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

PROCESS OF AND APPARATUS FOR PROGRESSIVE ELECTROSTATIC SEPARATION OF COMMINUTED MATERIALS.

APPLICATION FILED OCT. 25, 1912.

1,073,645.

Patented Sept. 23, 1913.

4 SHEETS—SHEET 1.

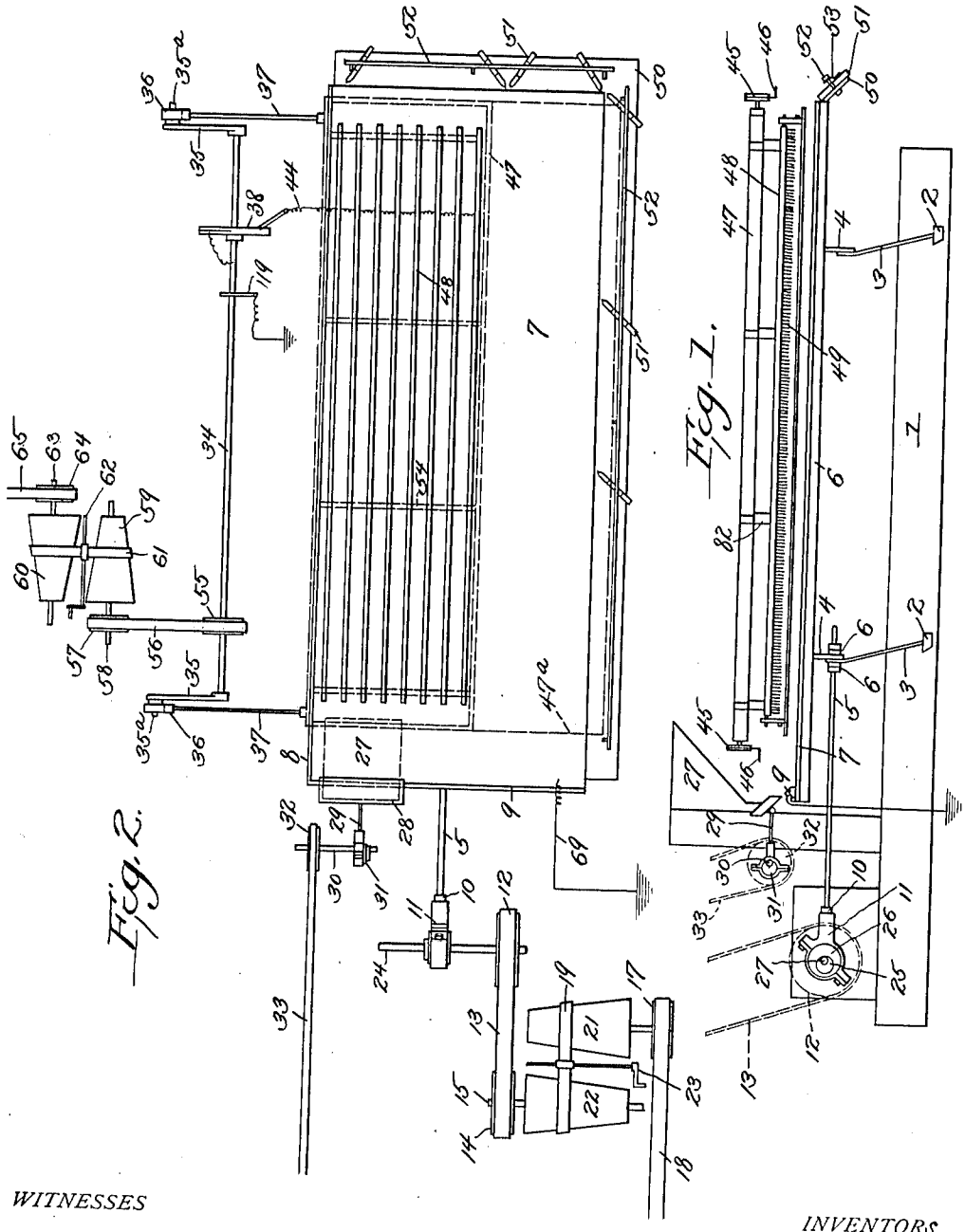


Fig. 2.

Fig. 1.

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Fig. 3.

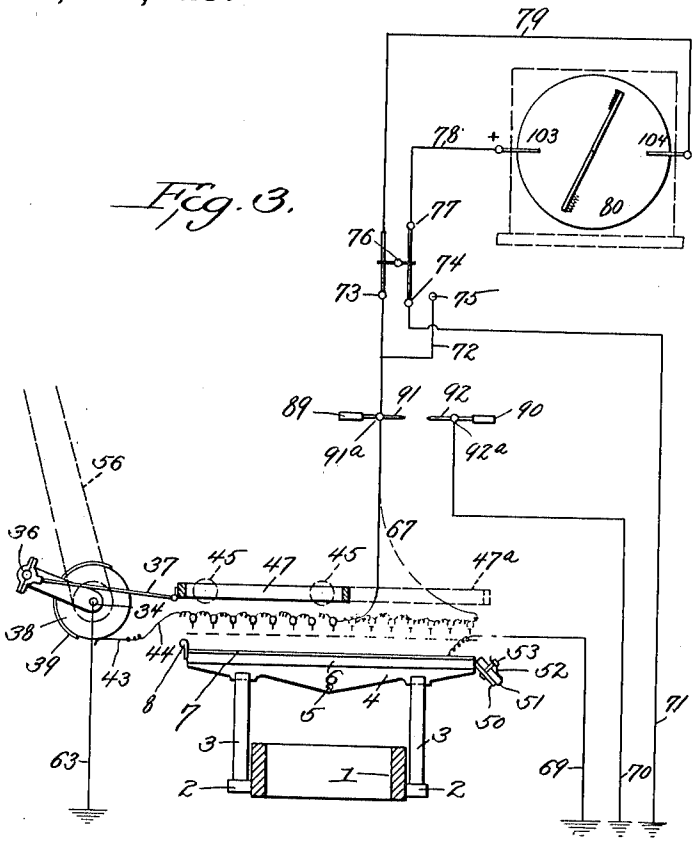


Fig. 7.

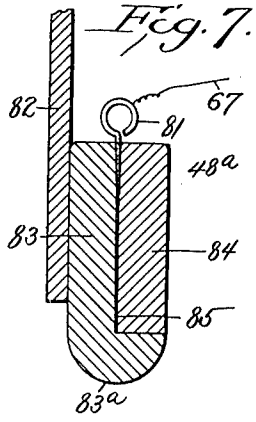


Fig. 8.

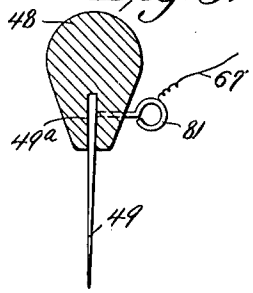


Fig. 4.

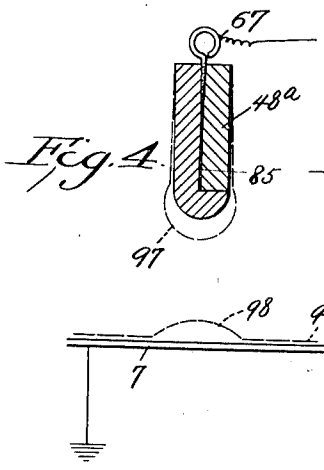


Fig. 5.

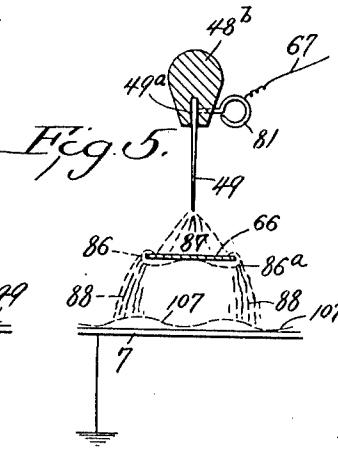
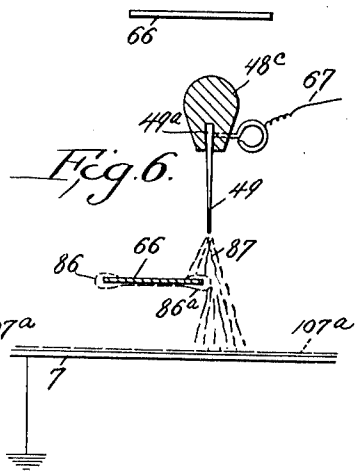


Fig. 6.



