thus the table T may be given a movement of rotation and at the same time a movement of agitation.

Over the table T there is suspended the skeleton frame F which is conical in its general shape and composed of radial bars *f* and concentric circular bars *f'*. This frame is suspended upon rods *f*² which carry insulation on their supports at *f*³. Segmental electrode plates E' are provided and are supported by the radial and circular bars *f* *f'* of the frame F. These plates E' are of metal and carry projecting from their lower surfaces a suitable number of metal points E². An electrical connection *e'* leads from the frame F to some suitable generative source of electricity which supplies, by preference, a fairly constant and unidirectional charge. By constructing the electrode plates E' as above described, as many as desired may be employed on the frame F. The metallic bars of the frame F are of such dimensions and the suspension of the frame above the table T should be so adjusted that the frame F, although charged with electricity, shall have very little effect upon the material, much less upon the table T, whereas the points E² which hang to a considerable distance below the frame F will constitute the effective electrical factors in the treatment of the material on the table. Taking into account the material of which the table T is

formed (it should be preferably of electro-conductive material) the inclination of this conical surface to the horizontal is by preference such that the material, to be treated, will, if spread upon the surface of the table, without being subjected to any electrical action remain there at rest, provided the table be not moved or agitated, and such that on the other hand the mechanical agitation if imparted to the table will cause all of the particles to move from the upper to the lower margin of the table T. If a mass of material be placed upon the table or conducted thereto as by the spout H', and the table be rotated meanwhile and also agitated, (no electrical action being present) the particles will spread out and make their way to the lower margin of the table where they will fall off. The object of the electrical devices which form part of this apparatus is to produce pronounced differences between several classes of materials in the adhering intimacy of the materials themselves with the table T.

The points E² which extend over such portions of the table T as the operator may select, when supplied with electrical energy from a suitable source will direct upon the table T a spray discharge, in other words, will sprinkle the table and the materials on it with electrons, the table T serving as an electrode opposed to the points E²; to this end the table T should either be grounded as at *e* or connected with a terminal of the source of electrical energy which supplies the points E² from its other terminal. If now we suppose that the material M is composed partly of iron pyrite, partly of blende, and partly of quartz (these being the three materials employed hereinabove as illustrative examples) the electrons sprayed upon the table T and upon these particles will plaster themselves upon the exposed surfaces of the particles, of whatever material they may be. Electrons thus plastered upon a particle of pyrite will be promptly conducted over the pyrite to the table T where they are neutralized by the electrons of opposite sign wherewith the table T is charged. The pyrite particles, under these conditions move much as if they were subjected only to the mechanical conditions of progression and agitation of the table T and consequently will roll or slip down the surface of the table in much the same way that they would if there were no electrical factors at work; thus, in Fig. 3, the dotted line 1 from the spout H' to the margin of the table T indicates the path of a particle of pyrite from the spout to the edge of the table from which it may fall into a suitable receptacle as D. If now we consider the behavior of a particle of blende which is a poorer conductor than pyrite but not nearly so poor a conductor as quartz, the electrons spread upon a particle

of blende linger thereon passing to the table T sluggishly and with reluctance so that there resides on each particle of blende a charge of creeping electrons which are attracted by the electrons on the table T and cause the particles to adhere to the table much more persistently than was the case with particles of pyrite. Nevertheless the escape of electrons from the blende particles to the table T is sufficiently free to enable the mechanical agitation of the table to shift the positions of the blende particles, which travel toward the margin of the table but more slowly than the pyrite particles. Thus, in Fig. 3, the dotted line 2 indicates the path of such particles of blende toward the margin of the table from which they may fall into a receptacle as D'. As the shape of the individual particles has a considerable influence on their behavior under such conditions as these, it may be observed that some particles of a substance cling more persistently to the table than other particles of the same substance. This may be due to the fact that the electrically exaggerated friction between the particle and the table has a greater effect when the particle rests upon a face than when it rests upon three or four salient points. Thus some particles of blende might, for such reasons as these, follow such a path as indicated by 3 in Fig. 3 and be delivered from the table at a different point from other blende particles, falling, it may be, into a receptacle as D².

In the case of the quartz particles whereof the conductivity is so low that the movement of electrons through or over such particles is so slow as to be negligible, the electrons deposited upon these particles remain there, holding the particles firmly to the surface of the table, so that the mechanical agitation thereof will have little or no effect to dislodge them. For the purpose of removing particles which follow the path marked 4 in Fig. 2, a brush or scraper C may be employed to scrape off these particles and deposit them in a suitable receptacle as D³.

