No. 859,998. PATENTED JULY 16, 1907.

H. A. WENTWORTH.

METHOD OF ELECTRICAL SEPARATION.

APPLICATION FILED DEC. 20, 1906.

4 SHEETS—SHEET 1.

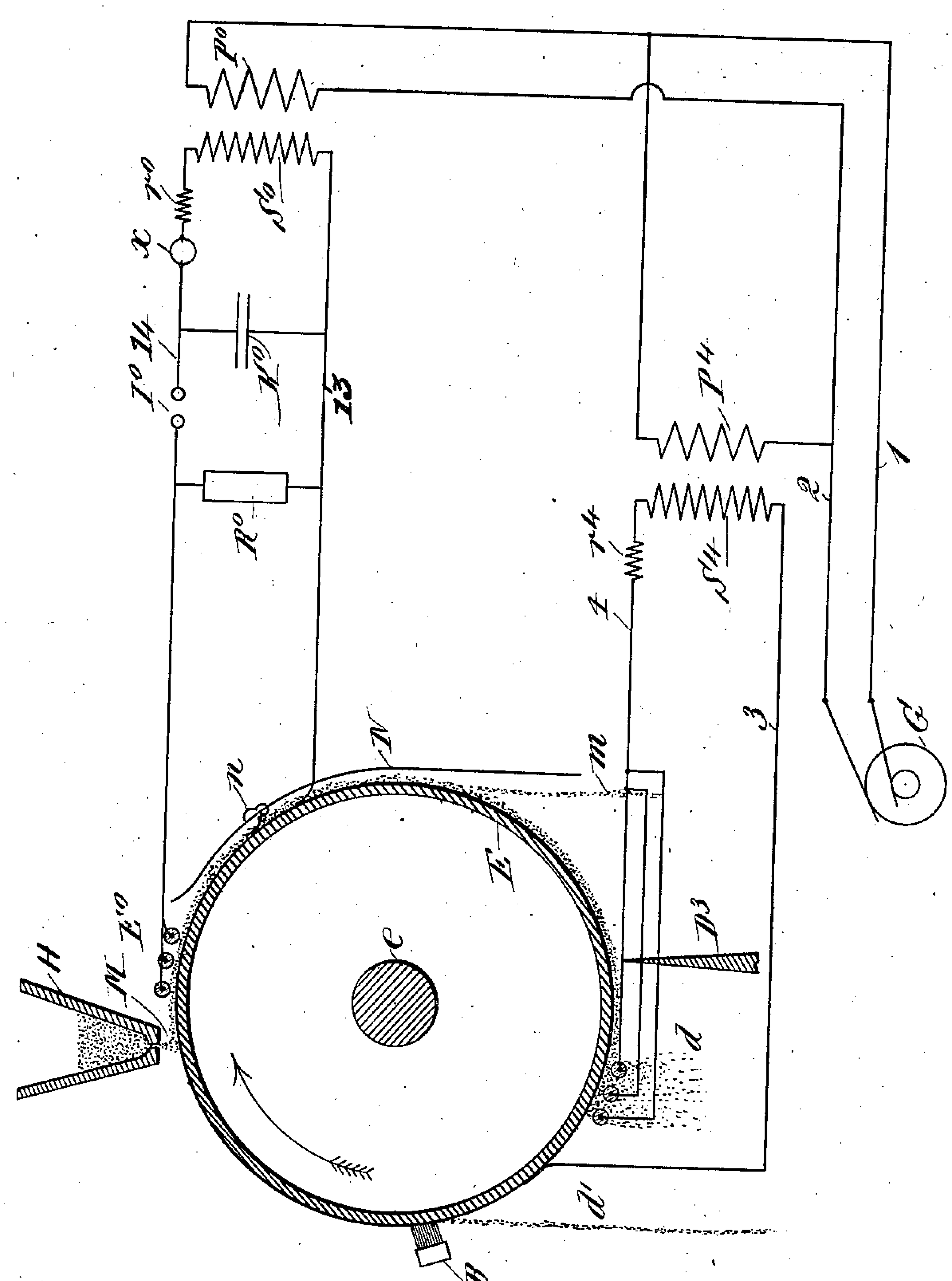

FIG-1-

WITNESSES=

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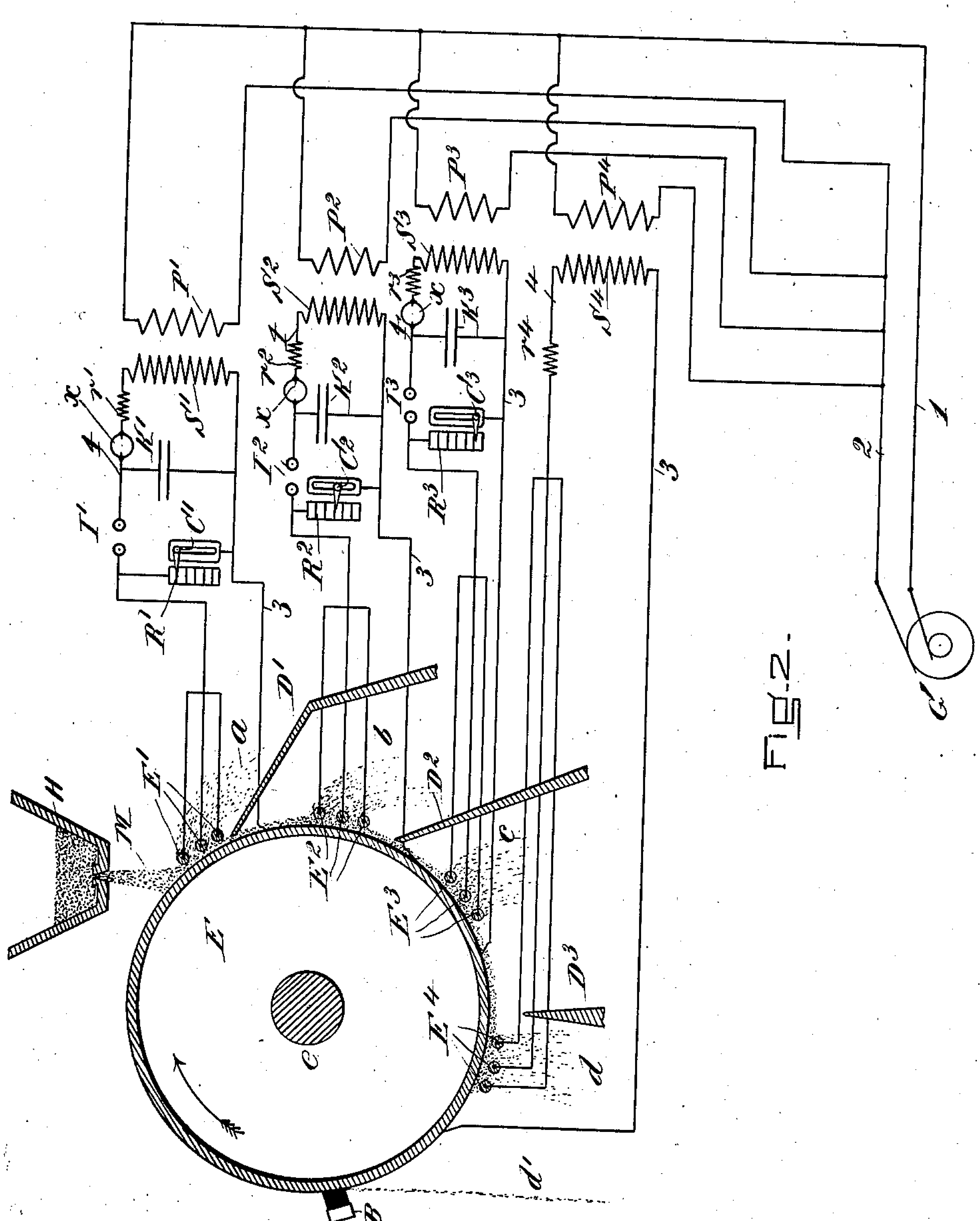

FIG. 2.

