H. M. SUTTON & W. L. & E. G. STEELE.

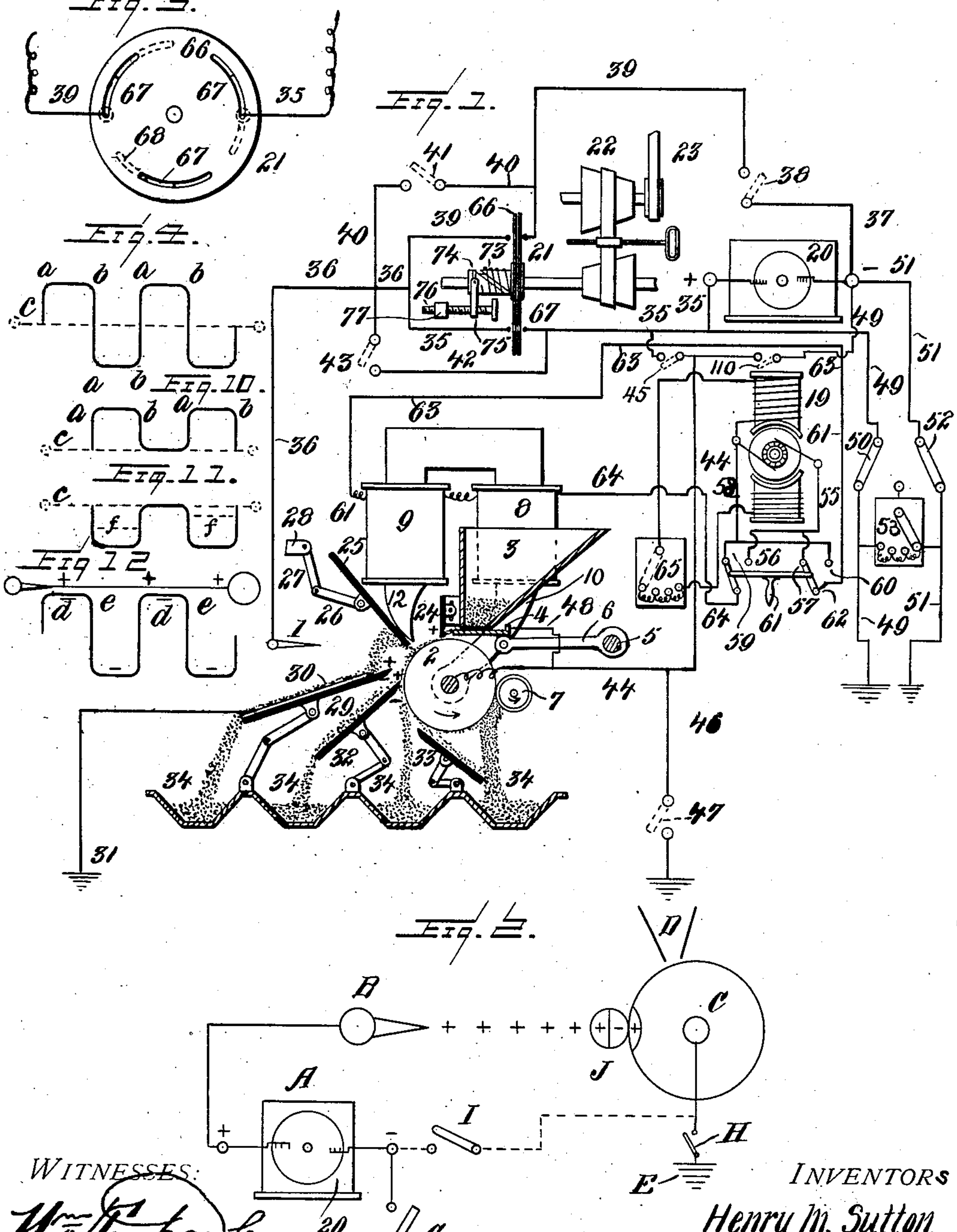
PROCESS OF ELECTROSTATIC MAGNETIC SEPARATION.

APPLICATION FILED DEC. 27, 1906.

977,570. Patented Dec. 6, 1910.

2 SHEETS—SHEET 1.

Fig. 5. Fig. 7. Fig. 9. Fig. 10. Fig. 11. Fig. 12. Fig. 8.



WITNESSES:

Wm F. ...

Alfred T. Gage

INVENTORS

Henry M. Sutton,

BY Walter L. Steele & Edwin G. Steele.

E. B. Stocking

Attorney

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2 SHEETS—SHEET 2.

FIG. 5.

