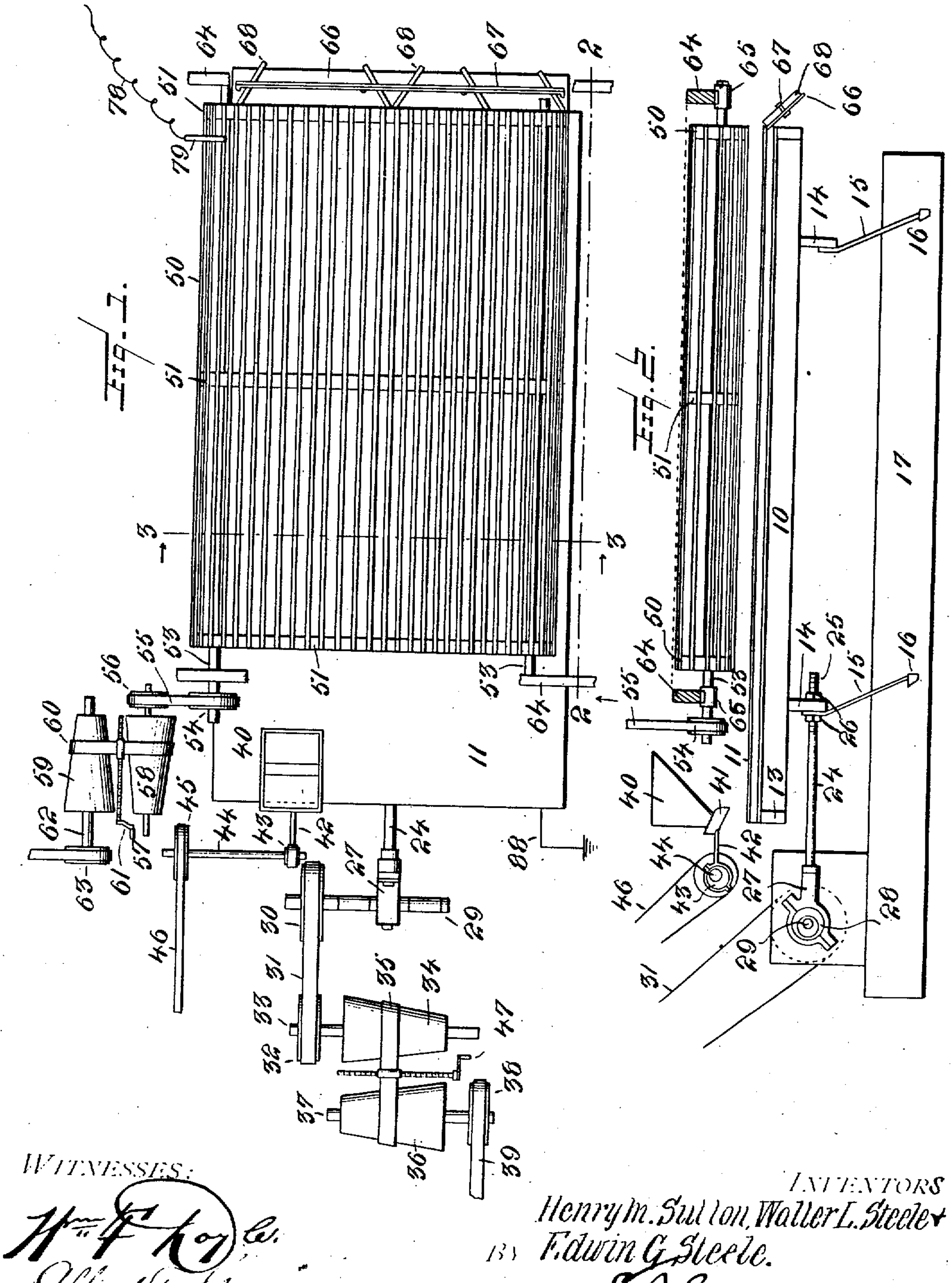
H. M. SUTTON & W. L. & E. G. STEELE.
ELECTROSTATIC SEPARATOR.
APPLICATION FILED JUNE 21, 1909.

1,017,701.

Patented Feb. 20, 1912.

4 SHEETS—SHEET 1.



WITNESSES:

Wm F Koch

Alfred T. Gage

INVENTORS

Henry M. Sutton, Walter L. Steele + Edwin G. Steele.

By E B Stocking

Attorney

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

ELECTROSTATIC SEPARATOR.

APPLICATION FILED JUNE 21, 1909.

1,017,701. Patented Feb. 20, 1912.

4 SHEETS—SHEET 2.

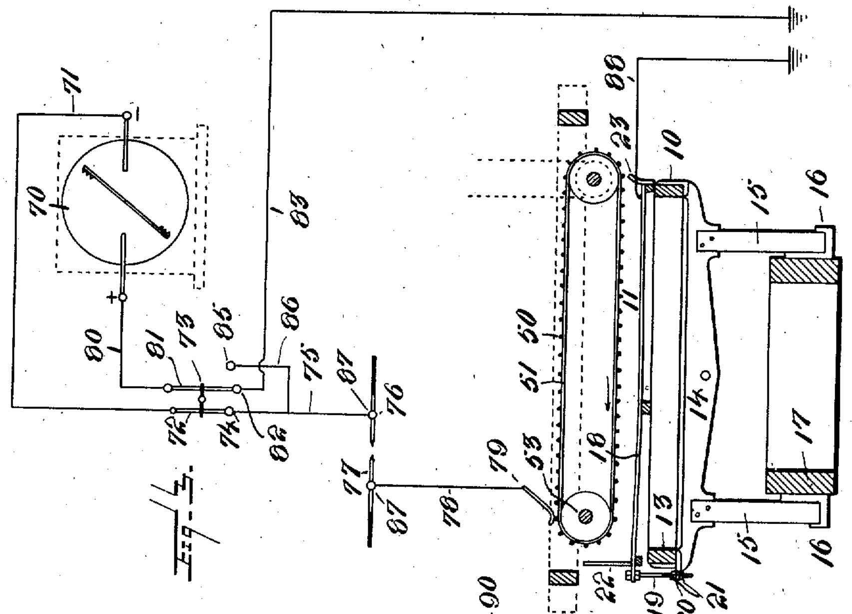


Fig. 3.