The gist of the above described process lies in the differential modification of friction between the surface on the one hand and several classes of particles on the other by the various electrical attractions of the several classes of particles for the surface; these differences in electrical attraction depending upon the differences in electrical conductivity as between particles of the several ingredients. The process has this in common with other electrical separation processes: Under the influence of an electrical field which may preferably be modified or qualified by spray discharge, particles of high conductivity are, through the agency of electricity, readily liberated from the surface on which they lie, whereas particles of

inferior conductivity are not so readily liberated by reason of the more or less persistent residence thereon of electrons which are attracted to the charge on the electrified surface. Into this process there also enters the feature of support of the particles during the separative process upon a surface whereof the function is, in part at least, to eliminate from the electrical separation the disturbing influence of gravitation, reserving only such contribution of gravitative effort as may be of assistance in segregating and distributing the particles. It is quite possible by these processes and with such an apparatus as above described or with equivalent apparatus to effect a separation by the conjoint mechanical and electrical operations between particles of considerable size so that it is not necessary for practical purposes to comminute the material to the degree heretofore found requisite to successful electrical separation. For the most part and in most instances it will be found necessary only to granulate the material to a degree sufficient to insure the material freedom of the several ingredients.

While electrical repulsion, such as manifested in all of the electrical separation apparatus with which I have heretofore come in contact or of which I have been informed, does not manifest itself visibly in the within described apparatus, or at all events need not manifest itself visibly, nevertheless the essential conditions which elsewhere manifest themselves in repulsion are the same. The friction between a good conductor and the table due to the weight of the particle should be to some extent diminished by the repulsive effort manifested by electrons of like character so that it may be expected that particles of very good conductivity will descend, in such an apparatus as above described, more promptly when the apparatus is electrified than they would if mere mechanical agitation were employed.

The action of a separator constructed and operated according to the principles specifically illustrated by the above described machine has for its fundamental physical conditions, first: two divergent components of movement, imparted to a mass of particles, and second, the modification of the responsiveness of the particles to one of the directional tendencies. Thus, in the examples above described, the means to impart one component of movement to the particles consists in the inclination of the electrode surface to the horizontal, assisted, if need be, by the agitation of the surface. This directional tendency is radial from the center of the electrode surface. The means to impart the component of movement, or directional tendency divergent from the first component, consists in the translative movement of the electrode as a whole, this movement, from the particle as

a point of reference, being circumferential, or circular, and thus divergent from the radial component. Then while the particles are responding mechanically to these two divergent components of impulse, and thereby manifest movement expressive of the resultant of the two component impulses, the electric charge is applied. The imposition of the electrical factor modifies the effect of one of the component impulses to movement—in the instance shown, the radial component, gravitative in its essence—and modifies this effect differentially as between different particles of material. Thus the ratio between the radial gravitative component and the circumferential translative component is made different for different materials, and the resultant movements, manifested by the paths taken by different materials, vary correspondingly.

I claim:

1. A process of separation of differentiated ingredients of comminuted solid material which consists in subjecting the material simultaneously to directionally divergent motive components and at the same time directing an electric spray discharge upon the material, thereby differentially modifying the responsiveness of ingredient particles to one of said motive components, and subsequently separately collecting the separated ingredients.

2. A process of separation of differentiated ingredients of comminuted solid material which consists in depositing the material upon a conductive surface, subjecting the material while on said surface simultaneously to directionally divergent motive components, at the same time directing an electric spray discharge upon the material,

thereby differentially modifying the responsiveness of ingredient particles to one of said motive components, and subsequently separately collecting the separated ingredients.

3. A process of separation of differentiated ingredients of comminuted solid material which consists in subjecting the material simultaneously to movement in response to gravitative action and a movement of translation directionally divergent from the gravitative movement, at the same time directing an electric spray-discharge upon the material, thereby differentially modifying the responsiveness of ingredient particles to one of said motive components, and subsequently separately collecting the separated ingredients.

4. A process of separation of differentiated ingredients of comminuted solid material, which consists in depositing the material upon a conductive surface under mechanical conditions favorable to gravitative movement of the material over the surface, agitating the material and simultaneously subjecting it to a motive component directionally divergent from the gravitative movement, at the same time directing an electric spray-discharge upon the material, thereby differentially modifying the responsiveness of ingredient particles to one of said motive components and subsequently separately collecting the separated ingredients.

Signed by me at Boston, Mass. this thirteenth day of February 1908.

HENRY AZOR WENTWORTH.

Witnesses:

ODIN ROBERTS,
CHARLES D. WOODBERRY.