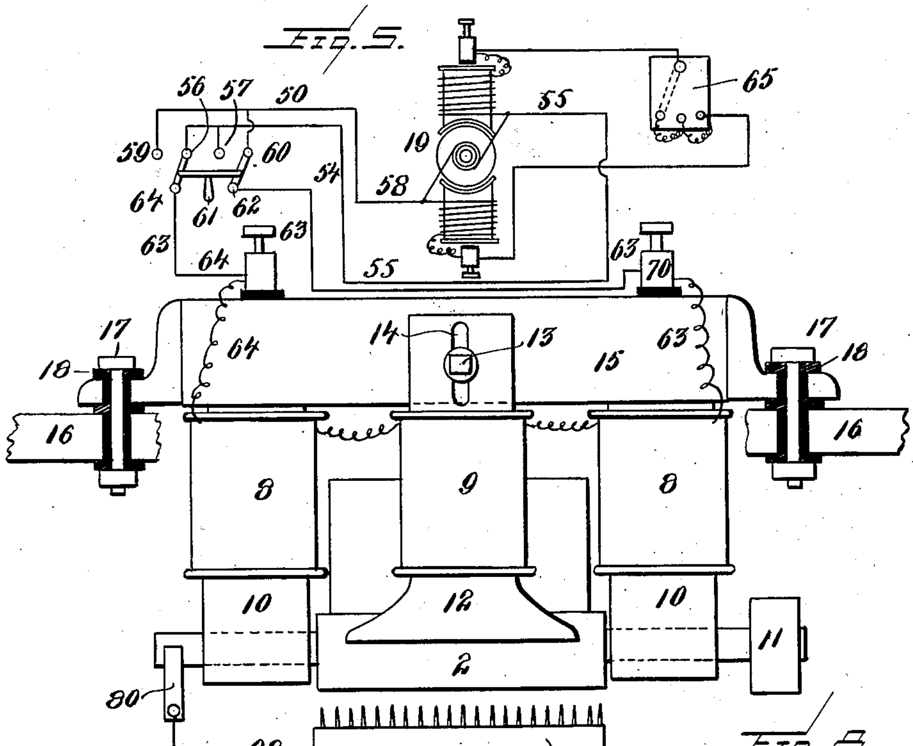
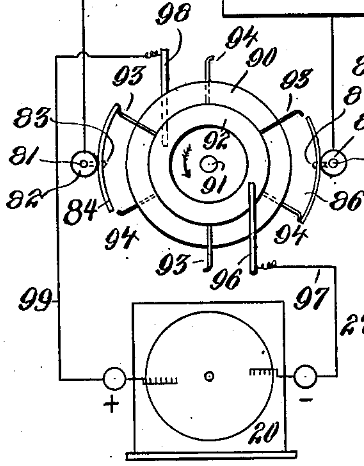



FIG. 8.

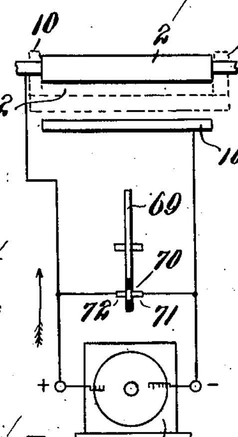


FIG. 9.

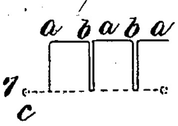


FIG. 6.

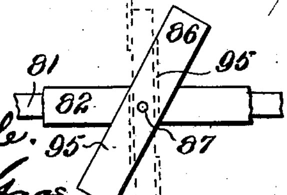
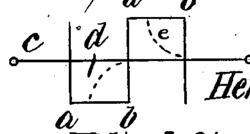


FIG. 7.



WITNESSES:

Wm. F. Kohle.
Alfred T. Gage.

INVENTORS

Henry M. Sutton,

BY Walter L. Steele & Edwin G. Steele.

E. B. Stocking
Attorney

UNITED STATES PATENT OFFICE.

HENRY M. SUTTON, WALTER L. STEELE, AND EDWIN G. STEELE, OF DALLAS, TEXAS.

PROCESS OF ELECTROSTATIC MAGNETIC SEPARATION.

977,570. Specification of Letters Patent. Patented Dec. 6, 1910.

Application filed December 27, 1906. Serial No. 349,698.

To all whom it may concern:

Be it known that we, HENRY M. SUTTON, WALTER L. STEELE, and EDWIN G. STEELE, citizens of the United States, residing at Dallas, in the county of Dallas, State of Texas, have invented certain new and useful Improvements in Processes of Electrostatic Magnetic Separation, of which the following is a specification, reference being had therein to the accompanying drawing.

This invention relates to a process of separating the particles of a mass or the components of a mixture which is in the nature of an improvement upon the process patented to us on November 25th 1902 in Patent #714,256, and on February 20th, 1906 in Patent #813,063, and the invention consists in subjecting the mass of particles to be separated to the action or influence of magnetic and electrostatic action, the latter being in a constant charge produced by an electrode having a pointed or sharpened termination, or by an electrode having a rounded termination, the charge supplied to which being non-continuous or interrupted, whereby in either case there is set up and maintained a dielectric polarity in particles of the mass being treated. In other words, the invention consists in subjecting the material to be treated to an electrostatic charge regulated to produce and maintain in some of the particles of the mass a constant difference of potential to that of one electrode while in a magnetic field.

The invention also consists in the process above stated followed by depolarizing said particles thereby electrically releasing them from an electrode.

The invention consists in further details of operation hereinafter set forth and described in the claims.

While we do not confine ourselves to any particular form of apparatus for the embodiment or use of our process, we have herein shown an apparatus adapted to that purpose.

Referring to the drawings forming a part of this specification:—Figure 1 represents in diagrammatic relation the principal elements of an apparatus to be used in practicing our process; Fig. 2 is an illustrative diagram presented for the purpose of rendering the description of the principles of the invention more readily understood; Fig. 3 is a side elevation of an interrupter shown in edge view in Fig. 1; Fig. 4 is an illustration of the wave form produced by said interrupter; Fig. 5 is a modified arrangement of the apparatus shown in Fig. 1 and involves the substitution of a different form of interrupter; Fig. 6 is a detail of a portion of the interrupter shown in Fig. 5; Fig. 7 is the wave form produced by the interrupter shown in Fig. 5; and Fig. 8 is still another modified form of the apparatus which is also adapted for the embodiment of our process. Figs. 9, 10, 11 and 12 represent wave-forms.