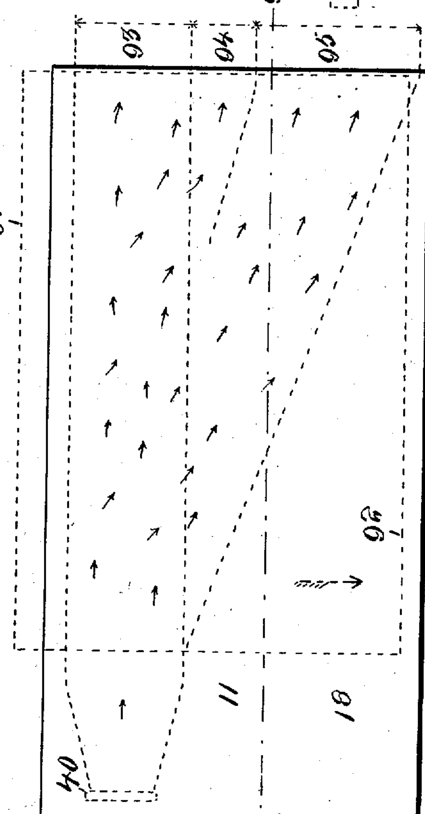


Fig. 4.

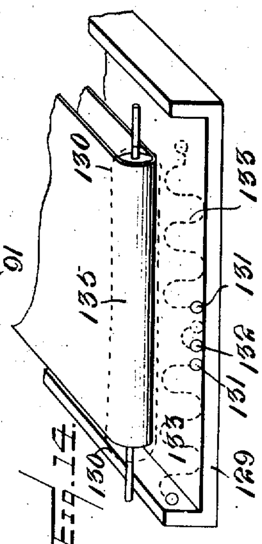


Fig. 14.

WITNESSES:

Wm. F. Koyle.

Alfred T. Gage.

INVENTORS

Henry M. Sutton

Walter L. Steele &

Edwin G. Steele.

E. B. Stocking

Attorney

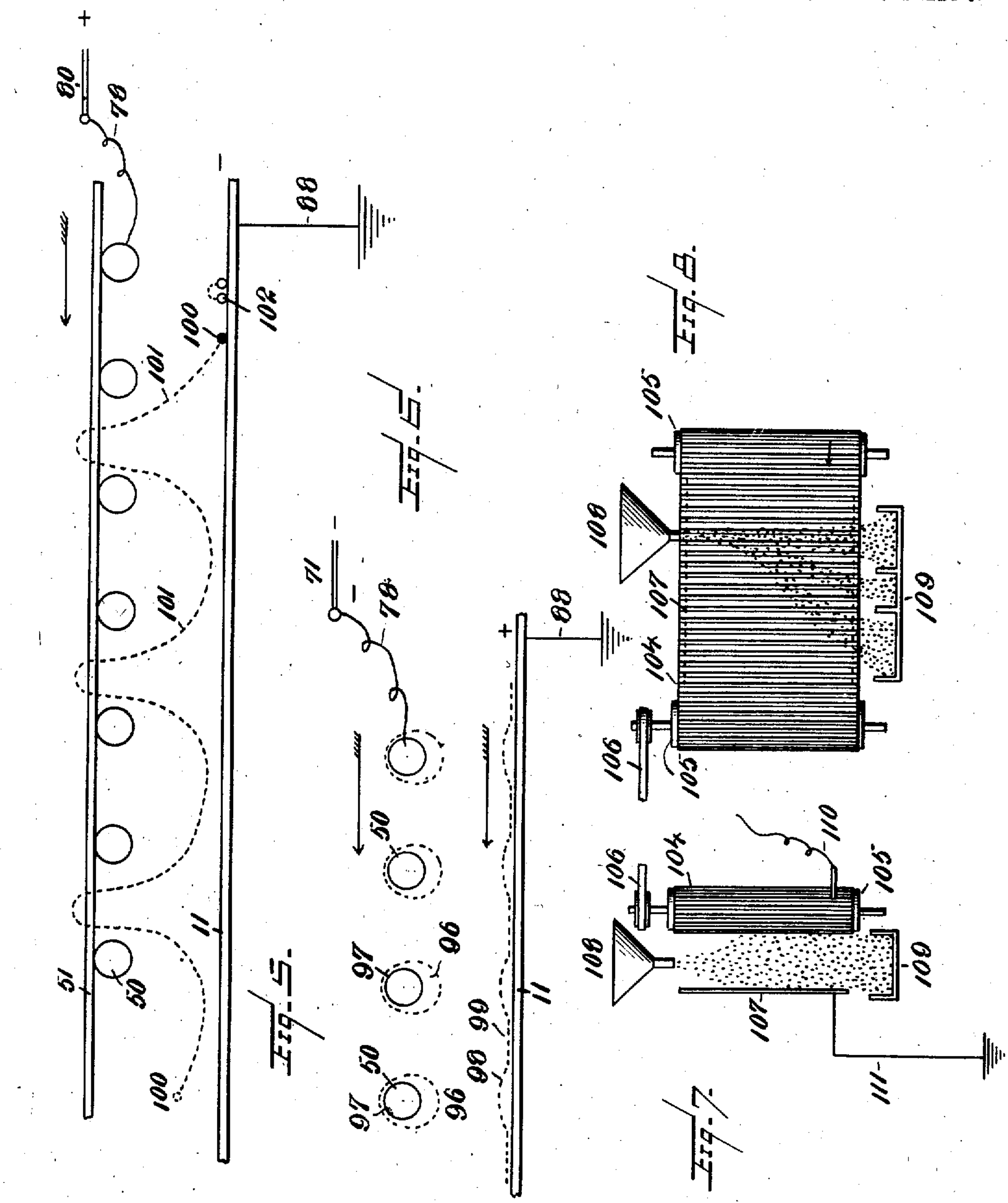
H. M. SUTTON & W. L. & E. G. STEELE.