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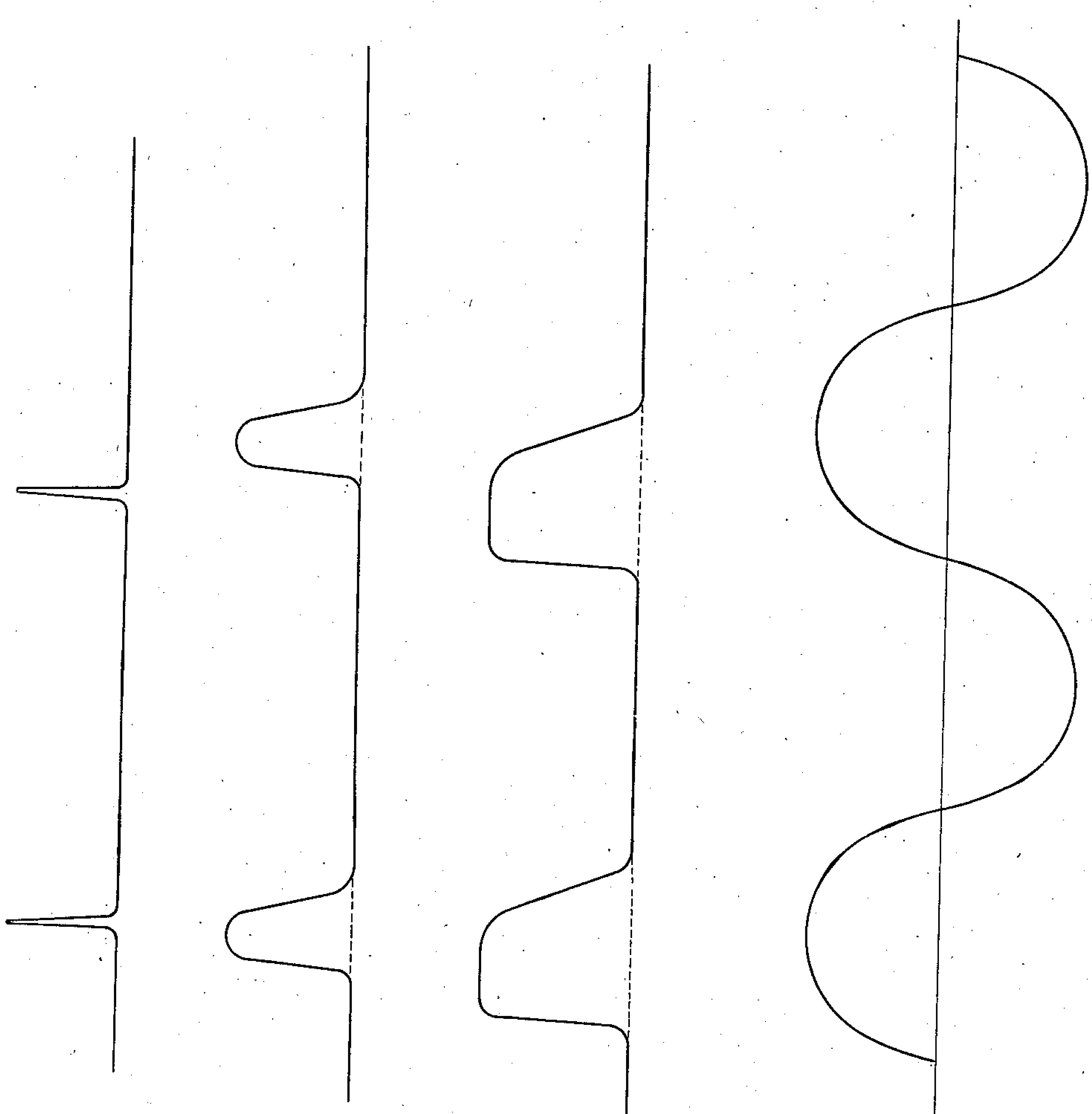

Fig. 3. Fig. 4. Fig. 5. Fig. 6.

