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APPARATUS FOR ELECTROSTATIC MAGNETIC SEPARATION.

APPLICATION FILED DEC. 27, 1906.

948,599. **Patented Feb. 8, 1910.**

3 SHEETS—SHEET 1.

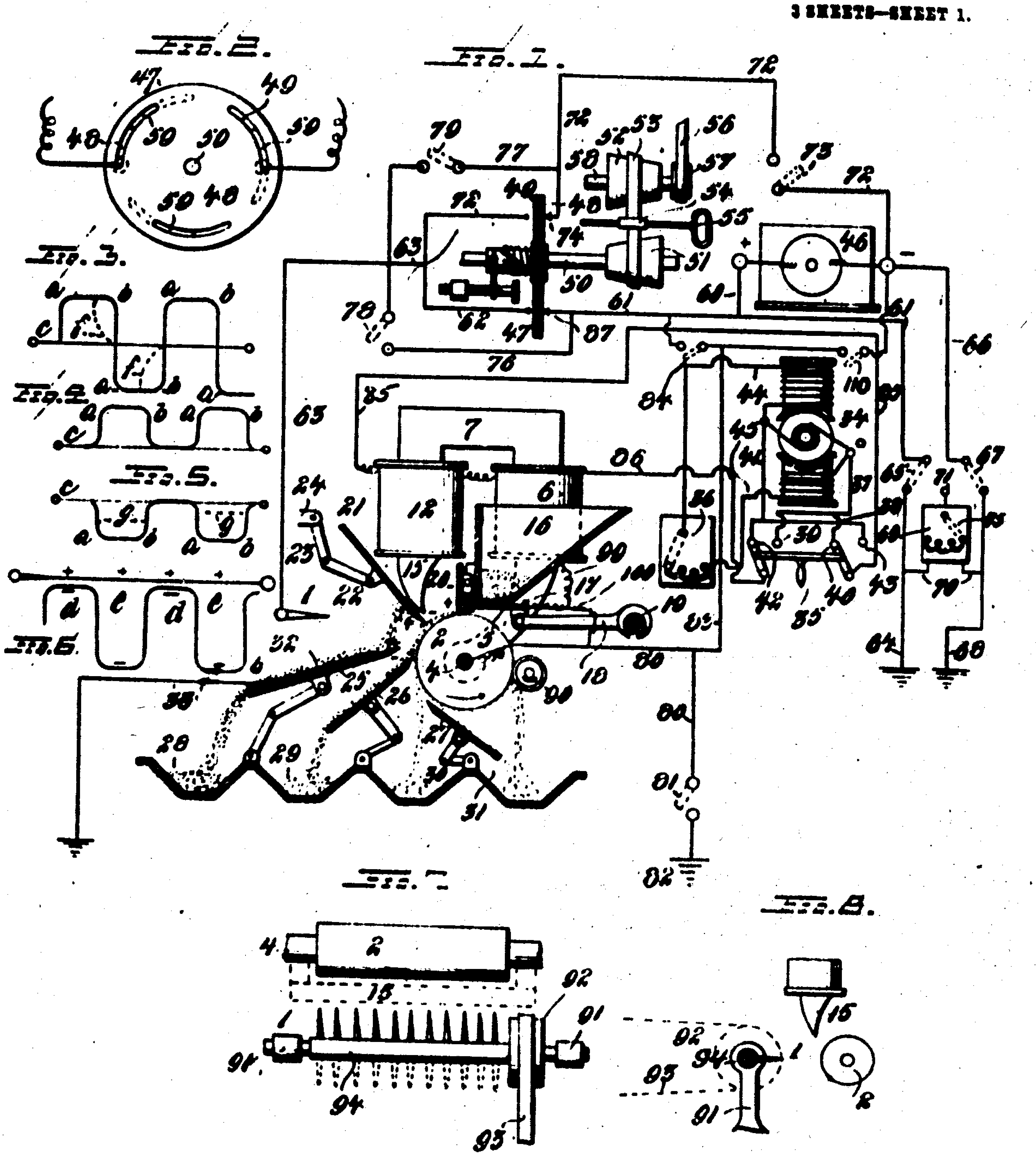

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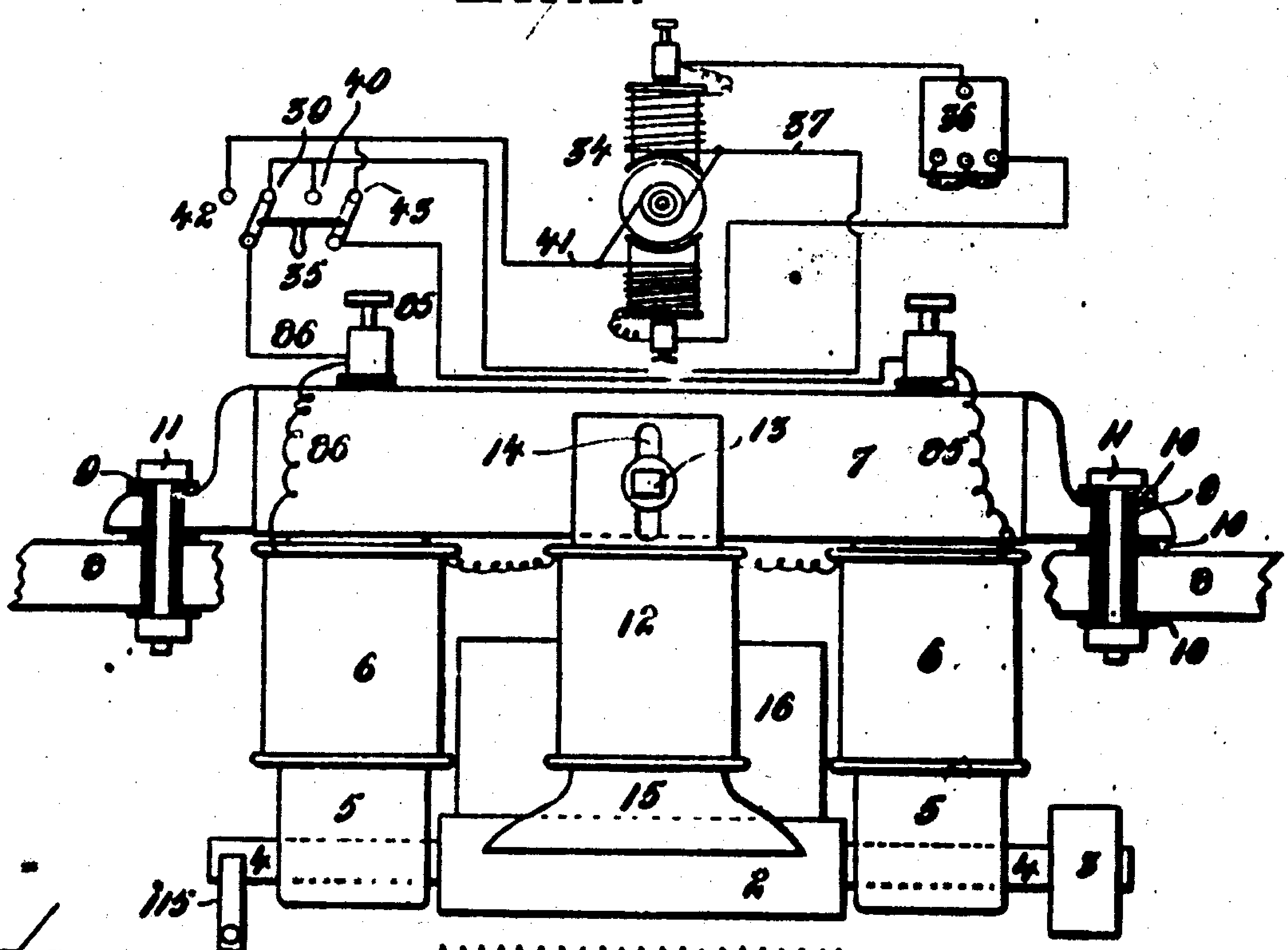
Fig. 9.