ELECTROSTATIC SEPARATOR.

APPLICATION FILED JUNE 21, 1909.

1,017,701. Patented Feb. 20, 1912.

4 SHEETS—SHEET 3.



WITNESSES:

[signature]

Alfred T. Gage.

INVENTORS

Henry M. Sutton, Walter L. Steele &

BY Edwin G. Steele.

E. B. Stocking

Attorney

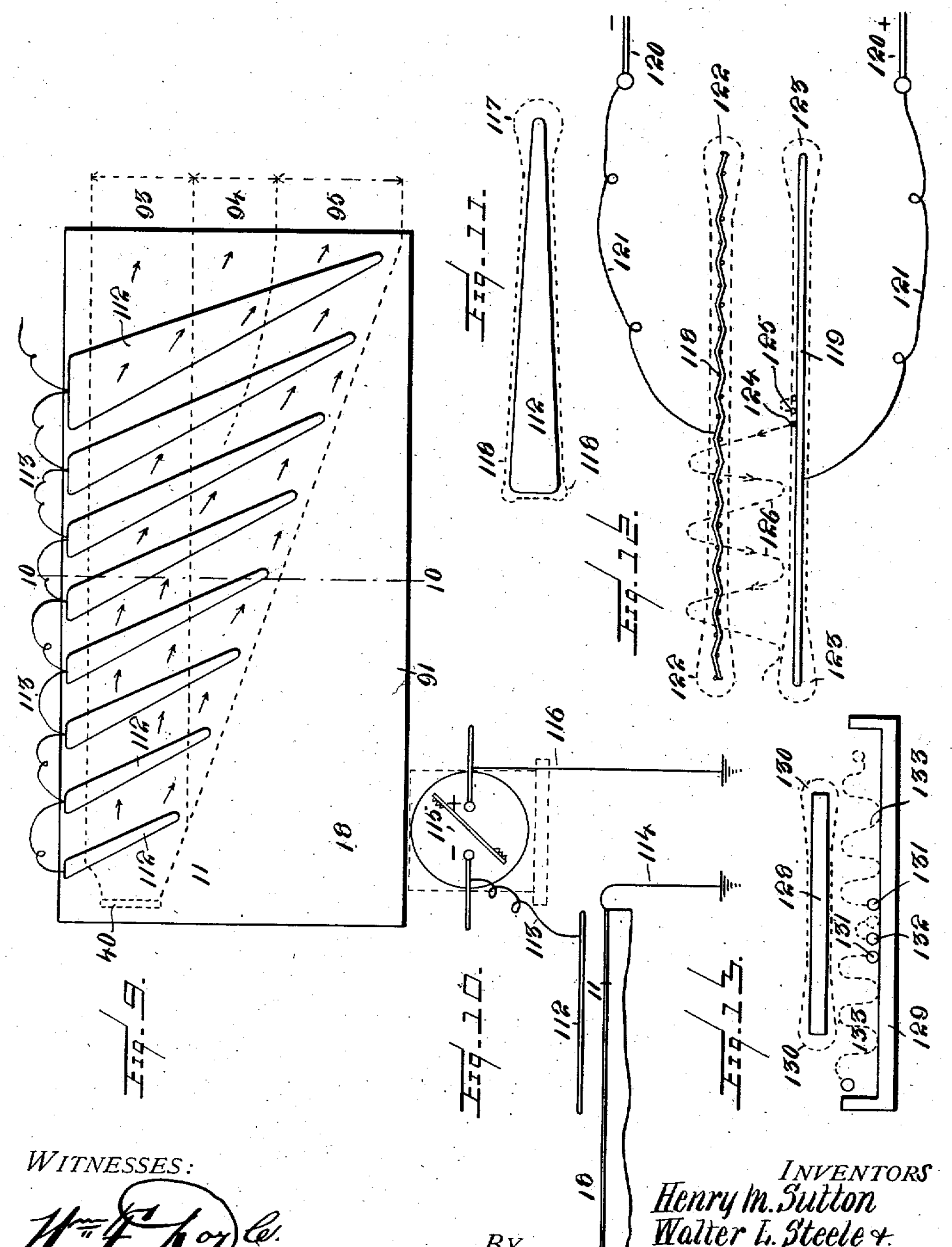
H. M. SUTTON & W. L. & E. G. STEELE.

ELECTROSTATIC SEPARATOR.

APPLICATION FILED JUNE 21, 1909.

1,017,701. Patented Feb. 20, 1912.

4 SHEETS—SHEET 4.



WITNESSES:

Wm F. Koyle

Alfred T. Gage

INVENTORS

Henry M. Sutton

Walter L. Steele &

Edwin G. Steele.

BY

E. B. Stocking Attorney

UNITED STATES PATENT OFFICE.

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

ELECTROSTATIC SEPARATOR.

1,017,701. Specification of Letters Patent. Patented Feb. 20, 1912.

Application filed June 21, 1909. Serial No. 503,484.

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, county of Dallas, and State of Texas, have invented certain new and useful Improvements in Electrostatic Separators, of which the following is a specification, reference being had therein to the accompanying drawing.

This invention relates to an apparatus for electrostatic separation, and particularly to a structure where the comminuted material is subjected to the influence of an electrostatic field, and comprises a division of our application filed January 30, 1909, Serial No. 475,297.

An object of the invention is to submit the comminuted material, consisting of particles of different electrical susceptibilities, to the action of an electrical field of force of unequal densities, said particles being delivered into the field at or near a point where the electric charge has the least density.

Another object of the invention is to expose such pulverulent material to the action of a suitably electrically charged conductor moving in a direction either the same as the line of travel of the material or in a different direction therefrom in order to cause the material attracted by said conductor to change its position in the line of travel relative to other material not so attracted.

A further object of the invention is to change the polarity or electric sign of the field or force of unequal densities in accordance with the preference shown by certain particles of electrical susceptibility to either the plus or minus field of electrification.