Like numerals refer to like parts in the several figures of the drawings.

We have heretofore discovered that by employing an electrode having a sharpened or pointed terminal in connection with an opposing electrode, a continuous charge passes from the pointed electrode to the other and produces in such particles of the mass as possess dielectric properties a polarity which, in connection with the polarity of the electrode with which they are in contact serves to cause them to adhere to the same. This principle of our invention may be more readily understood by a reference to the diagram shown in Fig. 2. Let A represent a source of high tension electricity which may be either dynamic or static, as shown in this case, and let B be an electrode terminating in a point. Let C be an opposing electrode and D a hopper or any other suitable device for feeding material to the electrode C. The electrode C and the source of energy A may each be connected either directly to the ground, as shown at E and F, respectively, by closing the switch G; or the electrodes B and C and the source of energy A may be directly connected by opening the switches G and H and closing the switch I, as is clearly apparent. With either connection, that is, directly through the switch I, or through the earth, the resulting effect of the passing charge between the two electrodes is the same. Assuming the charge to be passing continuously from the point and being + and assuming a particle J of the material being treated as having passed from the hopper in contact with the electrode C intercepting the path of the charge, the result is that the particle becomes polarized and that equally, one half thereof will be + and the adjacent half toward the electrode will be —. The electrode being connected to the earth or to a source of energy permits a continuous passage of the current therethrough, and therefore has practically no density of charge thereon but there is a bound or induced charge, produced inductively by the — polarity of the particles, at the point immediately adjacent to the place of its contact with the electrode C and of an opposite polarity, to wit +, consequently there exists between the electrode and particle at the place of contact therewith opposite polarities, and said particle is retained in contact with the electrode so long as that condition exists. It will be noticed that this result of retaining the particle in contact with electrode in the manner described by the use of a continuous current from a pointed electrode is directly the opposite of the result produced by a current or charge supplied to a rounded electrode, as in that case there is no binding charge produced, and consequently the particle and the electrode C being of the same polarity the particle is repelled therefrom by reason of the similarity of polarity.

In our present process we have added to the attractive force generated in the particle by convectively delivered charges the step or additional feature of providing a magnetic attractive force acting in unison with the static force whereby certain particles of certain materials which may be comparatively feebly influenced by either a static or magnetic force, both forces are utilized and therefore the attractive attachment of such particles is enhanced and their separation from their fellows more completely accomplished. It seems proper to state at this point that we have discovered that the same advantageous results may be produced by our process with a round electrode in place of a pointed electrode by providing means for interrupting the convectively delivered charges passing therefrom to the opposite electrode, and we therefore include as a feature of our process the interruption of the convectively delivered charges whenever rounded electrodes are employed, and furthermore, we apprehend as included within our invention such other various modifications and changes as may be suggested to persons skilled in the art and in the electrical sciences involved so long as the production of polarization in dielectric particles is secured either by a continuous or an interrupted convectively delivered charge in the manner hereinbefore and hereinafter described.

The principal object of this process of electrostatic magnetic separation is by means of the joint application of static electricity and the magnetic field of force, to increase the susceptibilities of certain particles having feeble magnetic properties to the attractive influence of the magnetic field or force so that they can be separated from others that have less or none. It has heretofore been discovered in the art of magnetic separation that the shape or form of magnetic pole pieces has great influence in rendering certain particles susceptible to magnetic attraction that would not otherwise be affected, and in this manner it has been possible to separate out from a mass of particles substances that would not respond to such a magnetic field of force as is produced by magnetic poles of ordinary construction. If the pole piece is rounded in form having approximately the same cross section as the opposite pole the neutral line would then be about midway between the two poles. That is, if a particle of matter susceptible to magnetic attraction be placed exactly on this line the attractive force of each magnet upon the particle will be exactly balanced or neutralized. A particle placed either side of said line is attracted toward the pole to which it is nearest and thus particles may be attracted to either pole. In the case of a pole brought relatively to a point or having but small cross section at its tip, then under these conditions the magnetic lines of force are greatly concentrated on the tip which becomes supersaturated and the neutral line under these conditions, the other pole being of greater area, is very much nearer the larger pole. In the above illustration, the effect of static electricity acting in the manner as we have described has not yet been taken into account, and we will now consider in what way the discharge of electricity in the current form from an adjacent pointed terminal affects the result. When the mineral is fed to an electrode which is also the opposite magnetic pole, the effect of the convective discharge acting directly, not inductively, on the particles is to polarize them on the pole to which they are fed. It is evident that if the attractive force of the magnetic pole on to which the material is fed is acting to attract such particles as possess magnetic properties that said particles will adhere much more strongly to such pole than would be the case with either force acting alone. This magnetic pole upon which the material is fed is also the grounded electrode that receives the electrical discharge from the point. It is understood that our invention may involve scientific principles other than those just specified and we do not limit the same in this regard.

In the drawing one form of apparatus is illustrated which is adapted to the practice of our process, and reference is made to Fig. 1 in which 1 is an electrode having a sharpened or pointer terminal and 2 is an opposing electrode which in this instance is in the form of a roller or cylinder which by any suitable means is adapted to be rotated. 3 is a hopper in which the comminuted material to be separated into its constituent elements is placed and from which it is fed to the cylinder in any suitable manner which in this instance is a shaker pan 4 which is vibrated by means of an eccentric 5 connected thereto by the rod 6. The wiper 7 may be provided for removing adhering particles from the cylinder and at a point upon its rear surface.