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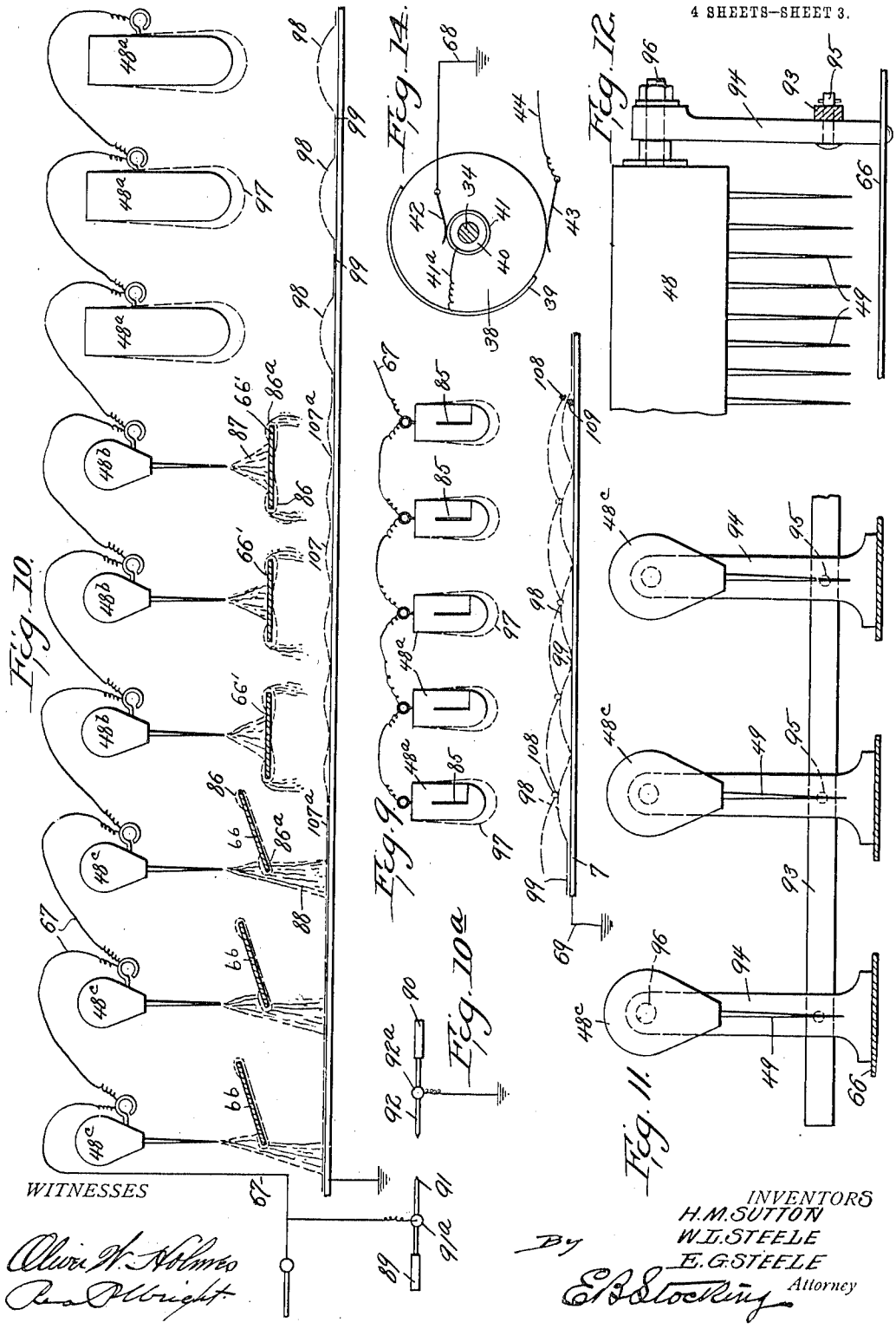
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4 SHEETS—SHEET 4.

Fig. 18.

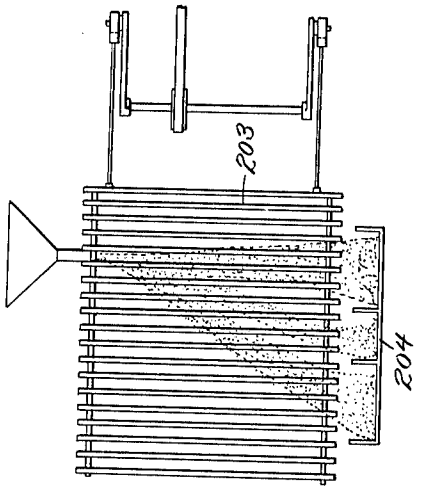
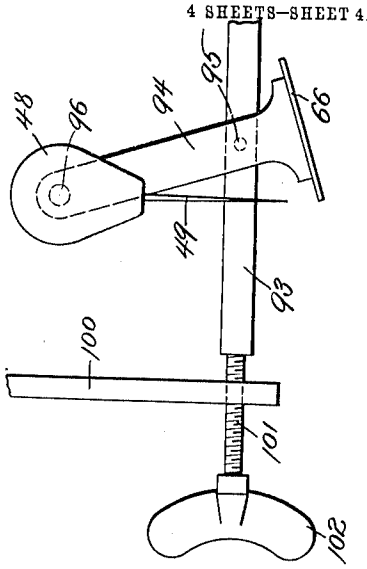


Fig. 13.



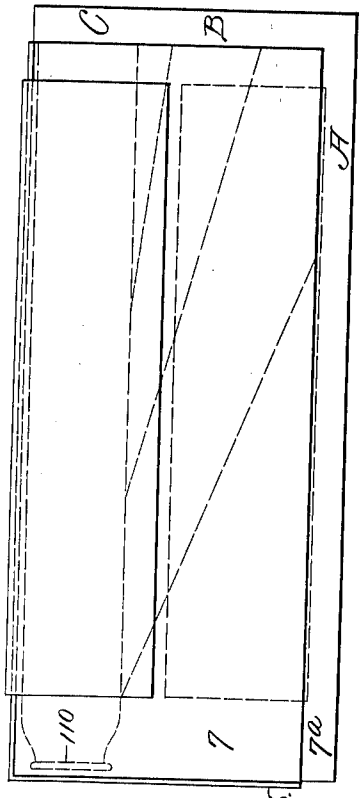


Fig. 15.

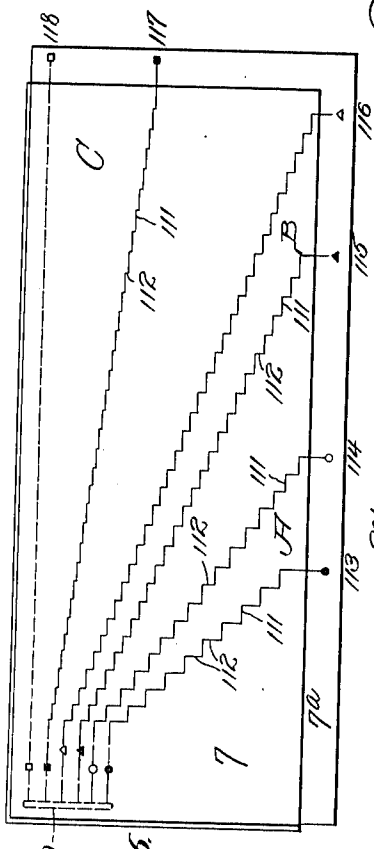


Fig. 16.

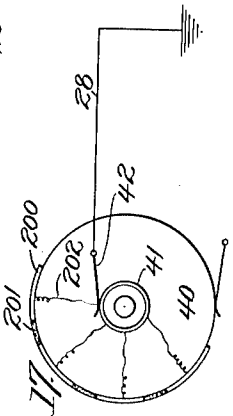


Fig. 17.