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

In the drawing:—Figure 1 is a plan view of one form of the apparatus; Fig. 2 is a longitudinal section on line 2—2, Fig. 1 showing the belt and table of Fig. 1 in elevation; Fig. 3 is a cross section on line 3—3, Fig. 1 with the electrical generator and connections shown in diagram; Fig. 4 is a diagrammatical plan of the table shown in Fig. 1 indicating the lines of travel of the different materials; Fig. 5 is a diagram of the traveling electrodes and table showing by dotted lines the action of the charges upon the particles; Fig. 6 is a similar view showing the distribution of the charges upon the bars and table; Fig. 7 is an end elevation of a modified form of apparatus for action upon a falling field of material; Fig. 8 is a side elevation of Fig. 7; Fig. 9 is a plan of a further modified form of apparatus comprising separated tapering electrodes above the table; Fig. 10 is a detail elevation of one end of Fig. 9 with electrical connections; Fig. 11 is a detail of one of the electrodes showing the distribution of the charge thereon; Fig. 12 is a diagram of another modified form of apparatus and consists of relatively fixed electrodes; Fig. 13 is a diagram of a further modified form of apparatus embodying a solid electrode disposed above the path of travel of the material. Fig. 14 is a detail of a modification of the form shown in Fig. 13.

The apparatus consists essentially in means for electrically influencing a mass of particles between stationary electrodes traveling over a suitable deck or table, or even falling from a hopper, by means of an electric field having one portion of greater density than another portion thereof so that the particles are caused to travel in divergent paths. In the use of a moving charge the waves of greater density travel across the table, and the lines of travel of the particles, thus electrically attracting one class of particles from among the others. This differs from a dielectric treatment of the material where the dielectrics are polarized to such an extent that the polarization becomes sufficiently permanent so as to require an extraneous force to remove them from the separating electrode. In this apparatus there is no convection of the charge from one electrode to another and it is essential that the electrodes be charged to such a degree of tension that there is no appreciable convection nor a disruptive discharge as the action of one electrode upon the other is entirely by induction.

For the purpose of effecting a continuous separation the construction shown in Figs. 1, 2 and 3 is preferably used. In this form any desired construction or arrangement of table may be used, for instance, as shown at 10, the upper surface or deck 11 of which is composed of good electrical conducting material, such as sheet metal. This deck is supported by means of a frame 13 resting upon cross pieces 14. To each of these cross pieces a supporting spring 15 is attached, the lower end of which rests in a socket 16 provided on the base 17, as shown in Fig. 3. The portion 18 of the deck 11 is rendered adjustable by any suitable means, as shown in Fig. 3, so that the inclination thereof may be varied. One means for that purpose comprises the bolt 19 secured at its upper end to the deck, while its lower end passes through a support 20 and has threaded thereon nuts 21 for adjusting the bolt and securing it in position. When it is desired to raise the outer edge of this portion of the deck, the lower nut 21 is loosened and the upper nut adjusted upon the threaded bolt, thus bending or springing the side of the table slightly upward. At the edge of this adjustable portion a stop plate 22 is provided and extends for the entire length of the deck. This plate is formed of poor electrically conducting material or a dielectric. The object of the plate is to prevent the particles being pushed over the side edge of the deck 11 and to so modify the density of the charge on the electrode at this point that none of the particles are carried by or beyond the plate when a traveling electrode is used. The opposite edge of the deck is provided with a similar plate 23. In this form of apparatus it is desirable to impart to the material a movement or travel by gravity and momentum longitudinally of the deck. The means for accomplishing this is shown in Figs. 1 and 2 where the rod 24 is adjustably secured to one of the cross pieces 14 by means of the threaded end 25 and the nuts 26 coöperating therewith. The opposite end of this rod is provided with an eccentric sleeve 27 within which an eccentric 28 is disposed. The eccentric is mounted upon the driving shaft 29 adapted to be driven by the pulley 30. For the purpose of speed regulation a belt 31 extends from the pulley 30 to a pulley 32 upon the shaft 33. This shaft also carries a cone pulley 34 provided with a belt 35 connected to shifter 47 and extending to an oppositely disposed cone pulley 36 on the shaft 37 which is also provided with a driving pulley 38 from which the belt 39 extends.

For the purpose of feeding comminuted or pulverous material to the table a hopper 40 is disposed at one end and near one side thereof, as shown in Fig. 1. This hopper is provided with a shaker pan 41 from which an actuating rod 42 extends to the eccentric 43 mounted upon the shaft 44. This shaft is driven by means of the pulley 45 from which a belt 46 extends. As showing a convenient means for producing a moving field of force of different densities, a series of bar electrodes 50 are provided and fastened in any suitable manner to the outer surface of the series of belts 51, these being mounted on pulleys 52 which are insulated from the shaft 53 by collars upon which they are mounted, as shown in Fig. 3. These belts should be composed of electrically conducting material or coated with such material upon the face where the bar electrodes are applied in order to maintain all of the bars at the same potential. This belt travels laterally of the direction of feed or travel of the material due to the movement of the table, and the belt may be driven by any desired means, for instance, as the pulley 54 on shaft 53. From this pulley belt 55 extends to the pulley 56 on the shaft 57 of the cone pulley 58. A coöperating cone 59 is provided and connected with cone 58 by belt 60. This belt is adjustable to determine the speed of travel of the bar electrodes by means of the belt shifter 61. This adjustment is important as the travel of the electrodes must be in proportion to the movement of the table and the consequent feed of material thereon as well as the time required for the separating action due to the electrical susceptibility of the particles. The shaft 62 of the cone 59 may be driven by any suitable connection as shown at 63. The shafts upon which the electrode belt is mounted may be supported by any suitable form of frame work, for instance, as at 64. This frame carries bearings 65 for the shaft 53. The tail or delivery portion of the table is provided with a downwardly inclined delivery plate 66 which is formed with a bar 67 spaced above the same so as to retain in position the directing boards 68 which are disposed in proper position to receive and direct the zones of separated material to receptacles.