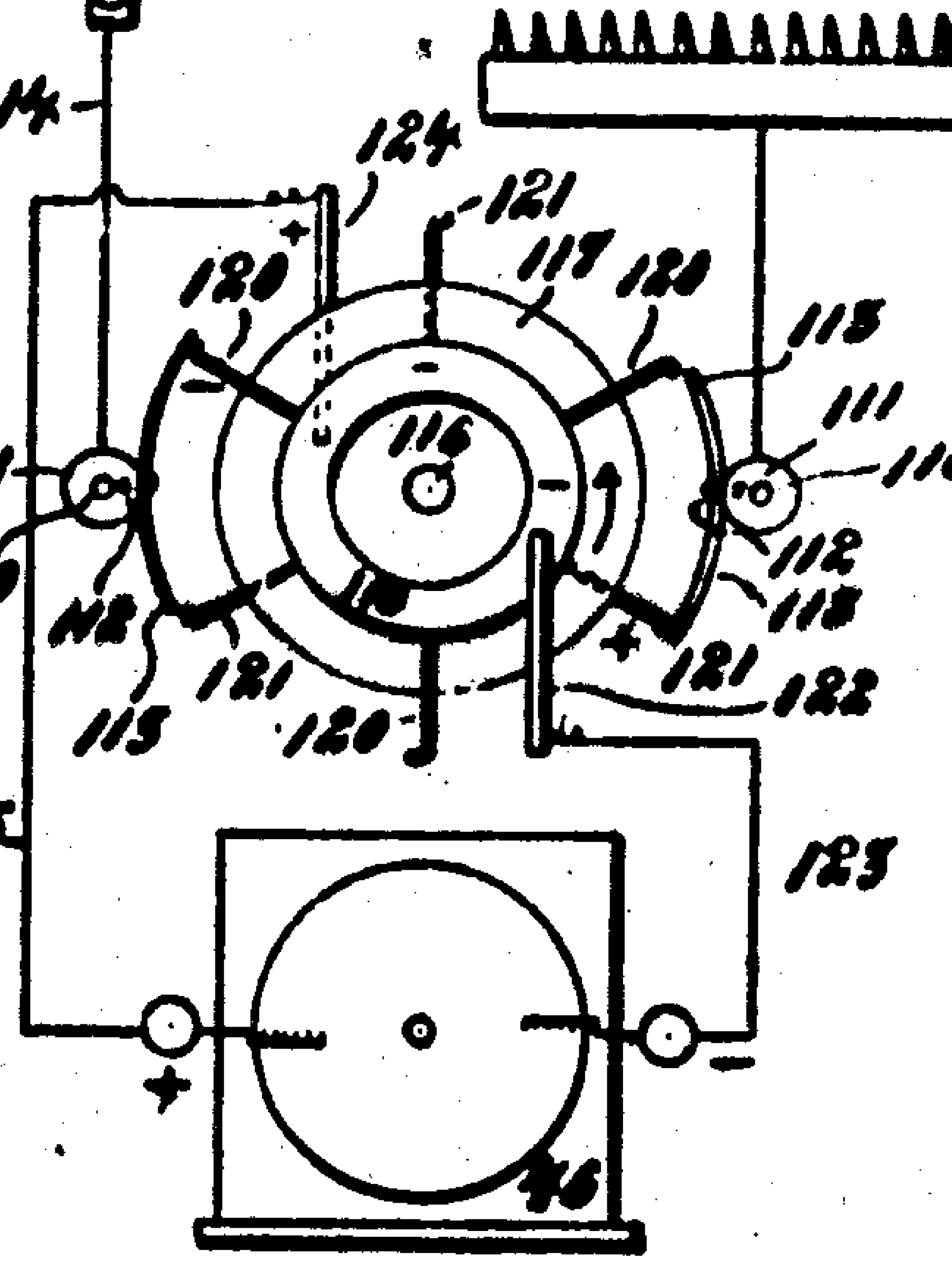


Fig. 10.

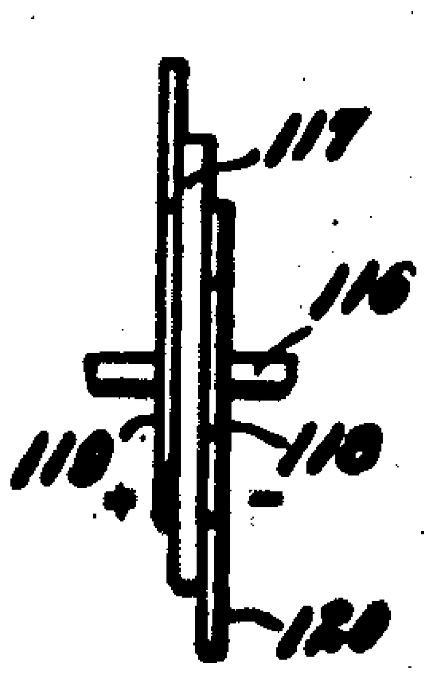


Fig. 11.