By reference to Fig. 5 the manner of supporting said cylinder and adjacent magnets will be clearly understood where 8, 8 and 9 are magnets, the poles of the magnets 8, 8 extending downward, as shown at 10 to form bearings for the journals of the roller 2 on one of which is a belt pulley 11 serving for imparting rotative power to the roller. The magnet 9 has the pole 12 extended in the form of a thin edge and adjustably arranged in relation to the cylinder 2. In this instance the adjustment is accomplished by the bolt 13 and slot 14 securing said magnet to a cross beam 15 which also supports the magnets 8 in any suitable manner, and which is insulated from the framework 16 of the apparatus by means of the bolts 17 passing through insulated sleeves 18 in a manner well known in electrical constructions. The magnets are energized by a dynamo 19, the connections of which will be hereinafter described. The electrodes 1 and 2 are served from a source of energy 20, which as before stated may be of any character and which in this instance is an electrostatic generator, and the connections employed will also be hereinafter described. An interrupter 21 is shown together with a cone speed regulating mechanism 22 from which the belt 23 goes to any suitable source of power for giving motion to the interrupter.

In the practice of the process we have discovered that the same is facilitated to a material degree by producing a segregation of the particles at the instant they leave the hopper or shaker pan and during their passage to the cylinder electrode. This result we attain by placing a dielectric shield in advance of the discharge point of the hopper and in close proximity to the surface of the cylinder, whereby the convectively delivered charge from the pointed electrode is intercepted by said shield, such being the shield 24 adjustably mounted as shown. It is to be understood in this instance that the magnet 12 and shield 25 are in an elevated or adjusted position which gives the convectively delivered charge from electrode 1 free access to the shield 24 at the hopper. The effect of this shield 24 is that said charge imparts a + charge to the shield by the pointed electrode and induces a − charge upon the opposite side of the shield thus producing in the particles back of the shield an inductive charge of like polarity on each particle which has a tendency to separate them one from the other and in which condition they fall upon the cylinder electrode, and the material is thus presented to said electrode in a thin sheet-like form which facilitates the subsequent separating action of the convectively delivered charges thereon.

25 is a dielectric shield adjustably mounted by means of the arms 26 and 27 and the bracket 28 extending to any fixed part of the apparatus whereby the proximity of the shield to the cylinder electrode 2 and its relative inclination may be determined to suit the conditions or character of material to be treated. The action taking place caused by the presence of this shield is somewhat similar to that heretofore described. It is understood though not in a restrictive sense, that a portion of the convectively delivered charges from electrode 1 are converted into a static charge of sufficient density on the tip of the shield to induce through the shield a charge of opposite sign, or that the whole tip of the shield may be charged with the same sign as that of the electrode 1. In either event, the polarity of the shield, where it affects the particles, would be opposite to that of the opposing or cylinder electrode. In this case the convectively delivered charges from the pointed electrode act to impress upon the shield a charge of opposite polarity upon the opposite side of the shield, and as the electrode revolves the more weakly adhering particles are released by the charge on the front of the shield and they fall upon the shield 29. This shield 29 is adjustably supported in practically the same manner as the shield 25 and is constructed, like the remaining shield, of hard rubber or other dielectric material. But there is placed upon the upper surface of the shield 29 a plate 30 of metal or other suitable conducting material whereby portions of the charge from the pointed electrode 1 are neutralized or prevented from acting through the body of the shield so as to affect material below the same. It will be noticed, however, that the extreme front edge of the shield 29 of dielectric material is not covered by said plate so that the same electrical action takes place as that of the shields previously described, and here the + charge from the pointed electrode produces an induced − charge upon the opposite or under surface of the shield which by reason of the similar polarity of the particles on the cylinder electrode has a tendency to release those particles from the cylinder which were not released in the previous action above described. It will be noted that the plate 30 is connected to the ground, as shown at 31 which removes from it any charge received from the pointed electrode. The shields 32 and 33 although represented as being made of dielectric material practically serve as division plates, it being understood that all of the shields described extend longitudinally for practically the entire length of the cylinder electrode. It is

possible, however, that the induced charges upon the lower surface of these shields may have more or less effect in releasing from the cylinder those particles having such strong attraction thereto as to carry them past the influence of the shields 25 and 29. Separate compartments 34 are provided to receive the various collections of separated particles.