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PROCESS OF AND APPARATUS FOR PROGRESSIVE ELECTROSTATIC SEPARATION OF COMMINUTED MATERIALS.

1,073,645. Specification of Letters Patent. Patented Sept. 23, 1913.

Application filed October 25, 1912. Serial No. 727,797.

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 of America, residing at Dallas, in the county of Dallas and State of Texas, have invented certain new and useful Improvements in Processes of and Apparatus for Progressive Electrostatic Separation of Comminuted Materials, of which the following is a specification.

This invention relates to a process of electro-static separation which is in the nature of an improvement upon the invention disclosed in patents issued to us, Nos. 1,020,063 patented March 12, 1912; and 1,017,701 patented February 20, 1912; and consists in establishing three different types of electrostatic fields upon a single conveying or electrical surface, and shifting these fields across the line of normal movement, or the path of a falling mass of comminuted material composed of particles of diverse electrical susceptibility.

In the above-mentioned patents, the preferred form of the process consists in feeding comminuted materials composed of particles of different electrical susceptibilities to a support designed to push or propel the material in one direction, while above this support is a member composed of a number of statically charged electrodes or bars which move at an angle to the movement of the material. The process of separation depends upon the fact that the electrode bars are connected to a source of high potential electricity each carrying a static charge which produces by induction upon the support, an electro-static field of varying density corresponding to the charged electrode bars above, consequently, when these bars are moved above and across the lines of movement of the material on the support, these waves of relatively greater density shift likewise, and the particles of greater electrical susceptibility follow this movement to a more or less extent, the separation taking place as the resultant of the two forces upon the material and the particles are separately collected at different places at the delivering end, or edge, of the support or deck.

The present invention consists in an improved process for submitting for separation, a mass of particles of diverse electrical susceptibilities to an electrode surface, and producing upon said surface, a series of electro-static fields of variable density and different electrical characteristics, the first characterized by that of static stress solely, the second by that of static stress but modified by the outer discharges of a convective discharge, and the third by that of static stress and to the intermittent action of the full strength or central portion of a convective discharge so that materials of greatly diverse electrical susceptibilities can be treated simultaneously and progressively separated through the different types of static fields upon a single electrode surface adapted to deliver such material into whatever particular type of electro-static field is best adapted for the further separation of the particles, or the particles may be submitted to one or more of these fields of action singly as the nature of the material may require, as the electrode bars can be wholly composed of either one or all of the three types.

Our invention also contemplates means of reciprocating the electrode bars, and in the manner of so establishing electrical connections, thereto from a source of high potential electricity that the static charge can be cut out of the electrode bars during a predetermined portion of the stroke of said bars.

Our invention further consists in an improved form of these electrodes attached to suitable supports.

Other and further objects and advantages of the invention will be hereinafter set forth and the novel features thereof, defined in the appended claims.

Referring to the drawings: Figure 1, is a side elevation of the electro-static table; Fig. 2, is a plan view of same; Fig. 3, is a cross section showing the electrical connections; Figs. 4, 5 and 6, are diagrams showing the three types of electrodes used; Fig. 7, is an enlarged view of the electrode of Fig. 4, showing an insulating support for the electrode; Fig. 8, is an enlarged view of the electrode of Fig. 5; Fig. 9, shows a series of electrodes of the type shown in Fig. 4; Fig. 10, shows a series of electrodes combining the three types of electrode bars employed; Figs. 11, 12 and 13, show the type of electrode shown in Fig. 6, showing the arrangement whereby the shield 66 is operated; Fig. 14, shows means whereby the

electrical current is broken or interrupted; Fig. 15, is a plan showing the position of the electrodes at the start and finish of their stroke and showing the approximate position of the zones of separated mineral when three differentiations are made; and Fig. 16, is a diagram showing the line of travel of the particles across the deck of the machine; Fig. 17, shows means for producing pulsating fields for carrying out our improved progressive process of separation; and Fig. 18, shows a modified form of apparatus for carrying out the progressive process of separation by acting upon a falling field of material.

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

In the drawings 1 is a suitable base frame on which are secured sockets 2 in which are mounted supporting inclined deck supports 3 which are attached to cross beams 4 on which is secured the electrically grounded deck 7, this deck having raised edges 8 and 9. The deck is provided with apron 50, on which are located sliding fingers 51, retained in position by rods 52 and springs 53, thus permitting the cutting fingers 51 to be placed at any position to cut the desired product. A pitman rod 5 is flexibly connected to beam 4 at one end, and at its other end is attached to the eccentric strap 11 by an adjustable joint 10; the object of this eccentric being to oscillate the electrically grounded deck longitudinally, this movement or oscillation being made adjustable by providing a shaft 24, on which is fixed an eccentric 25 and an adjustable eccentric 26; the whole being driven by pulley 12 and belt 13. It will thus be seen that by adjusting the relative position of the two eccentrics 25 and 26, any desired stroke can be imparted to the grounded deck 7. In addition to the longitudinal stroke imparted by the eccentric head motion, the grounded deck 7 is given a slight rising and falling motion by means of the inclined supports 3, the deck rising on its forward stroke and falling on its return stroke; this combined movement of the deck imparting to the granular pulp on its surface, a movement or travel longitudinally across the electrically grounded deck 7.

Mounted on the base frame 1, is a suitable support carrying a feed hopper 27 which is provided with a feed pan 28 connected by pitman rod 29 to eccentric 31 mounted on a shaft 30 which is driven by a belt 33 traveling over a pulley 32 fixed on said shaft; this feed arrangement permitting of the even distribution of the feed of material to the machine in the position shown at 27, Fig. 2. Supported above the electrically grounded deck 6 are a series of electrodes 48; which electrodes may be of either type or a combination of the types shown. These electrodes are insulated from their support 47, by straps of electrically insulated material 82; the supporting frame 47 being provided with carriers 45 running on suitable tracks 46; the object being to provide a suitable support in order to allow the electrodes to reciprocate transversely across the electrically grounded deck 7.

As one means for reciprocating the electrodes, we show in Fig. 2, a shaft 34 driven by pulley 55 and belt 56, on which are located cranks 35 to which are attached pitmen 37, driven by crank pins 35^a and flexibly attached to the supporting frame 47. In Fig. 2, we show speed-change transmissions for changing or regulating the speed or number of strokes of the supporting frame 47 and the electrically grounded deck 7. A pulley 12 is located on head motion shaft 24 which is driven by a pulley 14 located on shaft 15 through the medium of the belt 13. The shaft 15 is driven by a cone pulley 22 from a cone pulley 21 located on a parallel shaft 16 through the medium of a belt 19; and the shaft 16 is driven by a belt 18 passing over a pulley 17. Adjusting means 23 is provided for shifting the position of belt 19 on the cone pulleys 21 and 22, thus regulating the speed of shaft 15 and consequently shaft 24, this adjustment permitting any number of strokes or reciprocations of the electrically grounded deck 7 per minute desired; the object being to propel or move the granular pulp being treated longitudinally across the deck 7 at the proper speed of travel. In a similar manner, the supporting frame 47 and electrodes 48 can be caused to reciprocate transversely across the deck at any desired speed or stroke per minute by the belt 65 which drives a pulley 64 located on a shaft 63. A cone pulley 60 is located on shaft 63 and drives a cone pulley 59 through the medium of a belt 61. The cone pulley 59 is fixed on the shaft 58 on which is located a pulley 57 which drives a pulley 55 arranged on a shaft 34 by a belt 56. The adjusting means 62 permits the adjusting of the belt 61 into any position desired on the cone pulleys 59 and 60. The position of the belt 61 in relation to the cone pulleys 59 and 60 changes or regulates the speed of the shaft 34 and consequently the reciprocating or the supporting frame 47 through the pitmen 37.