Various forms of electrical charging apparatus and connections may be used for producing the electric field from the bars. One form is shown in Fig. 3 and comprises the generator 70 from the minus side of which a conducting line 71 extends to the bar 72 forming part of the reversing switch 73. The terminal button 74 of this switch is connected by line 75 to one terminal 76 of the resistance gap over which the charge passes by convection to the opposite terminal 77 and thence by line 78 to the wiper 79 which contacts with the electrode bars 50. By this means a minus charge is imparted to the bars for use when the material treated demonstrates a preference for that polarity. Then the plus polarity of the generator 70 is connected to the ground through line 80 extending to switch bar 81 of the reversing switch 73 and thence to the switch button 82 and through line 83 to ground. When it is found desirable to send plus charges to the bar electrodes 50, the switch bars 72 and 81 are moved until the former rests on the button 82 and the bar 81 rests upon the button 85 which is in circuit by line 86 with the line 75 leading to the electrodes. The charge will then pass from the plus side of the generator by means of the line 80 to bar 81 through branch line 86 and line 75 across the resistance gap and by line 78 to the wiper 79 contacting with the bar electrodes. The terminals 76 and 77 of the resistance gap are adjustably mounted in their supports 87 so that the gap may be increased or diminished at will to vary the amount of charge supplied. The charge passes across the gap by convection in the well known manner and is simply intended to keep the potential of the bar electrode to the desired tension. The gap is regulated to supply the amount of electricity to the bar electrodes when charged that they would lose by leakage. Any other desired form of resistance suitable for high potential currents could be used in place of this gap. It is preferable, but not absolutely necessary that the metal deck of the table be connected to ground and this may be accomplished by means of a line 88 connected to the table deck. The grounding of the deck has the advantage that the separation is mostly carried out by the induced or bound charges traveling across the deck and avoids the presence of a free charge upon such portions of the deck, table and other parts of the machine as do not enter directly into the process of separation. The grounding of the deck is equivalent to its connection to the opposite pole of the generator to that from which the bars are charged.

In Fig. 4 a diagram of the deck 11 is shown and the portion from the line 90—90 to the edge 91 is inclined upward as at 18 in Fig. 3. The adjustment of this portion of the table restrains in some cases the too rapid cross travel of the particles under the influence of the traveling electrode. The inclination of the deck tends to force them back toward the center. The relative position of the belt of bar electrodes and the area covered thereby is indicated by dotted lines 92, the direction of movement of the belt being toward the edge 91 of the table. As indicated by dotted lines the material least affected by the travel of the electric field of greater density thereover will be delivered in an area such as indicated at 93, while that slightly more affected will be discharged over the delivery board in an area indicated at 94, while that most affected and comprising the particles which have followed the greatest density of field are delivered at 95.

The electrical conditions of the bar electrode are indicated by diagram in Figs. 5 and 6, the dotted lines in the latter figure showing the relative distribution of the charge, the greatest density of which exists at the face of the bar next the material as indicated at 96 and the least at the opposite face 97. This produces corresponding charges by induction of the opposite sign on the deck immediately below the bars as indicated by dotted lines at 98, the greatest density being at this point and the less at the intermediate point 99 opposite the space between the electrode bars. This charge upon the deck is usually termed an induced or bound charge, that is, the deck is not evenly charged as a whole but particularly that portion of it immediately facing the electrode bars. It is evident that if these bars are moved in the direction indicated by the arrow that the peaks 98 of the charge upon the deck will likewise shift or travel at the same rapidity. It will thus be seen that the charges are moving across the deck in peaks of different densities at an angle to the travel of the particles imparted by movement of the table. Those particles which are most susceptible to the action of the moving charge are consequently dragged out of the line of travel that they would otherwise take were they only subjected to the propelling action upon the table. It is preferable to accurately regulate the movement of the electrode bars across the table and also regulate the speed at which the particles are propelled over the table so that the two forces, one working at an angle to the other, can thus be governed to produce any desired separation.

By reference to Fig. 5 the action of the particles of diverse electrical susceptibility will be diagrammatically shown, the path of travel of such particles being exaggerated for the purpose of illustration, as unless the particles are very strongly attracted by placing the bar electrodes close to the deck, and thus increasing the potential between the particles and bars, the particles do not rise up through the bars as shown, but ride over the table apparently on the peaks of the moving charges 98 99, Fig. 6, as if suspended in an extremely elastic medium. The highly attracted particle 100 is drawn upward upon approximately a curved line as indicated at 101 toward the traveling field of greater density and passes into the space between adjacent fields thus permitting the return of the particle toward the deck but effecting a continued movement thereof toward the edge of the deck. The particle indicated at 102 has only a slight attraction and its movement is generally straight up and back to its place of starting or toward a weaker portion of the field. Under normal conditions the electrode bars exert only sufficient energy to divert some of the particles from their otherwise straight line of travel from the feed hopper to the point of delivery.

In Figs. 7 and 8 a modified form of apparatus is shown and consists in disposing the bar electrodes or their equivalent as described in connection with Figs. 1, 2 and 3 in position to act upon a falling body of comminuted material and to divert some particles thereof during their movement in order to separate them from others. In these figures the bar electrodes are indicated by 104 and connected together as described in connection with Figs. 1, 2 and 3 to form a continuous belt which is mounted on rollers 105 at opposite ends and driven by any desired means, for instance a driving belt 106. Opposite the bar electrodes is a stationary plate electrode 107. The material is fed between these electrodes from a hopper 108 and falls in a stream which is deflected laterally by the action of the moving electrode so as to be deposited in a series of separate receptacles as indicated at 109. The bars are charged from a generator as described in connection with Fig. 3, by means of the wiper 110, while the plate 107 is connected to ground by line 111. The relative travel of the particles under the influence of the two electrodes is shown in Fig. 8.