Referring to Fig. 1 the various electrical connections shown therein will be described. From the + pole of the generator there extends a circuit wire 35 to the interrupter 21 where the wire is cut for the passage of the disks, and beyond the disks said wire is extended to a point where it merges into the wire 36 leading to the pointed electrode 1. From the — side of the generator the wire 37 leads to the switch 38 by which it is connected to the wire 39 which is also severed for the passage of the interrupter disks therethrough and is afterward merged into the wire 36 leading to the pointed electrode. For the purpose of cutting out the interrupter the branch 40 is provided having the switch 41 and merging into the wire 36, and a second branch 42 having the switch 43 likewise merging into the wire 36 is provided so that by closing the switches 41 and 43 a constant charge either + or — may be conducted to the electrode. The connection of the cylinder electrode with the source of supply may be accomplished directly by means of the branch 44 having the switch 45 therein switch 110 being open, extending from the wire 35 to the journals of the cylinder or to — side of the generator by opening switch 45 and closing switch 110. Another branch 46 having the switch 47 extends to earth so that by opening the switches 45 and 110 and closing the switch 47 the circuit may be grounded. A line 48 extends from the shaker pan to the ground line of the cylinder in order to prevent any charge being conducted to the elements of the material in the hopper. The line 35 from the + side of the generator is also extended to the ground by the branch 49 provided with the switch 50, while the — side of the generator is provided with a similar branch 51 for the purpose of grounding that side of the machine. A switch 52 is placed in this latter branch to prevent grounding the apparatus when the direct connection of the cylinder electrode with the generator is employed. The lines 49 and 51 beyond the switches 50 and 52 are connected with the resistance 53, the switch 50 or 52 of the ground lines is adapted to connect either the line 49 or the line 51 with the resistance so that the grounding effect upon either line may be modified to more or less neutralize the + or — charge supplied to the pointed electrode.

The circuits for the purpose of energizing the magnets 8, 8 and 9 comprise a line 55 from one of the brushes to the terminals 56 and 57 of the double throw switch, while the opposite brush is connected by wire 58 to the remaining terminals 59 and 60 of said switch, the operating handle being shown at 61. From the terminal 62 of the switch, a line 63 extends to the spools of the magnets, and the return line 64 extends therefrom back to the switch, as clearly shown. A resistance 65 is connected into the fields of the dynamo magnets for the usual purpose of regulating the strength of the current generated and of the magnetic fields of the magnets employed.

It now remains to describe the construction of the interrupter 21. It consists of a pair of disks 66 each of which are slotted as at 67, Fig. 3, and by moving one disk upon the other the length of the opening extending through both disks may be adjusted to be the entire length of the slot or confined to a fractional part thereof. For example, at 68 the dotted lines represent the open portions of the slot of the rear disk which is covered by the solid portion of the other disk, whereby the slot thus formed through both disks is represented by practically one half of the length of the slot in each single disk. These disks being constructed of dielectric material serve in their solid portion to prevent the passage of a charge and serve to permit the passage of a charge wherever an opening is formed by a proper adjustment of the slots of the two disks. This adjustment which determines the length of the opening through both disks determines the length of time during which a charge may pass from the generator to the pointed electrode, while the solid portions of the disks regulate the inactive intervals between the charges. The terminals of the circuit adjacent to the interrupter disks and at each side of the interrupter are in this instance represented as being round. If the terminals were pointed the wave produced would be that shown in Fig. 4 by reason of the brush like nature of the charge from a pointed electrode, but in the use of the rounded terminals upon both sides of the interrupter the wave line shown in Fig. 7 is produced as these terminals serve a disruptive discharge instead of a brush discharge, and consequently produces the difference in the wave as represented in the two figures referred to. With either the pointed or rounded electrode at the interrupter the rise and fall of the potential is sudden as represented by the vertical lines intersecting the horizontal line *c*, Figs. 4 and 7 which represents zero potential. This sudden abrupt rise and fall in potential, in the wave employed in our process, the + charge alone, or a — charge alone or both, is essential to the most successful separation of certain materials, and furthermore, it is essential to maintain for a given time the potential whether + or − when once secured so that, as shown in Fig. 4, the form of wave given by the pointed terminal at the interrupter the corners *a—b* are slightly rounded by reason of the brush form of the discharge in such terminal, but the potential is maintained from *a* to *b*. Now by reference to Fig. 7, and by the use of round terminals as shown in Fig. 1, the rounded corners *a—b* are avoided and to that extent the potential is maintained longer at a certain value without rising or falling. This is a diagrammatic representation of what is understood to occur in the use of terminals of different forms in connection with the interrupter in circuit. The disks in this particular instance are each provided with three slots, while the terminals of the lines 35 and 39 are arranged diametrically opposite each other, and the slots are so positioned that by a proper adjustment both terminals are opposite slots at one and the same instant which serves to short circuit the current back to the generator for a brief instant of time which is one manner of using the process which possesses material advantages under some conditions and character of material being operated on. The number of openings or their equivalent in the disks is a matter of preference. In fact, as illustrated in Fig. 8, a disk 69 is shown having a metallic plug 70 inserted in and passing therethrough, of which plug there may be a greater or less number, as desired, so that in the rotation of this disk contact is made with metallic terminals of the circuit of the electrostatic generator 20, as shown, by wires 71 and 72. Assuming that there is but one plug in the disk 69 and that the terminals 72 and 71 of the circuit of an electrostatic generator are placed in the path of that plug during the rotation of the disk, it will be seen that the wave produced by this interrupter is that illustrated in Fig. 9, wherein a sudden rise and fall of potential occurs and is maintained along the line *a—b*, and an exceedingly limited period of time exists between each rise and fall. By extending the surface of the plug to lengthen the time of contact with the terminals 71 and 72, thus lengthening the time during which the current is short circuited back to the generator the intervals of time represented by the spaces between the vertical line is increased during which the charge is inactive.

The means for adjusting the disks 66, shown in Fig. 1, for the purpose of regulating the length of the slot passing through both disks consists of a sleeve 73 fixed to one of the disks and having a tapered face and a coöperating movable sleeve 74 having a similar face, the latter sleeve being adapted for longitudinal adjustment by means of an arm 75 through which the threaded adjusting bolt 76 passes seated in the nut 77 supported by any suitable fixed part of the apparatus.