In Fig. 3, showing the cross section of the grounded deck 7, with its supporting beams 4 and inclined supports 3, we show the reciprocating electrode support 47 and the position of the electrodes 48 with the end view of the oscillating means for the supporting frame 7. In this figure are also shown, the electrical connections and the

means by which the electrodes 48 are intermittently charged and discharged at the predetermined intervals. The generator 80 which can be of any type of apparatus for the production of high tension electricity is connected from its + pole 103 by line 78 to terminal 77 of a double pole switch, while the — pole 104 of the generating device is connected through lines 79 to the opposite terminal of the double switch 76; this double throw being arranged to deliver a current through contact 73 and 74 or through contact 74 and 75; the object being to reverse the polarity on line 67 contact point 74 being grounded to the earth through line 71. The object of this construction is to ground the side of the generating apparatus not being used to excite the electrodes 48 through line 67 when the arms of the double throw switch 76 are resting on contact points 73 and 74. The negative side of the generating apparatus is connected direct through throw switch 76 and line 67 to the electrodes 48 while the positive side of the generating apparatus is going through contact 74 and line 71 to the earth. When the switch is thrown to the opposite side the negative side of the apparatus is grounded through line 79 to contact 74 and through line 71 to the earth while the positive side of the generating apparatus is connected through line 78 to contact point 75 and through lines 72 then 67 to electrodes 48. On line 67 connecting the double throw switch 76 with the electrodes 48 is located regulating means to regulate or modify the strength or intensity of the current delivered from the generating apparatus 80 to the electrode bars 48, this regulating or modifying device being composed of terminals 91 and 92 supported on sliding contact supports 91^a and 92^a provided with insulated handles 89 and 90, thus providing a spark gap connecting the circuit 67 with the ground through the line 70. It will be seen that the relative position of the contact points 91 and 92 will govern the amount of current flowing through line 67. By intercepting a portion of the current and grounding the portion cut out, in order to complete the electrical circuit through the generating apparatus 80, the electrically grounded deck 7 is grounded through the line 69 to the earth thus providing an electrical circuit from one side of the generating apparatus 80 through switch 76 and line 67 to electrodes 48 and by convection from electrodes 48 to electrically grounded deck 7 and ground line 69 and back to the opposite pole of the generating apparatus through the earth and ground line 71. In order that the electrical circuit may be interrupted or removed from the electrodes 48 at predetermined intervals, an insulating disk or support 38, Fig. 14, is mounted on shaft 34 and carries a contact sector 39. A brush 43 is adapted to contact with sector 39 and is connected through the line 44 to the electrodes 48 and a brush 42 contacts with sector 41 mounted on an insulating support 40 fixed on shaft 34 which forms grounding means through line 68 to the earth and the line 41^a connects sector 41 with sector 39. It will be seen that during one revolution of the shaft 34 the contact sector 39 is brought in contact with the brush 43 and the earth through lines 44, 41^a and 68, thus grounding the electrodes 48 once during each revolution of the shaft 34 and consequently during a portion of each stroke of the reciprocating frame 47 carrying the electrodes. The object of such a construction is to remove the charge from the electrodes on their return stroke by grounding the same to the earth and to permit the generating apparatus 80 to charge the electrode 40 during the forward stroke of the electrodes 48, when the brush 43 is not contacting with the grounded sector 39.

In Figs. 4, 5 and 6, are shown three types of electrodes 48^a, 48^b and 48^c, which can be used singularly or in combination to obtain the electrical charge or effect, this electrical action being more fully described further on. In Fig. 4, we show one type of electrode 48^a which is more fully shown in the enlarged view of the same, Fig. 7, in which a metallic terminal 85 is entirely inclosed in shields of low conducticity 83 and 84 with connecting means 81 to permit the metallic terminal 85 to be connected to the charging means through the line 67. In Fig. 5, a type of electrode 48^b is shown, an enlarged view of the same being shown in Fig. 8. This electrode comprises an insulated support 48 which carries a series of sharp needle bars or edges 49 secured in metallic sockets 49^a which are provided with suitable connecting means 81 to permit of an electrical connection with exciting means 80 through line 67, a side elevation of the needle bars being shown in Fig. 12. Electrode 48^b is provided with a stationary insulating shield 66′ adapted to intercept the charge 87, all but the outer portion of a convective discharge flowing from the points or edge 49. In Fig. 6, is shown a type of electrode 48^c which is identical in construction with electrode 48^b except that the insulating shield 66 is so placed as to permit of a part of the central portion of charge 87 flowing direct to the grounded deck 7, the insulating shield on this type of electrode being so arranged as to permit of its adjustment in relation to the points 49 at predetermined intervals or during a portion of the transverse stroke of the electrodes 48 across the grounded deck 7, one means for accomplishing this being shown in Figs. 11, 12 and 13.

In Fig. 11, we show a series of electrode

bars 48ᵉ on which are formed carriers 94 supporting the insulating shields 66, the supporting means 94 being flexibly connected by rods 93 operating on pins 95, a side elevation of this apparatus being shown in Fig. 12.

In Fig. 13, we show an adjusting screw 101 arranged in a portion of the machine frame 100 in position to contact with rod 93, and it will thus be seen, that on the back stroke of the reciprocating frame 47 carrying the electrodes 48ᵉ, that when the rod 93 comes into contact with the adjusting screw 101, the insulating shields 66 under the electrodes 48ᵉ are momentarily caused to assume the position shown permitting the charge flowing from points 49 to reach the grounded deck 7 unobstructed, the object being to permit the charge to flow from electrodes 48ᵉ to the grounded deck for a short interval of time at the beginning of its travel transversely across the deck, after which interval, the insulating shield 66 is allowed to take its natural position as shown in Fig. 5.

In further describing the operation of our new process of electrical separation, it will be seen that the apparatus for carrying out the process is provided with a metallic deck 7 over which the material to be separated is caused to travel longitudinally at a predetermined speed of travel. The material is fed through a feed hopper 27 as described, which is located on one side of the deck and the pulverulent material if allowed to pass over the deck without being influenced electrically, will travel in a straight path longitudinally across the deck and will be delivered at C, Fig. 15. Above this deck, is placed a reciprocating series of electrodes adapted to be charged by suitable means and discharged at predetermined intervals, the position at the beginning and finish of the stroke of these electrodes being shown in Fig. 15. The electrode bars are of such construction and are charged in such a manner as to influence or affect certain particles or components of the mixture being treated so as to cause certain particles to follow the electrodes in their transverse movement across the deck, the particles most effected by this electrical influence traveling diagonally across the deck intermittently and are delivered at A, and the particles not so strongly influenced or affected travel at a lesser angle across the deck and are delivered at B. The particles unaffected by this electrical influence are delivered as stated above at C. This electrical action is diagrammatically shown in Fig. 16, which shows the line of travel of six particles which are affected differently by the electrical charge, particle 113 being the most affected and particle 118 unaffected by the charge used. Referring to the diagram, Fig. 16, that portion of the line of travel of the particles shown as 111 shows the travel of the particles and the influence of the propelling deck, while that portion of the line of travel shown as 112, shows the line of travel of the particles under the influence of the charged electrodes. The particles travel longitudinally along the deck under the influence of the propelling means while the electrodes are grounded on the return stroke. The particles move transversely across the deck while the electrodes are charged and on the forward stroke.

In the prior art of electro-static separation of comminuted materials where high potential electricity has been applied in the process of separating a mass of particles differentiated as to electrical conducivity, two types of separators have been employed. The operation of these machines is based in the first type, on feeding a commingled mass of such particles to an electrode surface charged to a relatively high state of electrical density or pressure, whereby the electrical conductors of the mass become instantly charged at the same potential as the electrode surface and are repelled before the nonconductors of the same have time to become charged, enabling them to be separately collected by suitable means. In the second type of these separators these particles are fed to an electrode surface which is so electrically connected as to maintain the same at as low a degree of electrical potential as possible, while at the same time, there is directed from an opposing electrode, a convective or spray discharge upon the particles while they are in contact with the electrode surface. The process depends in this case, upon the principle that the electrical conductors of the mass give up to the electrode surface as much electricity as they receive from the convective or spray discharge, and remain practically in an unchanged condition, while the nonconductors not being able to transmit as much electricity to the electrode surface as they receive from the convective discharge become polarized, this is, they accumulate a charge of static electricity on their sides facing the convective discharge terminal, and this maintains one side of these particles at a different electrical potential from the other, which is in contact with the separating electrode and the particles at a different electrical potential from the same, consequently these electrically nonconducting particles remain adhering to the separating electrode, which being usually in the form of a cylinder or roller and rotated, are removed to separate receptacles from the former which drop from the electrode by gravity being practically electrically inert. It will be observed that the latter process is diametrically opposite to the former in its mode of