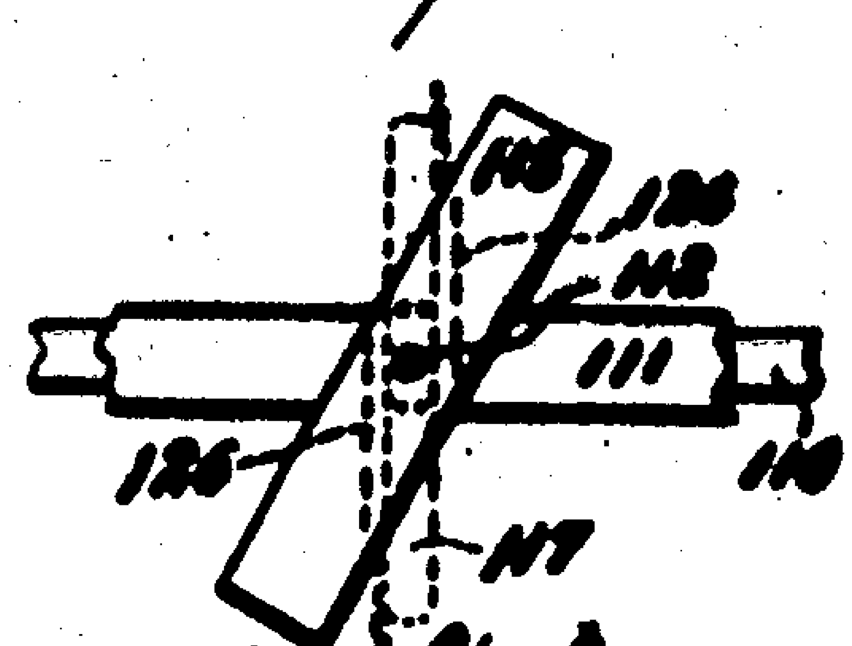
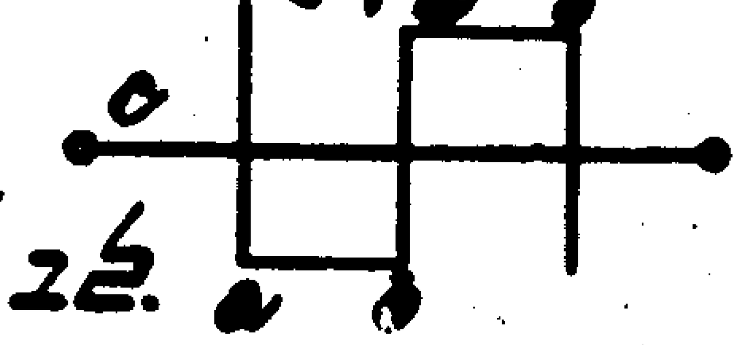


Fig. 12.



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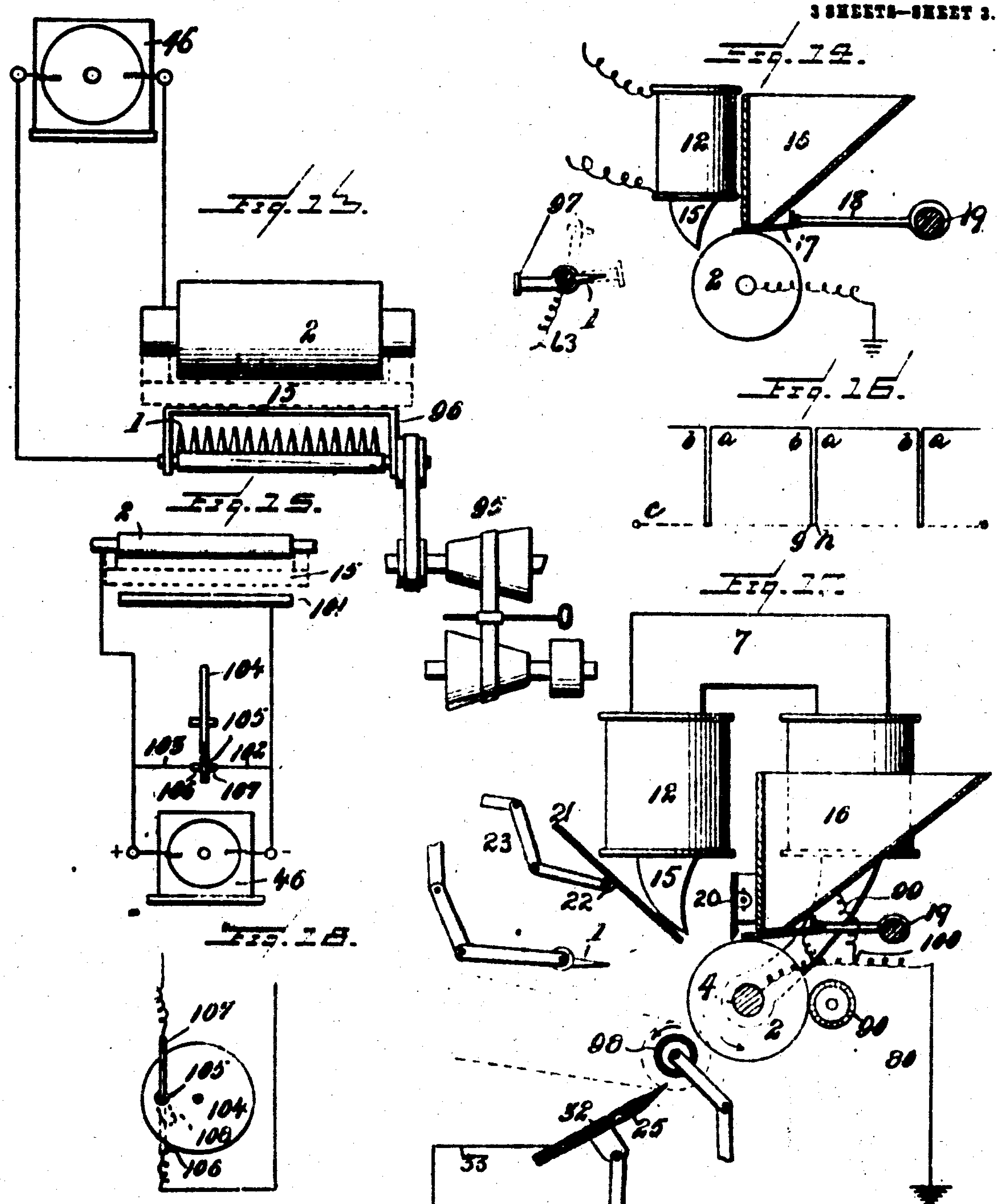
3 SHEETS—SHEET 3.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR ELECTROSTATIC-MAGNETIC SEPARATION.