In Fig. 5 there is illustrated practically the same means for energizing the magnets 8, 8 and 9 as before described, and in addition thereto a modified arrangement of the elements for charging the pointed electrode together with a modified form of interrupter. Upon one of the journals of the cylinder electrode 2 bears a brush contact 80 connected to a conducting wire 81 covered with insulation 82, and carrying by means of a pivot 83 of electrical conducting material extending from the bar 81 an adjustable contact plate 84. A similar bar 85 and contact plate 86 on its pivot 87 with similar insulation 88 is connected by wire 89 with the pointed electrode 1. A disk 90 is mounted upon the shaft 91 which may be rotated by any suitable means, and upon one side of the disk is an annular electrical conducting strip 92 from which project in this instance three wiping contact arms 93. Upon an opposite side of said disk is a similar annular strip, as stated, provided with three wiping contact arms 94. The adjustable contact plates 84 and 86 are curved, as shown, to conform to the path of the ends of the contact arms 93 and 94 and each is capable of retaining an adjustment upon its pivot 87 whereby the time of contact of any of the arms 93 or 94 may be predetermined and varied from a contact covering the entire length of said plate or to practically any desired distance diagonally across said plate determined by its inclination from a vertical position when the disk rotates in a vertical plane, as shown in Fig. 6. The dotted lines 95 in Fig. 10 clearly indicate the length of contact of the arms 93 or 94 on either side of the disk. A brush 96 bears continually upon one of the electrical conducting strips 92 and is connected by wire 97 to one pole of an electrostatic generator, and another brush 98 contacts the opposite conducting strip through the wire 99 with the opposite pole of the generator. The function of this form of interrupter is to supply a charge to the pointed electrode and to reduce the potential of both electrodes to zero, and to accomplish this with exceeding rapidity and accuracy and without any perceptible intervals of lapsed time between the alternations. These objects are secured in the following manner. Assuming a current from the + pole of the generator passing through the wire 99 and the brush 98 to the annular plate on the underside of the disk, the current would follow the plate until it reached the lower arm 94 at the left. Assuming the next adjacent arm 93 to be in contact with the plate 84, and that therefore both arms 93 and 94 are in contact with said plate, then in consequence of this contact of both arms with the plate, the current would follow the plate 84, upper arm 93, contact plate 92, brush 96 and the wire 97 back to the generator at its — pole. In other words, the entire charge of the generator is short circuited back to it from the cylinder electrode 2 for an exceedingly brief instant of time which would be occupied in the passage of arm 94 from plate 83 after arm 93 had contacted therewith. The same operation takes place at the other side of the interrupter with relation to the pointed electrode and consequently there is a sudden rise and fall of potential in this instance involving both polarities above and below the zero line *c*.

The construction of interrupter shown in Fig. 8 is, as hereinbefore described, but it only remains to say that by the use of such an interrupter the same results with a round electrode 100 substituted for the pointed electrode 1 can be produced in so far as bringing both electrodes to zero potential certainly and suddenly is concerned and that by short circuiting the current back to the generator, and this result is produced without any appreciable interval of time between the successive charges as illustrated by the diagram in Fig. 7.

In the application of our process to the separation of the particles of a mass the motive forces generally employed, to wit, convectively delivered charges and a magnetic field, act under conditions to be further described, to effect the purpose in view either by the production, existence or polarization by different wave forms in the convectively delivered charges, and different conditions of strength in the magnetic field. In the production of an alternating charge in the magnetic field switches 41, 43, 50 and 52 are open, while the switch 47 is closed to connect the cylinder electrode to the ground. The interrupter 21 is rotated at a desired speed regulated by the cone pulley connection to the source of power, when the opening 67 is opposite the terminals of the line 35 a + charge is given to the pointed electrode 1, the potential of which then rises and is maintained as represented in the diagram in Fig. 4 along the line *a—b* with the corners slightly rounded. When in the rotation of the interrupter disks the opening 67 is in alinement with the wire 39 and its extension there is an immediate sudden drop of potential to below the 0 line when a — polarity is maintained as at *a b* in said diagram so that we have produced and maintained an alternation of + and — polarity. In the diagram in Fig. 4 the corners are slightly rounded and it would only require an enlargement of the terminals of the wires 39 and 35 to produce corners more nearly approaching the square at the points mentioned. When the terminals are intercepted by the solid portions of the disks of the interrupter, the density of the charge increases upon the terminals, and portions of the charge creep toward the advancing alined slots and taking this longer path from one terminal at one side to the other terminal at the other side of the interrupter, there is a passage through the slots for an instant of a charge of low density, but when the slots and terminals are opposite each other, the full charge passes instantly and the potential falls practically to zero.

To apply in the magnetic field convectively delivered charges to the cylinder electrode which shall be grounded, said current being delivered from the pointed electrode 1, switches 43, 52 and 47 are closed, and 45 and 110 open. In this instance we will deliver plus charges from the electrostatic generator 20 through the lines 35, 42, switch 43 and line 36 to the electrode 1 and through the magnetic field to the electrode 2 and from thence by the line 44 to the ground. In this instance it will be noted that the interrupter is cut out of circuit, the switch 41 being open no current can pass in that direction. The current produced in this instance would be represented by a straight line, it being of + polarity. A similar arrangement closing the switch 41 on the — line and leaving the switch 43 open on the + side of the machine would give us a constant — current. In each of these instances, when delivering a + charge to the pointed electrode the — side of the machine should be grounded by closing the switch 52, and in delivering a — charge to the pointed electrode the + side should be grounded by closing the switch 50. It is understood that the distinction between a convectively delivered charge and a current is that the former passes through a gaseous gap between adjacent terminals while the latter being the same charge, when upon or directed by a suitable solid conductor, is or becomes electricity in the current form, if said conductor has the function of returning that electricity either to the earth or back to the generator thereof.