Figs. 9, 10 and 11 illustrate a form of apparatus in which a series of separated electrodes are fixed relative to the deck 11. These electrodes as indicated at 112 are tapered longitudinally with their larger cross section or base at the feed side of the table and are electrically connected by means of a line 113 with a generator as described in connection with Fig. 3, all thereof being supported by a suitable framework and spaced a short distance above the deck, as shown in Fig. 10. This deck is also connected by line 114 with the ground with which the opposite side of the generator 115 is also connected by means of line 116. When these plate electrodes 112 are connected to a high potential source of electricity the charge distributes itself as indicated by dotted lines in Fig. 11 where the greatest potential or density is present at the smaller end of the electrode as indicated at 117, while the remainder of the charge is distributed at less density and surrounding the edges of the electrode as indicated at 118. The separation and delivery under this construction is substantially the same as described in connection with Fig. 4, the feed being from the hopper at 40 where the particles are delivered to approximately the weakest part of the electric field of the first electrode of the series. The deck is given a reciprocating motion, as described in connection with Figs. 1 and 2, and as the particles are propelled along the deck those in the mass which naturally seek the electric field of greater density are drawn out from among the general mass toward the tapered end of the electrode 112 and are delivered in the area 95 as described in connection with Fig. 4. Others less affected are delivered in the area 94 while those least affected are delivered at 93 and in this manner the particles are separately collected. In Fig. 12 a form of apparatus is shown embodying spaced fixed electrodes connected to the opposite poles of a generator. In this form the charging electrode 118 is formed of metallic screen cloth having relatively large openings between the meshes, while the opposite electrode 119 is formed of an electrically conducting plate, preferably of metal. Both the screen and plate are connected to the opposite terminals 120 of a high tension source of electricity by means of the line 121. When the screen and plate are thus charged, the static charge distributes itself on their surfaces unevenly, the charges accumulating at a greater density around the edges of the screen and plate than at the centers thereof. This distribution of the charge is indicated by dotted lines showing the greatest density at 122 on the screen and 123 on the plate. The particles 124 and 125 shown upon the plate 119 are of diverse electrical susceptibility, and the particle 124 works its way toward the edge of the screen and plate where the charges have their greatest density, passing in some instances, though not necessarily, up through the screen in its course of travel as indicated by dotted lines 126. The less attracted particle 125 has only a slight movement generally directly upward and back to its place of starting or toward a weaker part of the field.

In Fig. 13 a solid form of charging electrode is shown at 128 which may be either stationary or moving in the form of a belt as described in connection with Figs. 1, 2 and 3. In this form the material to be separated is fed upon the table 129 at the center thereof or in the field of weakest density of the electrode as the greater density is present at the side edges thereof as indicated by dotted lines 130. The particles 131 and 132 being delivered beneath the center of the electrode 128, it is evident that those of greater attraction will seek the outer edges of the electrode where the field of greater density exists. The movement of the particle 131 is indicated by dotted lines 133 while the particle 132 remains substantially in the field of least density of the charge and travels therethrough in the movement of the table which is similar to that described in connection with Figs. 1 and 2.

Fig. 14 illustrates substantially the same form of apparatus as shown in Fig. 13 with the exception that the charging electrode comprises a belt 135 mounted for movement in line with the travel of the ore longitudinally of the table 129. In this form the particles are delivered to the table in a central line transversely of the belt and the particles 131 would seek the outer edges of the belt they being most susceptible to the field of greater density existing at that point. On the other hand the particles 132 remain substantially beneath the center of the belt and travel the length of the table in this position.

The operation of the preferred form of apparatus, as shown in Figs. 1 and 2 is as follows:—The materials to be separated are fed from the hopper by means of the shaker pan thereof to the deck of the table which is given a reciprocating motion and on account of the inclination of the supporting springs thereof rises diagonally on its forward stroke and recedes in the same line on its return stroke. This movement has the effect of propelling the particles longitudinally of the table. The bar electrodes being driven as described, the direction of their travel is transversely of the particles and on the under side of the belt next the table the movement is from the feed side toward the opposite side thereof. These bars when charged cause the particles to travel across the table in divergent paths from the hopper to the delivery end as indicated by dotted lines in Fig. 4 at which point they are separately collected. The operation of the several modified forms of the invention will be clearly understood from the description thereof in connection with each form.

Heretofore in the art of static separation of comminuted material it has been found essential to so deliver the particles to a charging electrode that only the superior conductors of the mass will be charged and repelled before the nonconductors can be affected, this feature being quite essential to such separation for if all the particles were allowed to remain for a sufficient time under the influence of the static charge those of lesser conductivity would also become charged and repelled thus defeating any successful separation. In the prior art the particles were also introduced at once upon the electrode where the static charge has its greatest density. In this apparatus the particles are fed into the electric field of least density and the field of greater density is moved across the line of travel of the particles. The time required to electrify conducting or nonconducting particles is not essential as the separation is determined by the electrical susceptibility of the particles in a field having the greater density of charge at one point than at another; and this susceptibility may arise from numerous conditions in the material treated. The particles are immersed in an electrostatic field of action and afforded ample opportunity to all become charged so that a thorough separation is effected. The difference in the weight or specific gravity of the particles may assist or be incidental to the separation, but it is more generally the case that the heavier particles are those which have the greatest electrical susceptibility and are carried toward the field of greatest density and up the inclined portion of the deck in opposition to the force of gravity thus leaving the lighter particles on the lower plane of the deck. While the invention acts primarily upon the dielectric properties of various substances it does not carry the polarity of the dielectric to a point where they become "set" but leaves them free to move within the confine of the electrostatic field of action.

The separation may be effected by electrodes and apparatus of different form from those herein shown, and the polarity of the charge fed to the particles is also important because of the preference demonstrated by some particles for a certain polarity is a most important factor in producing successful separation and therefore means are provided by which the polarity of the electrode may be changed to that most efficient for the materials treated. As before described in the use of a moving electrode it may travel either in the same line of travel as the material when propelled on the deck by gravity or other force independent of the electric charge or transversely thereto so as to move some of the particles toward the edges of the table. It is not the intention of the present apparatus to lift the particles into contact with the moving electrode, but to merely raise them slightly above the deck so that they may be supported as upon an elastic medium and in such an electric field moved into separate tracks or zones capable of independent collection from the remainder of the material not so electrically attracted.