948,599. Specification of Letters Patent. **Patented Feb. 8, 1910.**

Application filed December 27, 1906. Serial No. 349,699.

To all whom it may concern:

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

This invention relates to an apparatus for separating the particles of a mass, or the components of a mixture and for separately collecting the separated particles, and the invention consists in providing means for delivering the particles from the mass in a thin segregated sheet-like form, and means for subjecting the particles to the action of a magnetic field into or through which is passed an electrostatic charge or convective current.

The invention further consists in providing means for electrically releasing certain of the particles from their association with others during the operation or separation.

The invention also consists in providing means for varying or regulating the action or condition of the magnetic field.

The invention also consists in providing means for varying or regulating the condition, character and action of the electrostatic convective-current during the process of separation.

The invention also consists in providing means for varying, regulating or changing either the magnetic field or the electro static charge before the process of separation in order to adapt the apparatus to the treatment of materials the electrical and magnetic characteristics of which are well known.

The apparatus herein disclosed is also adapted by suitable means to produce varied conditions of the static charge or convective current in its wave form as illustrated by diagrams hereinafter to be described.

Other and further objects and advantages of the invention will be set forth in the description, and the novel features of the invention will be particularly pointed out in the claims.

In the drawings:—Figure 1 is a diagrammatic representation of the apparatus and its various connections and controlling devices shown in operative relation to the principal elements; Fig. 2 is a side elevation of an interrupter shown in Fig. 1; Figs. 3, 4, 5 and 6 are diagrams illustrating in a conventional manner the different wave forms of the electro static convective current which may be produced by particular arrangements of certain elements of the apparatus. Fig. 7 is a modified construction of the parts involved in the electrical release of the particles during the operation of the apparatus; Fig. 8 is an end elevation of the parts shown in Fig. 7; Fig. 9 is a front elevation of the principal elements of the apparatus shown in Fig. 1 with a modification of the interrupter therein shown; Fig. 10 is an edge view of the interrupter shown in Fig. 9; Fig. 11 is an enlarged detail of a portion of the interrupter shown in Figs. 9 and 10; Fig. 12 is a diagram of one wave form produced by the interrupter shown in Fig. 9; Fig. 13 is a modified arrangement of the principal elements of the machine from that illustrated in Fig. 7. Fig. 14 is a side elevation of the principal elements shown in Fig. 13 with a modification of the depolarizing shield shown in the latter figure; Fig. 15 illustrates the substitution of a round electrode for the pointed electrode shown in the other figures of the drawings; Fig. 16 is the wave-form produced by the principal elements illustrated in Fig. 15; Fig. 17 is a side elevation of the principal elements of the machine shown in Fig. 1 with an interposed rotatable depolarizer or electrical releaser which is substituted for other forms of such elements illustrated in the other figures of the drawings, and Fig. 18 is a diagrammatic representation of the interrupter shown in Fig. 15.

Like numerals indicate like parts in the several figures of the drawings.

In the various figures of the drawings, 1 represents a pointed electrode which, by reason of its form, is adapted when supplied with an electrostatic charge to deliver a continuous current, in contradistinction to a round electrode under the same conditions which gives off a disruptive discharge.

2 represents an adjacent electrode, which in this instance is a cylinder mounted for rotation by means of the belt pulley 3 (Fig. 9) affixed to one of the journals 4 thereof. The bearings for said journals are pole pieces 5 of a pair of magnets 6 which are supported in a cross bar 7 upon a fixed portion or portions 8 of the framework of the apparatus. The means of connection and

support of said bar 7 comprises insulating sleeves 9 and washers 10 through which securing bolts 11 are passed. At approximately the center of the bar 7 a third magnet 12 is adjustably mounted by means of the bolt 13 passing through the slot 14 into the bar 7. The pole piece 15 of the magnet 12 is extended laterally and brought to a pointed edge which is arranged slightly above and parallel with the surface of the cylinder electrode 2, as clearly shown.

Above the electrode 2 is the hopper 16, supported in any suitable manner and adapted to contain the mass of the material to be separated into its various particles. Beneath the hopper is a shaker pan 17 which is oscillated by means of the connecting rod 18 and eccentric 19 which is driven in any suitable manner from any movable part of the apparatus. This shaker pan performs the ordinary well known function of gradually transferring portions of the mass from the hopper to the electrode 2.

At the front of the hopper there is adjustably mounted a shield 20 which is made of dielectric material, such as hard rubber. The lower edge of this shield is pointed and extends parallel with and slightly above practically the entire length of the electrode 2. 21 is another similar shield pivotally mounted in a pivoted arm 22 which is also pivotally connected with another arm 23 pivotally supported in the bracket 24 attached to any fixed portion of the framework of the apparatus. This pivotal support of the shield 21 is for the purpose of rendering it adjustable with relation to the magnet 12 and the electrode 2. Any other well known means of adjustable support may be used. The shields 25, 26 and 27 are of similar material and similarly mounted for the purpose of adjustment and have as one of their functions the conducting of particles to separate compartments 28, 29, 30 and 31, as hereinafter to be described. The shield 25 differs from the remaining shields in this respect that its entire upper surface with the exception of the rear edge near the pointed end of the same, is covered by a metallic or other electrical conducting plate 32 which is connected to ground by the wire 33. With these principal elements of the apparatus in view the source of energy and the various connections between the same will now be described.