In producing an interrupted current switches 41 and 43 are open and the interrupter rotated, switches 47 and 52 are closed 47 to ground the cylinder electrode and 52 to ground the — pole of the generator. This gives us an interrupted current of + polarity, the wave of which is illustrated in Fig. 10.

To give an interrupted current of — polarity switch 47 is closed and either switch 45 or switch 50 is closed to ground the + pole of the generator and the switch 38 is closed on the — side of the generator and the switch 52, the ground line of the — pole of the generator, is left open. In this condition the wave is represented in full lines in Fig. 11.

The charges supplied to the pointed electrode may be varied by employing the resistance 53. For example, if it be desired to have a full strength + charge in an alternating current, and a weaker —, then switch 52 is thrown into contact with one of the posts of the resistance 53 to effect a greater or less diminution of the — whereby there will be discharged from the pointed electrode into and through the magnetic field an alternating current whose + is of greater strength than its — as indicated by dotted lines *f*, Fig. 11 representing the wave produced on the — line.

To give a constant charge of one polarity intermittently modified by a charge of the opposite polarity we close the switch 45 on the + side of the generator thereby directly connecting the cylinder electrode 2 with the generator, the grounding switch 47 being left open, then switch 43 is closed and switch 41 is opened and switch 38 closed and switches 50, 110 and 52 opened. Now, a + charge will be delivered both to the electrode 1 and to the electrode 2, and intermittently as the opening 67 of the interrupter alines with the wire 39 a — charge will be delivered to the pointed electrode. Under this condition we have a constant charge of one polarity (+) on one electrode represented by the straight line in the diagram of the wave shown in Fig. 12, and we also have a succession of charges of the opposite polarity (minus) which impinge and are active as illustrated in said Fig. 12 at the points *d d* and are inactive at the points *e e*.

It is to be understood that in producing all of these varied wave effects by the application of our process, still further modifications in said waves and their effect upon the material being treated is provided for in the regulation of the strength of and of the polarity of the magnetic field used in conjunction therewith.

In this invention it is to be understood that an electrostatic convectively delivered charge from an electrode having a sharpened termination produces an even flow of current to an opposing electrode as uninterruptedly as that produced by a galvanic current passing over a conductor, while a rounded electrode can be made to deliver to an opposite electrode intermittent charges of potential, the intermissions being caused by the accumulation of a charge of such pressure as becomes greater than the intervening air can withstand. The air, which is simply a dielectric, is broken down and a spark passes from one electrode to the other, through said air, or gaseous gap momentarily lowering the potential, so that when a slot opening in the disk is opposite one or both of the rounded terminals a series of discharges takes place in rapid succession, while if pointed terminals are used the transfer of potential takes place with an even flow of convectively delivered charges. While a discharge of static electricity from a sharp point acts upon a dielectric particle in a manner similar to an interrupted charge from the rounded electrode whose potentials are characterized by either a rapid rise or a rapid fall, or both, in the potential supplied them, we disclose means for causing violent fluctuations in the charge delivered from the pointed electrode. To illustrate the facts clearly, the electrostatic convectively delivered charge flowing from a sharp pointed electrode to one to which the material is fed for separation polarizes the dielectric particles strongly in the manner heretofore described, that is, without interruption. There is a difference in the time in which these particles can be polarized, or in which this constant difference of potential can be set up and maintained between them. Therefore by regulating the time as well as the character of the convectively delivered charges given from the pointed electrode one set of particles can be differentiated from the rest by the fact that in the time in which the charge is given one set is polarized while the other is not. The rounded terminals do the same with intermittent charges with, however, this difference; the longer the time of the charge delivered, the less will be the polarization owing to the fact that the particles acquire the same potential as the electrode and would be repelled. Therefore with rounded electrodes the charge must be accurately timed so that the particles will never become fully charged thus maintaining them at a constant difference of potential from that of the conveyer electrode to prevent repulsion. On the other hand, the longer the duration of application of the convectively delivered charges from the pointed electrode the greater will be the polarization of the particles up to the maximum of their capacity, but never reaching a repelling potential.

The material to be separated is in granular or pulverized form and is placed in the hopper 3 and is fed therefrom by the vibrating shaker pan 4 on to the electrode 2. The hopper 3 and shaker pan 4 being grounded by line 48, and the shields 24 and 25 further act to protect the material in the hopper and pan from the action of the pointed electrode so that the material falls upon the electrode 2 and is carried by it into the fields of the magnet 12 and pointed electrode 1. When in these fields those particles having feeble magnetic properties that are also dielectric adhere to magnetic electrode 2, while those that have no, or very feeble, dielectric capacity but being also feebly magnetic are carried by the rotative movement of the electrode 2 across the neutral line into the field of magnet 12 by reason of the concentrated lines of force thereof. Now comes into action the shield 25 which, is polarized at its tip by the action of the convective current from the points of the electrode 1, acts more strongly upon these particles having no or feeble dielectric capacity and attracts them to prevent their contacting with pole 12 and directs them onto shield 30. These particles are eventually delivered from the shield 30 into the first receptacle 34. Some of the particles that still adhere to electrode 2 are carried by it into proximity with shield 29 where some particles are thrown by the rotation of the electrode 12 upon said shield 29 and into the second receptacle 34, while others of such particles are polarized by the tip of said shield so as to release them from electrode 2 when they fall into the third receptacle 34. The particles that still adhere to electrode 2 are removed by the wiper roll 7, the shield 33 acting simply mechanically to divide said particles into two bodies depending for division only upon the shorter or longer duration of adherence to electrode 2.