operation, although both are capable of operation upon the same class of materials. While both of these processes are operative when applied to particles composed relatively of any one single class of particles of relatively high and low electrical conductivity, we have discovered that when they are applied to some of the mixed sulfid ore containing elements to be separated which represent every shade of electrical conductivity consisting of a class of particles which are of the highest type of electrical conductors found in these ores to that of the lowest which represent the electrical nonconductors that differ from each other only in slight gradations, that disturbing electrical causes manifest themselves which often partially and sometimes wholly, defeat these processes of separation. In separators of the first type mentioned above, we have discovered that one of the principal reasons of failure of these machines to perform their functions properly, is due to the fact that much of the gangue of some of these rebellious or refractory mixed sulfid ores are composed of nonducting particles of different elements, and when these and the electrical conducting particles associated with them are fed out of a hopper or over a surface to an electrode charged to a high state of electrical density, a portion of the electrically nonconducting elements becomes statically charged with electricity by frictional contact with each other or by friction with the support over which they travel at or before the time they reach the separating electrode, some of these particles acquire an electrical charge of the same sign as that with which the separating electrode is charged so that when the mass of particles is delivered to it, that portion of the nonconductors so electrified is repelled from the separating electrode with the same degree of force as the conductors and consequently an imperfect or no separation is performed. While this difficulty is obviated in the separators of the second type, we have found them open to the following serious difficulties when applied as a process of separation upon some of the rebellious ores of the type mentioned above: They are incapable of differentiating particles very closely related to each other as to electrical conductivity or nonconductivity in a manner practicable for commercial separation, the fault being due principally to the time factor in which these particles are exposed to this electro-static field of influence being too short to permit of a regulation, manipulation or adjustment of the degree of strength of the convectively delivered static charges to admit of a practicable separation of these closely differentiated elements. As to how our process takes advantage of these defects to fully perfect a separation of these classes of material, reference is now had to the more fully described electrical features of our invention herewith, and specifically the three different types of electro-static fields by which this separation is effected.

Referring to Fig. 4, of the drawings, we show a type of electrode capable of producing a field of static stress only, that is, there is no appreciable convective discharge given off by this form of electrode to the deck or table support 7, as the metallic electrode 85, is protected or covered with an electrically nonconducting material. The static charge accumulates when the electrode is connected to a source of high potential electricity, mostly at the lower surface thereof, shown by the dotted lines at 97. This produces by induction, upon the support 7, a corresponding field of static stress or charge of opposite potential as shown at 98, 99 the latter simply showing the light degree of static stress which exists on portions of the deck or support not immediately under the action of the electrode 48[a].

The second form of electro-static field is that shown in Fig. 5. With the connection 67, connected to a source of high potential electricity, this form of electrode produces a convective discharge from the needle points or sharp edge 49, the greater portion of which is caught and retained by the shield 66, which is composed of a suitable electrically insulating material. This charge accumulates at a greater degree of stress or density at the edges of the shield as shown by the dotted lines 86 and 86[a], and produces by induction as in the former case, a static charge upon the deck or support 7, as shown at 107, but at a very much less degree of density or pressure than that of the static field shown in Fig. 4; in addition to this, the outer discharges of the convective discharge 87 creep over the outer edges of shield 66 and these discharges act to modify the action of the field of greater stress 107 upon the particles under treatment, a more full description of which will be given later on.

The third type of electro-static field is that shown in Fig. 6. Here the electro-static field is the same as that of Fig. 5 except when the shield 66 uncovers the pointed terminal 49. This allows the central portion of the convective discharge, or the full force of the same, to impinge upon the table or support 7, the effect of which is to practically destroy the fields of greater stress on the support 7 approximately in line with the discharge or the field or area that is affected by its action upon the support 7. This type of electrode produces an intermittent field of static stress alternated with that of practically no electro-static stress. The shield 66, as has already been described elsewhere, is arranged to expose

the support 7 to the action of the convective discharge at predetermined periods, although should the character of the material require it, the shield 66 can be left in the position shown during the entire stroke of the electrode bars.

Having now described the static fields in detail, we show in Fig. 10, the preferred form or arrangement of these various types of electrodes above the deck or table 7 and the position thereon of the different types of electro-static fields. 48[a] shows the position of the first type of electrode described in Fig. 4, and is preferably arranged immediately in line with the feed 110 (Fig. 16) at the point of delivery to the table or support, and approximately in line with the reciprocating movement of the table or support 7. 48[b] shows the type of the electro-static field described in Fig. 5, is next and then 48[c] that type of electro-static field which is shown at Fig. 6.

Reference is now had to Fig. 16. We have here in this illustration, a mass of particles composed of three classes of material, it being essential to separate the particles of each class from each other. Class C consists of particles which are electrical nonconductors to an equal or to approximately the same degree, but composed of different elements. Class B represents a mass of particles which are composed of neither good electrical nonconductors or conductors, but differ slightly in that property from each other. Class A is composed of particles of the highest degree of electrical conductivity but these also differ from each other in some degree in this respect. When such a commingled mass of particles is fed to the table or reciprocating support 7, at the point of feed 110, and the electrodes are in position above the same as shown in Fig. 10, and suitably electrically connected to a source of high potential electricity, and reciprocated as described elsewhere so that these various electro-static fields are moved across the line of travel of the particles on the support, the following separation takes place. The particles enter the field of action at 110, they encounter the type of electro-static field described under Fig. 4, and shown in Fig. 10 as the initial field of operation, being in line with the point of feed 110 and here encounter the fields of greater electro-static stress represented by 98, 98, 98 (Fig. 10), the electrical conductors and those that are partially so, being more freely acted upon by these static fields of greater stress are carried, during the first stages of the operation, into the static fields 107, leaving behind the two classes of particles 118 and 119, as these are traveling in line with the pushing movement of the deck 7, they become electrified either by friction with themselves, or with the support over which they are traveling. The fact that the table or support 7 is of metal and electrically grounded does not interfere materially with this action, as the self-electrification of the particles is not hindered by the metal support, as owing to the electrical non-conducting character of these particles, they acquire this charge at a faster ratio than that which they give up, if any, to the support 7. As these particles are composed of two different elements, their tendency is to acquire in this action, static charges of opposite signs. With the connections as shown in Fig. 3, with the negative side of the generator connected through the double pole switch 76 by line 79 and by line 67 to the electrode bars 48[a], 48[b] and 48[c], we then have these bars negatively charged; there are then produced by induction, from these electrodes upon the table or support, static fields of stress corresponding to those on the electrode bars, but of opposite sign, viz., positive. Now those particles in this class which acquire a negative charge after the manner before mentioned, find themselves at the same electrical potential as these fields of greater static stress or density, and are consequently carried more or less by these fields transversely to the oscillating motion of the table 7, in other words, these class of particles are slightly repelled from the table support upward and incidentally, attracted toward the electrode bars 48[a] to the same degree, but said particles do not reach them, but ride upon the peaks or upper edges of these fields of greater static stress as illustrated more fully in Fig. 9 where particle 108 can be seen riding on the peaks of the static charges of greater density 98, while the other particle 109 remains unaffected. Referring back to 116, the class of particles represented by 118 of class C being electrified after the manner mentioned, have a tendency to acquire positive static charges, and as the fields of greater static stress are negative, the initial charges acquired by these particles are constantly being neutralized by these fields, consequently these particles are electrically neutral and respond wholly to the pushing or propelling action of the table and travel in a straight line from the point of feed 110. The class of particles represented by B which are only partial electrical conductors, but differ in that degree, have been carried by the fields of greater stress of 48[a] (Fig. 10) in their transverse movement to the support into the static fields produced by electrodes 48[b] where they are electrically differentiated as follows. The outer discharges 88, 88, as shown in Fig. 5, leak over the outer edges of shield 66 and act upon the lesser electrical conductors of the mass in a manner sufficient to retard their travel in the direction exerted by the fields of