The source of energy for the magnets comprises a dynamo 34 provided with a double throw switch 35 for the purpose of reversing the current from the dynamo to the magnets. The resistance 36 is connected with the dynamo for the purpose of regulating the strength of current supplied to the magnets. The switch and resistance may be connected in any suitable manner as they perform their well known functions. In this instance, lines 37 and 38 extend from one brush of the dynamo to the terminals 39 and 40 of the double switch, while another line 41 extends to terminals 42 and 43 of the switch. The resistance is connected with the field magnets by lines 44 and 45. As thus far described it will be seen that a current of any desired strength may be imparted to the poles of the magnets, and thus establish a magnetic field extending from the pole 15 to the electrode 2, and that said current may be reversed by operating the double switch. This reversal of the magnetic field or direction of the magnetic flux through a specified class of particles relative to the electro static flux therethrough is important. When a particle which is susceptible to magnetic action is polarized in definite directions, such particle has a plus and a minus pole. The electro static charge from the points impinging upon the particles gives a plus and a minus polarity, but this latter consists of static charges upon the surfaces of the particles. In the treatment of some classes of material it is preferable that these plus and minus magnetic poles should coincide with the plus and minus static charges on the surfaces of the particles as in this manner the attractive force of the particles for the electrode would be increased over what it would be if either force were acting alone. It may also be desirable to reverse this condition and have the magnetic force working in opposition to the static discharge so that the magnetic poles in the particles would be reverse to those of the static poles. All of this depends upon the class of treatment certain kinds of ores or compounds may require when there are other particles in the mass from which it is not necessary or desirable to make a separation. In the treatment of some complex ores to concentrate them for profitable smelting it is not always necessary to separate each constituent of the mass but merely those that are detrimental to smelting. The reversing of the magnetic poles would not appreciably lessen the attraction of that class of particles that are highly susceptible to magnetic action and have no appreciable dielectric capacity, while it would affect particles that would be equally susceptible to both forces.

46 represents an electro static generator for the purpose of supplying energy to the pointed electrode 1. It is to be understood, of course, that any usual source of energy may be employed.

47 is an interrupter or pole changer which is arranged to bisect the connection or conductor wires extending from the source of energy to the electrode 1. Any suitable pole changer or interrupter may be employed in lieu of that herein shown and described. The interrupter 47, shown in Fig. 1 consists of two disks 48 and 49 mounted

upon a shaft 50 arranged in suitable bearings in the framework of the machine, and in this instance driven by means of cone pulleys 51 and 52 and a connecting driving belt 53 passing over the belt shift 54 adapted to be adjusted to and fro by means of the threaded shaft 55 for the purpose of varying the speed of rotation of the disks 48 and 49, the power of rotation being supplied by belt 56 and pulley 57 on the shaft 58 to which cone pulley 52 is secured.

Each of the disks 48 and 49 has a series of curved slots 59 formed therein, and by means of the adjusting devices 130, shown in Fig. 1, one of the disks is adjustable circumferentially upon its shaft for the purpose of determining the length of the opening or slot passing through both disks. The solid portion of the disk 49 will serve to cover a portion of the slot in disk 48. By this means there is provided a series of three openings passing completely through both of these disks, and these openings may be merely apertures, or extended to the length of the entire slot in one of the disks so that in performing the function of an interrupter the length and duration of the successive charges given to the electrode 1 may be accurately regulated, and in proportion to the shortness of the charge permitted to pass through the interrupter, the length of time during which no charge is passed is lengthened by reason of the existence of the solid portions of the disks bisecting the conducting wires. It is, of course, understood that the material of which these disks are made is dielectric or nonconductive. In Fig. 2 the terminals of the conducting wires are shown as of much larger size than illustrated in Fig. 1. This is mentioned because of the fact that the character of the charge or convective current passing is modified by the formation of the terminals, the rounded formation giving off or partaking of the nature of a series of disruptive discharges while the more pointed the terminal is the more constant is the current delivered.

It now remains to describe the connections between the electro static generator and the principal elements of the machine. Starting at the + side of the generator a line 60 merges in the line 61 with the terminal at the disk 48 and is continued by the line 62 from the opposite side of the disk which merges with the line 63 extending to the electrode 1. The line 61 from the point at which the line 60 merges therewith is extended to ground at 64 when a switch 65 therein completes the connection.

From the — pole of the generator there is a ground line 66 which when the switch 67 is thrown in extends to the ground at 68. It will be observed that at this point of the apparatus there is inserted a resistance 69 connected at its lower end by wires 70 to each of the ground lines, while at its upper end a single pole or terminal 71 is located between the switches 65 and 67 so that the grounding of either the + or — side of the source of energy may be accomplished through the resistance 69 thereby grounding less than the complete charge or convective current of either line for the purpose hereinafter to be described.

Referring to the connection which passes from the interrupter it will be noted that the — side of the generator has the connection 72 with the switch 73 therein, and that the terminal 74 is disposed in relation to the interrupter to be in the path of the slots therein. From the interrupter the line 72 passes to and merges with the line 63 and from thence to the electrode 1. In this connection it will be noticed that a continuous convective current will be delivered from the pointed electrode to the cylinder electrode through the magnetic field, but that said current will be of successive polarities as an opening in the disk passes the lines 81 and 82 or the line 72 extending from the source of energy, and that either the + or — charge may be reduced in intensity or strength by throwing switch 65 or 67, as the case may be, into connection with the resistance and moving its switch 75 to determine the portion of either the charge or current to be grounded.

As a means for throwing out all portions of the interrupter, shunting line 76 on the + and 77 on the — side of the generator together with their respective switches 78 and 79 are provided. It will be seen that by closing switch 73 on the — side a continuous — charge or supply will be given to the electrode 1 provided the switch 79 be closed and the switch 78 open. So also by closing the switch 78 and opening 73 a continuous + charge from the generator will be supplied to the electrode 1 and passing through the intervening space to the electrode 2 and from thence by line 80 having the switch 81, which if closed, grounds at 82 and thence through the ground to the ground 68 of the — pole of the generator. When desired the electrode 2 can be directly connected to the — side of the electro static generator by opening switches 81 and 84 and closing switch 110, or, in case electrode 1 is being charged from the — side of the electro static generator the electrode 2 can be directly connected to the + side of the electro static generator by closing switches 81 and 110 and opening switch 84.