An important feature of this invention is the means for changing the polarity of the charge applied to the electrode bars which causes a separation by the selective action of the charge upon different particles, and this selective action is frequently manifested only when a certain density of the charge is reached. The selective action is more effective upon those particles which are classed as poor conductors, non-conductors or dielectrics. These have specific inductive capacity or dielectric capacity which is practically absent in particles classed as good conductors of electricity. The relative difference of conductivity does not effect the separation but rather the relative difference in the permeability of the different particles to the direction of the lines of electrostatic induction or the sign of electrification with which the electrode is charged. Some particles are more sensitive to the lines of force passing through them in one direction than in an opposite direction and this is particularly evident when the static charge traverses the line of travel of the particles. In the absence of conducting particles it will be seen that the relative difference in the permeability of the particles must depend upon the fact that they are more sensitive to one sign of electrification than to the opposite sign. It has also been found that a particular substance will respond more readily to a plus sign than to a minus one depending upon the composition of the mass of particles undergoing separation, while a particle which responds to a plus sign in one combination may respond to the opposite sign in another combination where the presence of other minerals may assist in determining the sign to which it will most readily respond.

The speed at which the particles are propelled mechanically through the field is also of importance. The movement of a mass of particles through the field at a certain speed will show no appreciable separation, but if the speed of propulsion is regulated relative to the material treated a complete separation is effected.

A further feature of importance is the use of a moving electric field across the line of travel of propulsion of the particles and regardless of any difference of density of such a field. It will also be noted that in an electric field of different density such density increases at an angle to the travel of the comminuted mass.

The invention also contemplates in its scope the feeding of the material to be separated to a relatively weak portion of the electric field which has substantially the same action as moving the field transversely of the line of travel of the particles with the exception that the action is not so effective.

Having described our invention and set forth its merits, what we claim and desire to secure by Letters Patent is:—

1. In an electrostatic separator, means for supporting and conveying material, and means for establishing upon said supporting means an electrostatic field of density varying across said supporting means sufficiently to deviate the travel of part of the material from the normal line of travel of the material.

2. In an electrostatic separator, a support for the material to be separated, means for feeding material to said support, means for producing an electrostatic field of unequal density along the surface of said support, said means being adapted to cause part of the material upon the support to move thereupon from its normal position.

3. In an electrostatic separator, means for supporting and moving comminuted material, means for producing an electrostatic field of density varying along said surface in a direction deviating from the line of normal movement of said material, and means for initially delivering material to the weaker portion of said field.

4. In an electrostatic separator, means for supporting and moving comminuted material, means for producing an electrostatic field of unequal density varying across said supporting means sufficiently to cause a deviation of travel upon said surface of a portion of the material from the normal travel of the material, means for moving said field crosswise of the normal path of said material, and means for separately collecting the thus separated particles.

5. In an electrostatic separator, a plurality of electrodes charged to produce an electrical field of suspension, means for moving said electrodes collectively in one direction, means for feeding comminuted material across the line of travel of said electrodes and at such distances therefrom as to deflect said material from the normal line of feed without attraction to the electrodes.

6. In an electrostatic separator, a supporting surface, means for imparting a movement to said surface to produce a mechanical travel of comminuted material upon said surface, means for producing adjacent to said supporting surface an electrostatic field of maintained unequal density in different portions of said surface, the greater density being sufficient to move upon said surface the more susceptible particles of a mass from the less susceptible particles thereof, and means for feeding comminuted material to said support.

7. In an electrostatic separator, a supporting surface, means for imparting movement to said surface to produce a travel of comminuted material thereon, means for producing and maintaining an electrostatic field of unequal density and distribution upon said surface, means for moving said field across the path of said material, and causing part of the material to deviate upon said surface from the line of normal travel.

8. In an electrostatic separator, a supporting surface for comminuted material, means for imparting to said material a movement upon said surface, means for producing an electrostatic field of maintained varying density moving across the path of travel of said material and causing the more susceptible particles of said material to deviate from its normal movement upon said support.

9. In an electrostatic separator, a supporting surface for comminuted material, means for imparting to said material a movement upon said surface, means for producing separated, moving electrostatic fields of varying density disposed across the line of travel of said material and causing said material to deviate upon said surface from its normal movement, and means for modi-

fying the density of said fields at one side of the line of travel of said material.

10. In an electrostatic separator, a supporting surface for the material, means for producing an electrostatic field of maintained potential and unequal density across said supporting surface, the greater density being sufficient to move the more susceptible particles from the less susceptible particles therein along the lines of stress from the lesser density, means for changing the polarity of said field and maintaining said changed polarity, and means for feeding comminuted material into the lesser density of said field on said surface.

11. In an electrostatic separator, a supporting surface, means for producing an electrostatic field of maintained unequal density upon said surface, the difference in density thereof being sufficient to remove the more susceptible particles of a mass from the less susceptible particles thereof within said field, means for feeding comminuted material into said field, means for separately collecting the separated particles, and means for regulating the speed of travel of said material.

12. In an electrostatic separator, a support for the material, means for producing a moving electrostatic field of maintained unequal density across said support, the difference in density thereof being sufficient to remove the more susceptible particles of a mass from the less susceptible particles thereof within said field, means for mechanically feeding the material in a path traversing the path of travel of said field, and means for regulating the speed of movement of said electrostatic field.

13. In an electrostatic separator, a supporting surface for the material, means for producing a moving electrostatic field of maintained unequal density across said supporting surface, the greater density thereof being sufficient to remove the more susceptible particles of a mass from the less susceptible particles thereof within the field of greatest density, means for mechanically feeding comminuted material in a path traversing the path of travel of said field, means for separately collecting the separated particles, means for regulating the speed of movement of said electrostatic field, and means for regulating the speed of travel of said material.

14. In an electrostatic separator, a support for the material, means for producing an electrostatic field of maintained unequal density across said support, the difference in density thereof being sufficient to remove the more susceptible particles of a mass from the less susceptible particles thereof within said field, means for feeding comminuted material into said field, and means for continuously moving said electrostatic field in one direction across the path of travel of said material.

15. In an electrostatic separator, a supporting surface, means for feeding material thereto, means for producing a feed of material along said surface, a traveling belt mounted above said surface and provided with a series of charged electrodes to travel laterally of said surface, and means for moving said belt transversely of said surface.