greater electro-static stress 107 while at the same time allowing them to become amenable to the pushing action of the deck or support 7, the superior conducting particles are not sensibly retarded as regards the two kinds of particles and are more freely carried with the static fields of greater density, which cause the particles of 115 to travel in a more diagonal path from those of 116, and to report at different places at the lowest side of the support as indicated by the triangular particles 115 and 116. The particles of class A, which consist wholly of the superior conductors of the mass, owing to their being more quickly responsive than all of the other particles mentioned to the action of the fields of greater stress produced by electrodes 48^a and 48^b upon the support 7, are carried by them into the static fields produced by the type of electrodes 48^c, illustrated in Fig. 6. Here they are subjected to the alternate effect of the direction action of the central or full force of a convective discharge and to the electro-static fields of greater density. The action of the convective discharge upon the particles upon the support 7 is as follows: The particles of superior electrical conductivity give up to the table or support 7 as much electricity as they receive from the convectively delivered charges obtained from the pointed terminal 49, and remain practically electrically neutral, but respond to the pushing action of the support 7, the lesser electrical conductors of this class do not give up quite as much electricity to the deck as they receive from the convective delivered static charges emitted from the pointed terminal 49 and consequently remain temporarily stationary or travel at a much slower rate of speed than the particles of the former class, or superior conductors. When, however, the shield 66 covers or protects the points 49 so that the fields of greater static stress or density reassert themselves, the freely electrical conducting particles respond immediately and are carried in the direction of movement of these fields. The lesser conductors of this class also respond to the action of these fields of greater density but at a little later time. This action causes them to travel in divergent paths over the support 7 and they report at different points on the side thereof as shown by round shaped particles 114 and 113.

As mentioned elsewhere in this specification, in the prior art of electro-static separation of materials of this class, close differentiation of particles closely related to each other as to electrical conductivity or non-conductivity is impracticable owing principally to the comparative brief time in which these particles are exposed to the electro-static fields of influence, and while the separation commences in these fields, it does not proceed sufficiently far to permit of a practicable separate collection of the particles of one type from the other. In our invention, this separation is accomplished a little at a time over an electrode surface or support of sufficient area to allow the particles to take different routes of travel over the same in proportion as they are affected either by the electro-static fields of greater density or the pushing movement of the support, or the combined action of both.

Our process is not confined in its operation to any one electrical factor, as the particles may be separated by their difference in electrical conductivity or their difference in specific inductive capacity or by the fact that the particles are differently electrified at or during the time they are presented for separation by friction with themselves or the support over which they travel. A mass of particles may also be separated by the difference in their dielectric hysteretic lag when the charge is cut on and off with sufficient rapidity by the interrupter as shown in Fig. 14 so as to develop this property among certain classes of particles.

It may be stated in general, that the particles which tend to travel with the movement of the electro-static fields of greater density are those which are electrically opaque to the lines of force of an electro-static field of stress and are consequently carried with the movement or force of such a field of greater density. Those classes of particles which are good electrical conductors to such high potential electricity as is essential to employ, in separators of this class, are practically speaking, electrically opaque to the lines of force of electro-static induction or stress. The partial conductors are less opaque and the superior conductors almost transparent to them at least at the initial time of their presentation to a surface charged at a relatively high electrical density, as the electro-static lines of force pass through them without sensibly affecting them until they become charged, when they become just as electrically opaque to the lines of force of the static field or stress as the conductors, and are repelled with the same degree of force. Now when the electrical nonconductors which may have acquired a prior charge by friction with themselves, or upon the support on which they travel with the electrically conducting particles and adjacent to an electrode charged to a high degree of electrical density then if this electrification happens to be of the same sign as that of the highly charged electrode, they are repelled with the same degree and no separation is effected. In our process, we take advantage of this feature of accidental electrification to eliminate this class of non-conducting particles during the initial stage of the separation as has been described.

As a mass of particles in our process can be differentiated by the different electrical properties of its elements, the term by which we designate this separation as that of the difference in the electrical susceptibility of the particles to the different electro-static fields of action is intended to cover a separation of a mass of particles by any electrical property that the various elements of the mass may have.

While we have described under Fig. 7, the construction of a type of electrode, in which a thin edged, metal, electrical conductor is inclosed, or partially so in an envelop of material which is either a non-electrical conductor or one of very inferior conductivity, any smooth or round metal electrode, without the insulating coating, would be capable of carrying out the part of the process for which this type of electrode is intended. The object of the insulating material 83 and 84, surrounding or partially so, the electrode 85 as described in Fig. 7, is to protect the same so as to prevent an electrical charge from easily passing from this type of electrode to the table electrode 7, either in the form of convection, or disruptive discharges, the action of this type of electrode on the other, or table electrode 7, being by induction only. This type of electrode will not deliver a convective discharge to an opposing electrode unless the pressure, at which it is electrically charged, is greatly in excess of that which is essential to carry out its part of the process. We have also described our electrode bars as being parallel with the oscillating movement of the table electrode 7. It will be observed, however, by any one skilled in this art that all that is essential to carry out this process, is that the electrostatic fields of greater stress, as well as the modified forms thereof, should move in a direction other than that of the travel of the particles over the support 7.

While the broadest feature of our process consists in shifting the above-mentioned types of electro-static fields across the line of travel of comminuted material of different electrical susceptibilities on a support or falling from a suitable feed hopper between adjacent electrodes designed to carry out the process, we do not confine ourselves to the arrangement of these fields as described. It would be evident to a skilled artisan that if the process was applied to separate a class of particles, composed wholly of non-electrical conductors, but of different elements, that it would be essential to equip the separator with electrodes wholly of the type of 48^c, as the presence of a convective discharge in this field upon these materials on the support 7 would not only destroy the static charges which they have acquired by friction or otherwise, but would polarize them so strongly as to cause them to adhere with such tenacity to the support 7 that they could not be propelled or pushed along its surface, and in this manner they would accumulate to such an extent in line with the feed, as to block the travel of other particles and thus defeat the process. On the other hand, if the process was applied to separate particles of a mass of different elements composed wholly of partial electrical conductors, but differing in some degree, it would be preferable to use all the electrodes of the type 48^b, while, if the class of particles were composed of those of the superior conductors, differing slightly in degree in that property, it would be preferable to use wholly electrodes of the type of the 48^c.

In Fig. 17, we show the insulated support 40 provided with a series of metallic plates 200 separated by insulating material 201; each of said plates being grounded by wires 202 leading from said plates to the sector 41 through the brush 42 and line 68 in order to produce a pulsating charge upon the electrodes, as it has been found in the treatment of some classes of material, that the making and breaking of the circuit or in other words, delivering to the electrodes 48^a, 48^b and 48^c static charges interrupted a number of times during the movement of a single stroke of the electrode bars, is necessary to carry out our improved progressive process with the best results.

In Fig. 18, the modified form of apparatus for carrying out the progressive process of separation is shown and consists in disposing the intermittently moving bar electrodes 203 or their equivalent in a position to act upon a falling body of comminuted material so as to divert some of the particles thereof according to their electrical susceptibilities during their downward movement into the different receiving receptacles 204 in order to separate the particles.

From the foregoing description, it will be seen that we have provided a progressive process of separating comminuted material in which a mass of material is fed upon a supporting electrode surface over which travels intermittently, a series of electrostatic fields which act upon the particles in accordance with their electrical susceptibilities so as to move the particles more susceptible to an electrical charge divergent to the normal movement of the material intermittently, or in other words, the more susceptible particles are moved out of the path of the bulk of material by the electro-static fields traveling across the path of travel of the material and then are acted upon by the impulse of mechanical propulsion of the table so as to cause the particles to travel in zigzag lines diverging from the point of feed in order that the particles will be

separated in accordance with their electrical susceptibilities.

Wherever in this specification, the terms "shielded" or "partially shielded" are employed, it is important to note that in this process, there is no actual positive shielding of the charge. We have discovered that the outside lines of force of a brush discharge possess the quality of affecting the material subjected thereto in a manner entirely different from the effect of the central lines of force of such a discharge. We have discovered that the side or outer lines of force possess the characteristic of neutralizing any charge which a poorly conductive particle of the material may have taken from the support whereby, the said particle is amenable to the mechanical feeding movement of the support. On the other hand, if the central lines of force of a brush discharge act upon poorly conductive material, it produces a positive adherence of said particles to the support, and thus obstructs the movement of other particles caused by the mechanical movement of the support. Thus it is seen that the action of different portions of a brush discharge vary to the extent of being directly opposite in effect upon certain portions of the material.