It is advisable to state at this point that the lines 85 and 86 serve to conduct the current from the dynamo to the magnets, as shown in Fig. 1.

By the connection thus described between the electro static generator to the electrodes of the apparatus, means are provided for giving either a direct or interrupted charge or convective current and for modifying the polarities of said current so as to subject material of a character requiring such treatment to a current having polarities of unequal intensity, and that by the use of the interrupter the duration of the active and inactive periods of the current may be varied, and that by a change in the form of the terminals of the lines at the interrupter a continuous or a series of disruptive discharge or charge may be applied to the terminal. These modifications in the character of the charge or convective current employed to act upon the material are conventionally illustrated in Figs. 3 and 6. The alternating charge, the wave of which is illustrated in Fig. 3 is produced by using the disks adjusted to provide an opening or a series of openings for the passage of the charge at the instant an opening is opposite the terminals of either the + or − conducting wire, whereby taking the line *c* (Fig. 3) to be zero potential, there is a sudden rise to full potential, the corners *a b* of the wave being slightly rounded, the high potential being maintained along said line *a b*, and so upon the − side the same maintenance is assured, and there is a sudden, positive and direct rise and fall of potential to zero between each line of maintenance of potential. The suddenness of the rise and fall of potential is essential to the successful operation of the apparatus. The curvature of the wave at *a b* is a matter which can be in a measure controlled by determining the formation of the terminals of the wires at the disks of the interrupter. When the terminal is pointed as at 87 on the + line 61 a continuous brush like convective current is delivered and by reason of the advancing end of the slot in the interrupter reaching into the outer portion of this brush like discharge the corner *a* is more rounded than when receiving the current at the disks from a round terminal like that shown in Fig. 2. and the maintenance of the polarity along the line *a—b* is followed by a practical drop for a short distance and then a gradual approach to zero, as shown by the dotted line *f* in Fig. 3 so that but a fraction of the wave is utilized. The same action takes place upon the − side of the zero line.

A charge having the wave line shown in Fig. 4, that is an interrupted + charge which is produced by opening the switch 73 thereby preventing the passage of the − to the electrode 1 but conducting to ground at 68, the + will pass through the opening in the disk by line 62, 63 to the electrode 1, from thence to the electrode 2 and to the ground. In this instance, as in the others the rise of potential is sudden and the maintenance of potential from *a* to *b* is secured. Taking a − charge, by closing switch 73, switch 79 being left open conducts a − charge to the interrupter and thence by line 63 to the electrode 1 and from thence to electrode 2 to the ground, the + side of the generator being grounded by closing switch 65. This produces the wave illustrated in Fig. 5, and by throwing in the resistance 69 the intensity or strength of the charge wave may be varied as indicated by dotted lines *g* in said Fig. 5.

The form of compound wave shown in Fig. 6 may be produced by the following connections. The switch 78 is closed thus shunting the + charge around the interrupter. The switch 79 is left open and the switch 73 closed thus taking the − through the interrupter to the line 63 and thence to the electrode 1 producing what may be termed a pulsating charge or convective current at and through the electrode 1 the interrupted current impulsing at *d d* and inactive at *e e*. The electrode 2 may either be grounded or connected back to the generator as hereinbefore described.

It now remains to describe the functions and operation of the dielectric shields present in the appartaus. It is extremely desirable to facilitate the arrangement of the particles as they fall from the shaker pan to the electrode 2 in a segregated or individualized condition and this may be accomplished by simply influencing them with a charge of single polarity which is accomplished by the action of the electro static charge from the electrode 1 impinging the shield 20 which implants a positive charge upon the front of the shield and along its pointed edge, which charge induces, that is, produces by induction a charge of opposite polarity upon the opposite side of said pointed edge of the shield, which charge in this case is of − polarity which induces in the particles a similar polarity to each other and which has a tendency to segregate or separate the particles one from the other and cause them to fall upon the electrode in a thin sheet like segregated form. The function of the dielectric shield 21 is in a measure the same as that of the shield 20, and by reason of its relative position to the electrode 2 the + and the induced − poles produced at its pointed edge serve to release the most feebly attracted particles upon the electrode and to cause them to travel upwardly along the shield 21 and then to fall upon the shield 25, as clearly shown in Fig. 1. Those particles in the magnetic field and under the influence of the electro static charge which are the more feebly adherent to the cylinder electrode 2 are immediately at the beginning of the process of separation electrically released and permitted to fall upon the shield 25, as before stated. By reason of the brush like formation of the constant convective charge from the pointed electrode 1, the same polarities are produced and maintained along its edge as hereinbefore described so that the — polarity induced at what is shown to be the lower side of the shield 25 acts to assist in electrically releasing the particles which are the most feebly attached to the cylinder electrode at a point succeeding that of the primary release just described. To prevent the existence of this electrical release from the greater portion of the upper surface of the shield 25 a metallic or other conducting plate 32 is put upon the upper surface of said shield and is connected by wire 33 to the ground, counteracting and qualifying the electro static action of the electrode 1 upon the particles as soon as they come upon said plate 32 from which they are delivered into compartment 28 simply by gravity. It will be readily seen that by adjustably mounting the shields the area of the electrode 2 which shall be under the influence of the action, direct and indirect, of the convective current maintained from the electrode 1 may be determined.

90 represents a felt covered roller which contacts with the electrode 2 and moves in opposition to the movement of the electrode at the point of contact for the purpose of brushing off the finely adherent matter. This matter may be of a powdered nature or a constituent of value which continues to adhere.

Various forms of electrically shielding and releasing elements of the apparatus may be substituted for those thus far described.