16. In an electrostatic separator, a supporting surface, means for feeding material thereto, means for producing a feed of material along said surface, a traveling belt mounted above said surface, a series of separated bar electrodes carried by said belt to traverse laterally the path of travel of material upon said surface, and means for moving said belt transversely of said surface.

17. In an electrostatic separator, a supporting surface, means for feeding material thereto, means for producing a feed of material along said surface, a traveling belt mounted above said surface, a series of separated bar electrodes carried by said belt to traverse laterally the path of travel of material upon said surface, means for moving said belt transversely of said surface, and means for regulating the speed of travel of said belt.

18. In an electrostatic separator, a supporting surface, means for feeding material thereto, means for producing a feed of material along said surface, a traveling belt mounted above said surface, a series of separated bar electrodes carried by said belt to traverse laterally the path of travel of material upon said surface, means for moving said belt transversely of said surface, means for regulating the speed of travel of said belt, and means for regulating the speed of travel of material upon said surface.

19. In an electrostatic separator, a supporting surface, means for feeding material thereto, means for producing a feed of material along said surface, a traveling belt mounted above said surface, a series of separated bar electrodes carried by said belt to traverse the path of travel of material upon said surface, means for regulating the speed of travel of said belt, means for regulating the speed of travel of material upon said surface, and means for reversing the polarity of the charge upon said bar electrodes.

20. In an electrostatic separator, a support for the material to be separated, means for producing an electrostatic field of unequal density and of successive impulses comprising a moving series of electrodes disposed across the normal path of the material adapted to create fields of force varying in density along the support and to cause the

more susceptible material to travel in the direction of such density variation.

21. In an electrostatic separator, a supporting surface, having at one side an upwardly inclined portion, means for feeding material thereto, means for moving the material longitudinally along said surface, a charged electrode mounted to travel across said support and toward said inclined portion thereof whereby gravity tends to direct some of the particles inwardly upon said support, and means for separately collecting the separated particles.

22. In an electrostatic separator, a supporting surface having a portion thereof constructed for adjustable inclination, a charged electrode movable transversely of said adjustable inclined portion, means for changing the speed of travel of said movable electrode whereby gravity may act upon some of the particles to differentiate their separation from others, and means for separately collecting the separated particles.

23. In an electrostatic separator, a supporting surface, means for feeding material thereto and therealong, a charged electrode movable continuously in one direction transversely to the path of travel of said material, a non-conductive plate disposed across the path of the movable electrode to modify the action of its charge and prevent passage of material from said supporting surface at or over said plate.

24. In an electrostatic separator, a traveling belt provided with a series of spaced electrodes thereon, a supporting table beneath said belt mounted for oscillatory movement toward and from the same and at an angle to said electrodes, and means for feeding material upon said table.

25. In an electrostatic separator, a traveling belt provided with a series of spaced electrodes thereon, a supporting table beneath said belt mounted for oscillatory movement toward and from the same and at an angle to said electrodes, means for feeding material upon said table, and means for regulating the speed of oscillation of said table.

26. In an electrostatic separator, a traveling belt provided with a series of spaced electrodes thereon, a supporting table beneath said belt mounted for oscillatory movement toward and from the same and at an angle to said electrodes, means for feeding material upon said table, and means for regulating the speed of travel of said belt.

27. In an electrostatic separator, an oscillatory supporting table, and a movable separating belt extending transversely of the table and provided with a series of spaced charged electrodes thereon.

28. In an electrostatic separator, an oscillatory supporting table, a movable separating belt mounted to travel transversely of the table and provided with a series of spaced charged electrodes thereon, and nonconducting plates extending upward from said table at opposite ends of said belt.

29. In an electrostatic separator, an oscillatory supporting table, a movable separating belt mounted to travel transversely of the table and provided with a series of spaced charged electrodes thereon, a generator, and connections between said generator and belt for feeding charges at will of maintained opposite polarity to the belt electrodes.

30. In an electrostatic separator, a supporting table having its upper face inclined upwardly at one side thereof, a separating belt extending transversely of the table and provided with a series of electrodes thereon, and means for feeding material longitudinally of said table.

31. In an electrostatic separator, a supporting table, a movable separating member disposed above said table, a generator, a line extending from said generator to said member, a reversing switch disposed in said line to change the polarity of the charges fed to said member, and means for separately collecting the separated particles.

32. In an electrostatic separator, a supporting table, a movable separating member disposed above said table, a generator, a line extending from said generator to said member, a reversing switch disposed in said line to change the polarity of the charge fed to said member, an adjustable regulator disposed in said line intermediate said switch and member, and means for separately collecting the separated particles.

33. In an electrostatic separator, a supporting table, a traveling separating belt above said table having a conducting face, a series of electrode bars secured to said face, and means for charging said bars.

34. In an electrostatic separator, a supporting table, a traveling separating belt above said table having a conducting face, a series of electrode bars secured to said face, means for charging said bars, a generator having one pole in circuit with said charging means, and a return connection from the conducting face of said table.

35. In an electrostatic separator, a generator, a charging electrode having a field of different densities connected with one pole thereof, a separating table having an electrically conductive surface connected with the other pole of the generator, means for feeding material to and along said table within the field of said charging electrode, and means for separately collecting particles from the differing densities of said field.

36. In combination, means for establish-

ing an extended electrostatic charge, means for varying the charged density along its extent to a degree sufficient to move the more susceptible particles of a mixture containing particles of different susceptibilities in the direction of density increase, and means for feeding said material to the region of least density charge.

37. In an electrostatic separator, a support for the material, means for producing a movable electrostatic field of unequal density along said supporting means, means for feeding material into said field, and means for separately collecting the thus separated particles at the terminations of the paths assumed by them through said field.

38. In an electrostatic separator, a support for the material, means for producing a movable electrostatic field having portions of different densities sufficient to deviate particles along the lines of force from a lesser to a greater density, means for moving material angularly through said field, and means for separately collecting the thus deviated particles at the termination of the paths assumed by them through said field.

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

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

Witnesses:
THEOBALD A. NAGLE,
E. V. KING.