When three types of electrodes are employed, the process involves the following actions and effects upon the material: In the initial type of electrodes 48ª, there is with practical entirety a charge by induction from the electrodes to the support, there being no practical passage of electricity by convection. The purpose of this step in the process is to separate the non-conductors from each other, as they travel along the support in line with the movement of the same varied by the transverse movement of the electrodes, as hereinbefore described. This presents conductors to the action of the remaining series of electrodes. In the second series of electrodes wherein the central lines of force are prevented from directly acting upon the material, these partial and good conductors which vary in their conductivity, are separated from each other; the outer lines of force acting to neutralize any charge taken up by the inferior conductors of this type from the support so that the mechanical action of the support shall force them in their normal path of travel, while the better conductors are acted upon by the field of stress between the outer lines of force in conjunction with the movement of the electrodes, so as to deliver them, the better conductors, to the third series of electrodes. These are acted upon by a more direct convective charge involving practically the full effect thereof. It is proper to state that at the initial transverse movement of the electrodes over the support, the electrodes of this third type are wholly exposed for action, while, during the progress of the entire series of electrodes in their operative movement, this type of electrodes is put into the condition of the second type of electrodes, all as illustrated in Fig. 10. On the backward or return movement of the entire series of electrodes, there is no electrical action whatever as before described, so that the movement at such a time, of the material is produced solely by the action of the support. The advantage of this non-active movement of the electrodes is to provide a period of time for each particle to become neutral, and to partake of the movement of the table in a direction different from that produced by the reciprocation of the charged electrodes. In this manner, it will be seen that there is a progressive separation, first, laterally of the table by the electrodes, and second, longitudinally of the table by its movement; the one succeeding the other as the different types of electrodes produce their effect successively and progressively.

We claim:

1. The progressive process of separating comminuted material, consisting in intermittently subjecting such comminuted material to be separated to an unshielded field of static stress, a centrally shielded convective charge and a partially shielded convective charge, in succession.

2. In an apparatus for separating comminuted material of diverse characteristics, the combination of means for moving such material in a predetermined normal path, means reciprocating across said normal path for establishing a series of electro-static charges of varying densities, means for energizing said reciprocating means during their movement in one direction, and means for deënergizing said reciprocating means during their movement in the reverse direction.

3. The progressive process of separating comminuted material consisting in supporting and imparting a movement to the material, subjecting such material alternately and intermittently to a series of electro-static fields of varying densities and of different electrical characteristics, moving in lines deviating from those of the normal movement of the material to cause the particles differentiated according to their electrical susceptibilities to deviate from the line of normal movement, and separately collecting the thus separated particles.

4. The progressive process of separating comminuted material consisting in feeding and imparting a normal movement to such material, subjecting the material to a series of electro-static fields of varying densities, partially shielding said charges, exposing the material alternately and intermittently

to the action of the respective fields, moving said fields in lines deviating from the line of normal movement of the material, and separately collecting the thus separated particles.

5. The progressive process of separating comminuted material consisting in imparting an impulse in one direction to said material, alternately and intermittently subjecting said material to a series of electro-static charges of varying electro-static stress, partially shielding said charges, moving said charges in directions deviating from the direction of impulse imparted to said material, and separately collecting the thus separated particles.

6. The progressive process of separating comminuted material consisting in supporting and imparting a movement to said material upon its support, subjecting said material to a series of electro-static charges of varying densities, shifting said charges in a direction deviating from the normal movement of the material, partially shielding said material from said charges in a portion of the movement of said fields, and separately collecting the thus separated particles.

7. The progressive process of separating comminuted material consisting in imparting a normal movement to the material in one direction upon an electrode supporting surface, alternately and intermittently subjecting said material to a series of electro-static fields of varying densities moving in lines deviating from the line of normal movement of the material to cause the particles of said material according to their electrical susceptibilities to move in lines deviating from that of the normal movement of the material, and separately collecting the thus separated particles.

8. The progressive process of separating comminuted material consisting in supporting and imparting a movement to the material upon an electrode surface, subjecting said material to a series of electro-static charges, intermittently shifting said charges in lines deviating from that of the normal movement of the material, partially shielding said charges at the initial movement of said charges across the support, and separately collecting the thus separated particles.

9. The progressive process of separating comminuted material consisting in supporting and imparting a normal movement to the material upon the support, subjecting said material to a series of electro-static charges, shifting said charges on lines deviating from the line of normal movement of the material to alternately act upon said material intermittently to cause the particles thereof according to their electrical susceptibilities to move in lines deviating from that of the normal movement, and separately collecting the thus separated particles.

10. The progressive process of separating comminuted material consisting in imparting a normal movement to the material in one direction upon a support, subjecting said material to a series of electro-static charges, intermittently shifting said charges across the line of the normal movement of said material, partially shielding some of said charges, and separately collecting the thus separated particles.

11. The progressive process of separating comminuted material consisting in imparting a normal movement to the material in one direction upon a support, moving the particles of said material intermittently according to their electrical susceptibilities in lines deviating from that of the normal movement by a series of alternately acting electro-static charges of varying densities, moving in lines deviating from the line of normal movement of the material and separately collecting the thus separated particles.

12. The progressive process of separating comminuted material consisting in supporting material upon an electrode surface, imparting an impulse in one direction to said material upon said surface, alternately subjecting said material to a series of electro-static charges moving in a line deviating from that of the normal movement of the material, partially shielding said charges, and separately collecting the thus separated particles.

13. The progressive process of separating comminuted material consisting in supporting and imparting a movement to the material in one direction, subjecting said material to a series of electro-static charges, intermittently shifting said charges across said support in lines deviating from that of the normal movement of the material, partially shielding said charges, and separately collecting the thus separated particles.

14. The progressive process of separating comminuted material consisting in feeding material into a series of electro-static charges of varying densities, intermittently shifting said charges, partially shielding said charges, and separately collecting the thus separated particles.

15. The progressive process of separating comminuted material, consisting in subjecting the material to the action of a series of electro-static charges of varying densities alternately and intermittently said charges consisting of unshielded fields of static stress, shielded convective charges and partially shielded convective charges, partially shielding said charges, and separately collecting the thus separated particles.

16. The progressive process of separating comminuted material consisting in supporting and imparting an impulse in one direction to said material upon an electrode surface, subjecting said material to the full

stress of a series of electro-static charges, intermittently shifting said charges across the normal movement of said material, then subjecting said material to a series of partially obstructed charges, and separately collecting the thus separated particles.

17. The progressive process of separating comminuted material consisting in imparting a normal movement to the material upon a support, intermittently subjecting the material to a series of electro-static charges of varying densities moving across the line of normal movement of said material, partially shielding said charges, and separately collecting the thus separated particles.

18. The progressive process of separating comminuted material consisting in imparting an impulse to said material in one direction, subjecting said material to a series of electro-static charges of varying electro-static stress, shifting said charges in a line deviating from the normal movement of said material and causing said charges to act upon said material alternately and in succession when moving in one direction only and causing the particles of said material to move in lines deviating from that of the normal movement, and separately collecting the thus separated particles.

19. The progressive process of separating comminuted material consisting in imparting a normal movement to the material in one direction and delivering directly to the material, a series of electrical charges for predetermined intervals separated by substantially inactive intervals, and causing the material to move alternately by the charges and imparted movement, and separately collecting the thus separated particles.

20. The progressive process of separating comminuted material consisting in imparting a normal movement to the material in one direction upon a supporting electrode surface, and intermittently delivering directly to the material, a series of pulsating electrical charges of variable density, intermittently moving said charges across the normal movement of said material and causing the particles differentiated according to their electrical susceptibilities to deviate along said support from the line of normal movement, and separately collecting the thus separated particles.

21. The progressive process of separating comminuted material, which consists in feeding said material upon an electrode surface into a series of moving electro-static fields of varying densities and of different electrical characteristics moving in lines deviating from the line of feed, to alternately and intermittently act upon the particles of said material according to their electrical susceptibilities, and separately collecting the thus separated particles.