It now remains to describe certain modifications in the form of the electro static releasing means employed in connection with the electro static and magnetic field. We have discovered that an electrical releasing device which is not adjustable, but relatively fixed in position with regard to the combined electro static and magnetic field may be employed. We have further discovered that in some instances the electrical releasing device may be formed of a rotating shield, and furthermore that in some instances it may be of other material than dielectric. For example, by referring to Fig. 7 it will be noted that the electrode 2, magnet 15 and pointed electrode 1 are in the same relation with each other as in Fig. 1, but that the electrode 1 is in the form of a shaft having points projecting therefrom and mounted in bearings 91 and carrying the belt pulley 92 with the power conveying belt 93, whereby said electrode is rotated. By rotating the electrode there occurs a passage of the convective current from its points to the electrode 2 when they are pointed toward the same, while in the opposite position no current passes and the electrode and magnet are shielded by the rear portion 94 of the shaft constituting the body of the electrode. This construction produces a succession of applications of current to the material intermittent with a shutting off of the current and depolarization of the particles adhering to the electrode 2 with feeble attachment thus performing the same function as do the shields 21, 22, etc. shown in Fig. 1. By regulating the rapidity of the rotation of the electrode 1 different effects are produced and the apparatus is thus adapted for the treatment of particles having different characteristics.

In Fig. 13, 95 shows a pulley driving mechanism for regulating the speed of rotation of the rotating shield 96 which in this instance may be of other material than dielectric, as its presence between the pointed electrode 1 and cylinder electrode 2 and magnet 15 displaces and neutralizes the charge or convective current delivered by the pointed electrode and thus stops the sticking or attaching of the particles by the current from the electrode 1 intermittently and facilitates the separation from the electrode of the more weakly attached particles. The interposition of the electric conducting shield 96 presents to the weakly attached particles an opposite polarity to that possessed by them and therefore serves to attract them from the cylinder electrode 2 and this by an opposite method, process and operation to that of a direct charge from the points producing in such elements a similar polarity to that of the electrode to which they are attached.

In Fig. 14 the equivalent shield 97 is rotatively mounted, but is intended to be moved by hand into different degrees of interposition between the electrode 1 and the electrode 2, the particular advantage of this form of mounting the shield being that it can be employed to interpose and cut off more or less of the brush like convective current passing from one electrode to the other and this either in the upper portion, central or lower portion of the same, or it may be temporarily thrown out of operation as shown by full lines in Fig. 14.

In the treatment of some particles of matter it has been found that centrifugal force may be utilized with the electro static and magnetic forces employed in this apparatus. In Fig. 17 98 represents a cylindrical rotating dielectric shield which is interposed between the electrode 2 and the adjustably supported shield 25 having a ground plate 32 upon its surface. Here the particles which become detached from the cylinder electrode by reason of their feeble attachment thereto under the action of the brush like convective current from the electrode 1 fall upon the rotating dielectric shield 98 and are thrown by centrifugal force outward and upon the shield 25. It is advisable to state that to prevent any preliminary charge of the mass of material in the hopper or upon the shaker pan these are grounded by the wires 99 merging or connected with the grounding wire 80 of the cylinder electrode.

In order to produce a perfectly square wave-form in which is maintained along the line *a b*, a polarity of either + or — and that with other than the pointed electrode 1, a slight modification of the interrupter is required. As hereinbefore stated a less rounded corner of the wave is produced by employing a round electrode or terminal as shown in Fig. 2, in connection with the interrupter therein illustrated, that is, that resulting in the different form of discharge of energy supplied to said terminal, the one being brush like and the other a series of disruptive or more sudden discharges.

In Fig. 15, 101 represents a round electrode which is substituted for the pointed electrode 1, and sustains the same relative position to the magnet 15 and electrode 2 and is connected directly to the — pole of the electro static generator 46, while the + pole is connected directly with the cylinder electrode 2, while branch lines 102 and 103 from the — and + lines respectively terminate at each side of the single rotary interrupter disk 104 having instead of the openings therethrough, a metallic plug 105. The terminals 106 and 107 are of metal and have contact with said plug on both sides of the disk once during each rotation thereof. In this instance, by reason of the metallic contact whenever the plug is in contact with the terminals 106 and 107 there is a positive short circuiting of the charge back to the generator thus depriving both electrodes from any charge once during each rotation of the interrupter and consequently the corners *a b* of the wave are for all practical purposes perfectly square and the potential is maintained along the line *a*—*b* of the wave. By lengthening the plug as shown by dotted lines in Fig. 18 at 108, the length or time of the contacts can be predeterminedly increased. With the plug as shown in Fig. 15, the short circuiting is for extremely limited instant as compared with the circumferential path of the terminals 106 and 107 on the nonconductive or dielectric portion of the disk so that the active period of the charge upon the electrodes is accompanied by intermittent inactive periods of extremely slight duration as compared with the active periods or the period during which potential is maintained upon the particles being treated.

The resulting wave just referred to is conventionally illustrated in Fig. 16 where *c* is zero potential and *a b* are the lines of maintained potential, while *g h* is the period of inactivity or the period of short circuiting by means of the interrupter provided with the metallic plug.

The same wave form shown in Fig. 16 may be produced bipolar in its nature indicating the subjection of the material to waves of successive polarity, as illustrated diagrammatically in Fig. 12. The means employed for producing this electrical action upon the material in the magnetic field of the apparatus is illustrated in Figs. 9 and 10. In this diagrammatic representation of the principal elements of the machine, the form described in connection with Fig. 1 is adhered to and for purposes of clearness a direct connection of the interrupter or pole changer is employed. From the electrode 1 there extends a line to a rod 110 covered with an insulation 111. From said rod there projects a pin 112 upon which is pivotally mounted a curved contact plate 113. A similar line 114 is connected with the brush 115 bearing upon the journal 4 of the electrode 2, and at its free end terminating in another rod 110 insulated and having a pin carrying a curved, metallic, pivotally, mounted contact plate 113. Upon the shaft 116 is mounted a disk 117 (see Fig. 10) upon each side of which is an annular conducting strip 118 and 119, respectively. From the annular strip 118 project beyond the disk 117 three wiper arms 120, and from the annular strip 119 project three annular wiper arms 121. Upon the same annular strip 118 bears brush 122 connected to the — pole of the electro static generator 46 by a wire 123, while from brush 124 bearing upon the annular strip 119 a wire 125 extends to the + pole of the generator. The curved contact plates 113 are of such a length that when in a vertical plane, as is the disk 117, they will be contacted with an arm from one of the annular strips at the instant that an arm from the other of said annular strips passes off from said plate. Taken in this condition the wave form shown in Fig. 12 is produced and an electric charge is supplied to the pointed electrode and both electrodes are reduced to zero with exceeding rapidity and accuracy and without any perceptible intervals or lapses of time between the alternations. The operation is as follows: Assuming the charge from the + pole of the generator through the wire 125 to the brush 124 of the annular plate 119 on the rear side of the disk 117, the charge would follow the plate until it reached the lower arm 121 on the left, and assuming that the next adjacent arm 120 on the left be in contact with the plate 113, then a + charge would go to electrode 2 and both arms 121 and 120 would be for an instant in contact with plate 113 so that any charge would follow the plate 118 on the front side of the disk 117 carried thereto by the upper arm 120 and from the plate through the brush 122 and line 123 back to the generator at its — pole. In other words, the entire charge of the generator is short circuited back to it from the cylinder electrode 2 for an exceedingly brief instant of time which would be occupied in the passage of the arm 121 from the contact plate 118. It will be seen that by tilting the plate 118 on its pivot out of the vertical plane of the disk, shorter lines of contact of the wiper arms, represented by dotted lines of contact 126 in Fig. 11, would result.