In some cases the magnetic action predominates and in others the static action predominates depending upon the responsiveness of the particles to one or the other force or effort. In the present invention the feebly magnetic particles are rendered, by the convective static charge or effort, more responsive to the magnetic force or effort. It is also not essential for successful operation that these forces act in opposing direction.

Having described our invention and several forms of apparatus in which it may be embodied for practical use, what we claim and desire to secure by Letters Patent is:—

1. The process of treating the particles of a mass for separation which consists in subjecting the same to the action of an electrostatic charge convectively delivered upon said particles and regulated to produce and maintain a polarity upon dielectric particles opposite to that of one electrode while in a magnetic field, and separately collecting the separated particles.

2. The process of treating particles of a mass for separation which consists in producing and maintaining by a convectively delivered electrostatic charge a difference of potential between the particles of material and an electrode while in a magnetic field, and separately collecting the separated particles.

3. The process of separating the particles of a mass which consists in producing and maintaining a difference of potential between the particles of the material and an electrode while in a magnetic field, subsequently depolarizing said particles to release them from said electrode, and separately collecting the separated particles.

4. The process of separating particles of a mass which consists in subjecting the same to an interrupted static charge of one polarity while in a magnetic field, and separately collecting the separated particles.

5. The process of separating particles of a mass which consists in subjecting the particles to an interrupted charge of one polarity and in modifying the strength of said charge while the particles are in a magnetic field, and separately collecting the separated particles.

6. The process of separating particles of a mass which consists in subjecting the particles to the action of a magnetic field and to a convectively delivered static charge of one polarity which polarity is continuous and to a convectively delivered static charge of alternating polarity, and separately collecting the separated particles.

7. The process of separating comminuted materials consisting in separating such materials by the action of combined static and magnetic fields, in reversing the polarities of the magnetic poles to adapt the polarities to the particular material being separated, and separately collecting the separated particles.

8. In a process of separating comminuted materials consisting in separating such materials by the action of combined static and magnetic fields, in reversing the polarities of the magnetic poles relative to the polarity of the static field, and separately collecting the separated particles.

9. The process of separating comminuted materials consisting in separating such materials by the action of combined static and magnetic fields, in reversing the polarities of said static field to adapt the polarities to the particular material being separated, and separately collecting the separated particles.

10. In a process of separating comminuted material consisting in submitting it to a combined static and magnetic field, electrically shielding the material from a portion of said static field, and separately collecting the separated particles.

11. In a process of separating comminuted material consisting in subjecting the material to a convectively delivered charge, shielding a portion of said material from said charge while in a magnetic field, and separately collecting the separated particles.

12. The process of separating particles of a mass which consists in subjecting them to the action of a varied electrostatic charge while in a magnetic field, and separately collecting the separated particles.

13. The method of separating the ingre-

dients of mixed comminuted material which consists in subjecting the material simultaneously to magnetic attraction exerted in one direction and a convectively delivered static charge exerted in another direction, the magnetic attraction dominating the electrostatic convective effort in respect to material inherently responsive to both forces, and separately collecting the separated particles.

14. The method of separating the ingredients of mixed comminuted material, which consists in subjecting the material simultaneously to magnetic attraction exerted in one direction and to a convectively delivered static charge acting in another direction in respect to material inherently responsive to both forces, and separately collecting the separated particles.

15. The method of separating ingredients of mixed comminuted material which consists in subjecting the material simultaneously to magnetic attraction and a static charge delivered convectively to the material, said material being inherently responsive to both forces, and separately collecting the separated particles.

16. The method of separating ingredients of mixed comminuted material which consists in subjecting the material simultaneously to magnetic attraction and to a static charge delivered convectively to the material, regulating the effective potential of said charge relative to the intensity of the magnetic attraction, and separa[illegible] separated particles.

17. The method of separating [illegible] of mixed comminuted material wh[illegible]sists in subjecting the material simu[illegible]ously to magnetic attraction and to a co[illegible]vectively delivered static charge, regulating [illegible] the period of duration of time of application of said charge to act selectively on the susceptible particles of the material and separately collecting the separated particles.

18. The process of treating particles of a mass for separation, consisting in subjecting the same to an electrostatic charge regulated to produce and maintain upon the nonconducting particles of the mass a polarity opposite to that of a separating electrode, passing said mass through a magnetic field, and separately collecting the separated particles.

19. The process of treating particles of a mass for separation consisting in passing said mass through a magnetic field and producing and maintaining upon particles of the mass in the magnetic field a potential differing from that of an electrode, and separately collecting the separated particles.

In testimony whereof we affix our signatures in presence of two witnesses.

HENRY M. SUTTON.
WALTER L. STEELE.
EDWIN G. STEELE.

Witnesses:
J. S. Moad,
J. P. Hubbell.