22. The progressive process of separating comminuted material consisting in establishing upon a support a series of electro-static fields of varying density across the support and sufficient to impart a movement to the more susceptible particles intermittently along the surface in the direction of increase of stress, delivering comminuted material to be separated to the surface at the field of greatest density of said series, and separately collecting the thus separated particles.

23. The progressive process of separating comminuted material consisting in creating upon a surface, a series of electro-static charges of relatively unequally distributed density, feeding material to such support and imparting an impulse in one direction to said material, intermittently subjecting the material to moving electro-static charges and moving said charges, and therewith the more susceptible material in another direction upon the surface, and separately collecting the thus separated particles.

24. The progressive process of separating comminuted material which has particles of different electrical susceptibilities, consisting in intermittently submitting the material to a series of electro-static fields of relatively varying density extending in planes approximating parallelism with the line of normal movement of the material, shifting said electro-static fields in a direction deviating from that of the normal movement of the material and moving therewith the more susceptible particles of said material, and separately collecting the thus separated particles.

25. The progressive process of separating comminuted material consisting in feeding the same to a series of electro-static pulsating charges of varying density and moving some of said particles by the influence of said charges intermittently along the lines of greatest density and across their normal path of travel, and separately collecting the thus separated particles.

26. The progressive process of separating comminuted material consisting in establishing a series of electro-static fields of varying density upon a support, delivering such material to the support in the regions of greater density upon said support, intermittently moving said electro-static fields across the normal movement of the material to cause the more susceptible particles to deviate from the normal movement, and separately collecting the separated particles.

27. The progressive process of separating comminuted material consisting in imparting a normal movement to the material upon a support, producing a series of pulsating electro-static fields of varying density upon said support, intermittently shifting said fields across the line of normal movement to cause the different components of said material to travel upon said support accord-

ing to their electrical susceptibilities in lines deviating from the line of normal movement.

28. The progressive process of separating comminuted material consisting in supporting and imparting a normal movement to said material, subjecting the particles thereof of different electrical susceptibilities, intermittently to the separating action of a series of electro-static fields of relatively varying density, moving in lines approximately transverse to the lines of normal movement of the material, moving the particles relatively to said support while in said fields, and separately collecting the thus separated particles.

29. The progressive process of separating comminuted material consisting in imparting a normal movement to the material upon an electrode surface, alternately directing a series of electro-static charges of variable density upon said material, partially shielding said charges and intermittently moving said charges to cause said particles differentiated as to their electrical susceptibilities to travel in lines deviating from the line of normal movement of the material.

30. The progressive process of separating comminuted material consisting in supporting and moving the material in one direction, directing upon said material a series of electro-static charges consisting in unshielded fields of static stress, shielded convective charges and partially shielded convective charges, intermittently moving said charges across the normal path of travel of said material, and then separately collecting the thus separated particles.

31. The progressive process of separating comminuted material consisting in feeding material in one direction, directing upon said material a series of electro-static charges, consisting in unshielded fields of static stress, shielded convective charges and partially shielded convective charges intermittently shifting said charges in a direction deviating from the line of movement of said material to cause the particles of said material differentiated according to their electrical susceptibilities to move intermittently in lines deviating from the line of travel of said material.

32. The progressive process of separating comminuted material consisting in supporting a mass of material upon an electrode surface, imparting an impulse to said material in one direction, directing upon said material intermittently, a series of electro-static charges, shifting said charges across the impulse movement of said material, partially shielding said charges in a portion of their movements, and separately collecting the thus separated particles.

33. The progressive process of separating comminuted material, consisting in imparting a normal movement to the material upon a support, intermittently establishing unshielded fields of static stress, shielded convective charges and partially shielded convective charges upon the support across the line of normal movement to cause the different components to travel according to their electrical susceptibilities in lines deviating from the lines of normal movement, and separately collecting the thus separted particles.

34. The progressive process of separating comminuted material, consisting in supporting said material and subjecting particles thereof of different electrical susceptibilities intermittently to unshielded fields of static stress, centrally shielded convective charges, and partially shielded convective charges extending in planes approximating transversely to the lines of normal movement of the material, moving the particles relative to their support while in said fields, and separately collecting the thus separated particles.

35. The progressive process of separating comminuted material consisting in imparting a normal movement to the material upon a support in one direction, intermittently subjecting the particles of said material to a series of electro-static charges consisting of unshielded fields of static stress, shielded convective charges and partially shielded convective charges traveling across the normal movement of the material to cause the different components to travel intermittently according to their susceptibilities upon the support in lines deviating from the line of normal movement.

36. The progressive process of separating comminuted material consisting in imparting a normal movement of the material upon a support, intermittently subjecting said material to a series of electro-static charges, traveling at an angle to the normal movement thereof, partially shielding said material from said charge in a portion of the movement of said charge, to cause the different components to travel according to their susceptibilities upon the support in lines deviating from the line of normal movement, and separately collecting the thus separated particles.

37. In an electro-static separator, an oscillatory supporting table, a reciprocating frame mounted to travel transversely of the table, and provided with a series of spaced charged electrodes, a generator, a connection between said generator and electrodes, and mechanism for breaking the circuit between said generator and electrodes on the return movement of said frame.

38. In an electro-static separator, a supporting table, a frame slidably mounted above said supporting table, a series of electrodes carried by said frame, a generator, a

connection from said generator to said electrodes, means for reciprocating said frame across said table, and means for depriving said electrodes of potential in one movement of said frame.

39. In an electro-static separator, a supporting surface for comminuted material, means for imparting an impulse to said material upon said surface, means for producing a series of electro-static fields of varying densities, means for reciprocating said means laterally across said table, and means for rendering said field-producing means inactive during one of its movements.

40. In an electro-static separator, an oscillatory table, means for feeding comminuted material upon said table, a frame mounted to move transversely of said table, electrode bars carried by said frame, means for reciprocating said frame, a generator, a connection between said generator and electrode bars, and means for periodically breaking the circuit between said generator and electrode bars in the movement of said table.

41. The process of separating comminuted material consisting in intermittently subjecting the material to be separated to an unshielded field of static stress, a centrally shielded convective charge, and a partially shielded convective charge, and separately collecting the thus separated particles.

42. The process of separating comminuted material consisting in intermittently subjecting the material to be separated to unshielded fields of static stress, a centrally shielded convective charge, and a partially shielded convective charge, and reciprocating said fields and charges across the material to be separated.

43. The process of separating comminuted material consisting in intermittently subjecting the material to be separated to unshielded fields of static stress, centrally shielded convective and static stress charges, and a partially shielded convective charge, and reciprocating said fields and charges across the material to be separated.

44. The process of separating comminuted material, consisting in feeding material in one direction, imparting an impulse to said material in the direction of feed, subjecting the material to be separated to an unshielded field of static stress, a centrally shielded convective charge and a partially shielded convective charge, and reciprocating said fields and charges across the path of normal movement.

45. The process of separating comminuted material consisting in feeding and imparting a movement to said material, subjecting said material to the action of electro-static charges of different characteristics, moving said charges across the normal path of the material, and rendering said charges active in one direction only.

46. The process of separating comminuted material, consisting in feeding and imparting a movement to said material in a normal path, subjecting said material to the action of the combined convective charge and field of static stress, moving across said normal path of material and acting intermittently and alternately upon the material, and separately collecting the thus separated particles.

47. The process of separating comminuted material consisting of feeding and imparting a movement to said material in a normal path, subjecting said material to the action of a combined convective discharge and field of static stress, moving across said normal path, and rendered inactive in a return movement.

48. The process of separating comminuted material consisting in subjecting a body of moving comminuted material to be separated to a series of unidirectionally shifting charges of electro-static stress moving in lines deviating from the line of normal movement of the material, and separately collecting the thus separated particles.

49. The process of separating comminuted material consisting in subjecting the material to be separated to a series of unidirectionally shifted partially shielded convective charges, and separately collecting the thus separated particles.

50. The process of separating comminuted material consisting in subjecting the material to be separated to a series of unidirectionally shifting centrally shielded convective charges, and separately collecting the thus separated particles.

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

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

Witnesses for Henry M. Sutton:
ALEXANDER CAMPBELL,
C. S. WALTRUBE.

Witnesses for Walter L. Steele and Edwin J. Steele:
H. R. PERKINS,
O. M. ANDERSON.