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

Some of the features of construction herein described are shown and described in our application Serial No. 225,852, filed September 24, 1904 and claimed therein.

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

1. In an electro static magnetic separator, means for producing a magnetic field, means for subjecting the particles of a mass to the action of a static charge regulated to produce and maintain dielectric polarity on some of the particles opposite to that of one electrode while in said magnetic field and means for separately collecting the separated particles.

2. In an electro static magnetic separator, means for producing a magnetic field, means for feeding material thereto, means for producing and maintaining difference of potential between some particles of material and one electrode while said particles are in said magnetic field and means for separately collecting the separated particles.

3. In an electro static magnetic separator, means for producing a magnetic field, means for feeding material thereto, means for producing and maintaining difference of potential between some particles of material and one electrode while in said magnetic field, means located adjacent to said electrode for subsequently depolarizing said particles and means for separately collecting the separated particles.

4. In an electro static magnetic separator, means for feeding comminuted material, means for delivering to the particles of a mass an interrupted static charge of one polarity while in a magnetic field and means for separately collecting the separated particles.

5. In an electro static magnetic separator, means for feeding comminuted material, means for delivering to the particles of a mass while in a magnetic field an interrupted charge of one polarity, means for modifying the strength of said charge and means for separately collecting the separated particles.

6. In an electrostatic magnetic separator,

means for feeding comminuted material, means for subjecting the particles of the material to a magnetic field, electro static means for polarizing the particles, means for interrupting the direct action of the electro static means for electrically releasing some of the particles and means for separately collecting the separated particles.

7. In an electro static magnetic separator, means for feeding comminuted material, means for subjecting the particles to the action of a magnetic field, means for subjecting them while in said field to either a static charge of one polarity which is continuous, or to a static charge of alternating polarity and means for separately collecting the separated particles.

8. In an electro static magnetic separator, means for producing an electro static magnetic field, means for retaining a mass of particles and feeding the same to said field, and interposed means between the retaining means and field for shielding the mass from the influence of the electro static magnetic field of the apparatus.

9. In an electro static magnetic separator, means for producing an electro static magnetic field, a hopper, a shaker pan, and means for electrically shielding the hopper and pan from said field.

10. In an electro static magnetic separator, electro static electrodes, an interposed magnet, a hopper, and an electro static shield between the magnet and the hopper.

11. In an electro static magnetic separator, electro static electrodes, an interposed magnet, and an electro static shield interposed between the magnet and the electrodes.

12. In an electro static magnetic separator, electro static electrodes, an interposed magnet, and electro static shields interposed between the electrodes and the magnet above and below the plane of the charging electrode.

13. In an electro static magnetic separator, a charging electrode, a separating electrode, a magnet coöperatively arranged, and means for electrically shielding a portion of one electrode from the action thereon of the other electrode to electrically release the particles from the first mentioned electrode.

14. In an electro static magnetic separator, a charging electrode, a separating electrode, a magnet coöperatively arranged, means for electrically shielding a portion of one electrode from the action thereon of the other electrode to electrically release the particles from the first mentioned electrode, and means for subsequently electrically shielding the released particles from the remainder thereof.

15. In an electrostatic magnetic separator, a charging electrode, a separating electrode, a magnet coöperatively arranged, means for electrically shielding a portion of one electrode from the action thereon of the other electrode to electrically release the particles from the first mentioned electrode, means for subsequently electrically shielding the released particles from the remainder thereof, and means for subsequently reducing said released particles to zero potential.

16. In an electro static magnetic separator, a charging electrode, a separating electrode, and means for electrically shielding bodies of separated particles from each other and from said electrodes.

17. In an electro static magnetic separator, a charging electrode, a separating electrode, an electrical shield of dielectric material, and means for restricting polarity to a portion of said shield.

18. In an electro static magnetic separator, means for feeding comminuted material, means for subjecting the particles to the action of a regulated varied static charge, means for simultaneously producing a magnetic field in which said particles are statically acted upon and means for separately collecting the separated particles.

19. In an electro static magnetic separator, means for feeding comminuted material, means for subjecting the particles to the action of a convective discharge while in a magnetic field, means for producing the magnetic field, means for varying the strength of said magnetic field and means for separately collecting the separated particles.

20. In a separator of the class described, means for feeding comminuted material, means for producing a magnetic field, means for producing an electrostatic field, means for varying the strength of the magnetic field, means for varying the strength of one polarity of the static charges operating in said field and means for separately collecting the separated particles.

21. In a separator of the class described, means for feeding comminuted material, means for subjecting the particles to the action of a convectively delivered charge, means for simultaneously producing a magnetic field in the region of said charge, means for reversing the polarity of the magnetic field and means for separately collecting the separated particles.

22. In a separator of the class described, means for feeding comminuted material, means for subjecting particles to the action of a convectively delivered charge, means for simultaneously producing a magnetic field in the region of said charge, means for changing the polarity of the convective charge and means for separately collecting the separated particles.

28. In a separator of the class described, means for feeding comminuted material, means for subjecting particles to the action of a convectively delivered charge, means for simultaneously producing a magnetic field in the region of said charge, means for short circuiting said charge back to the generator thereof and means for separately collecting the separated particles.

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

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

Witnesses:
J. S. MOAD,
J. P. HUBBELL.