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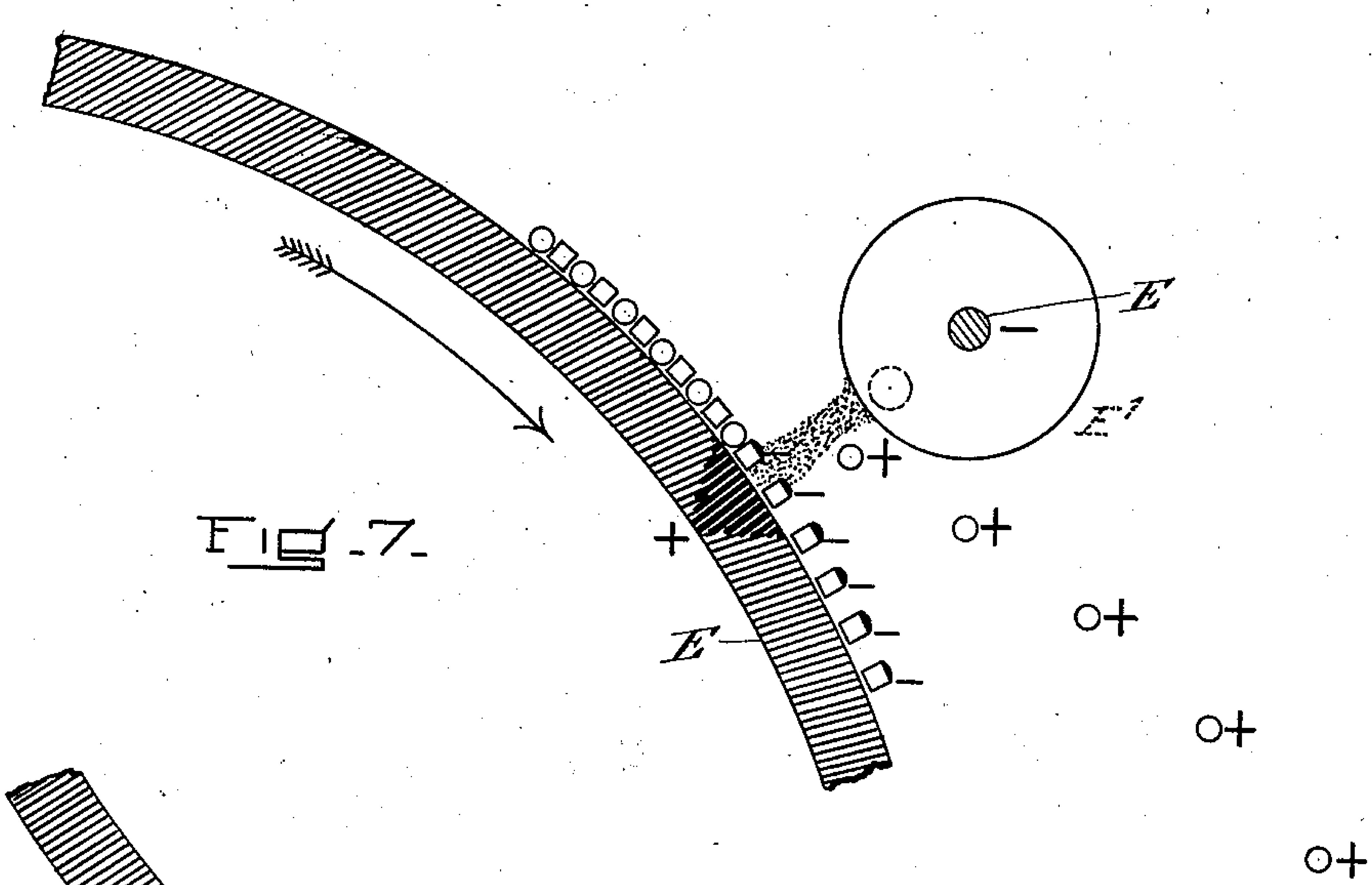

Fig. 7.

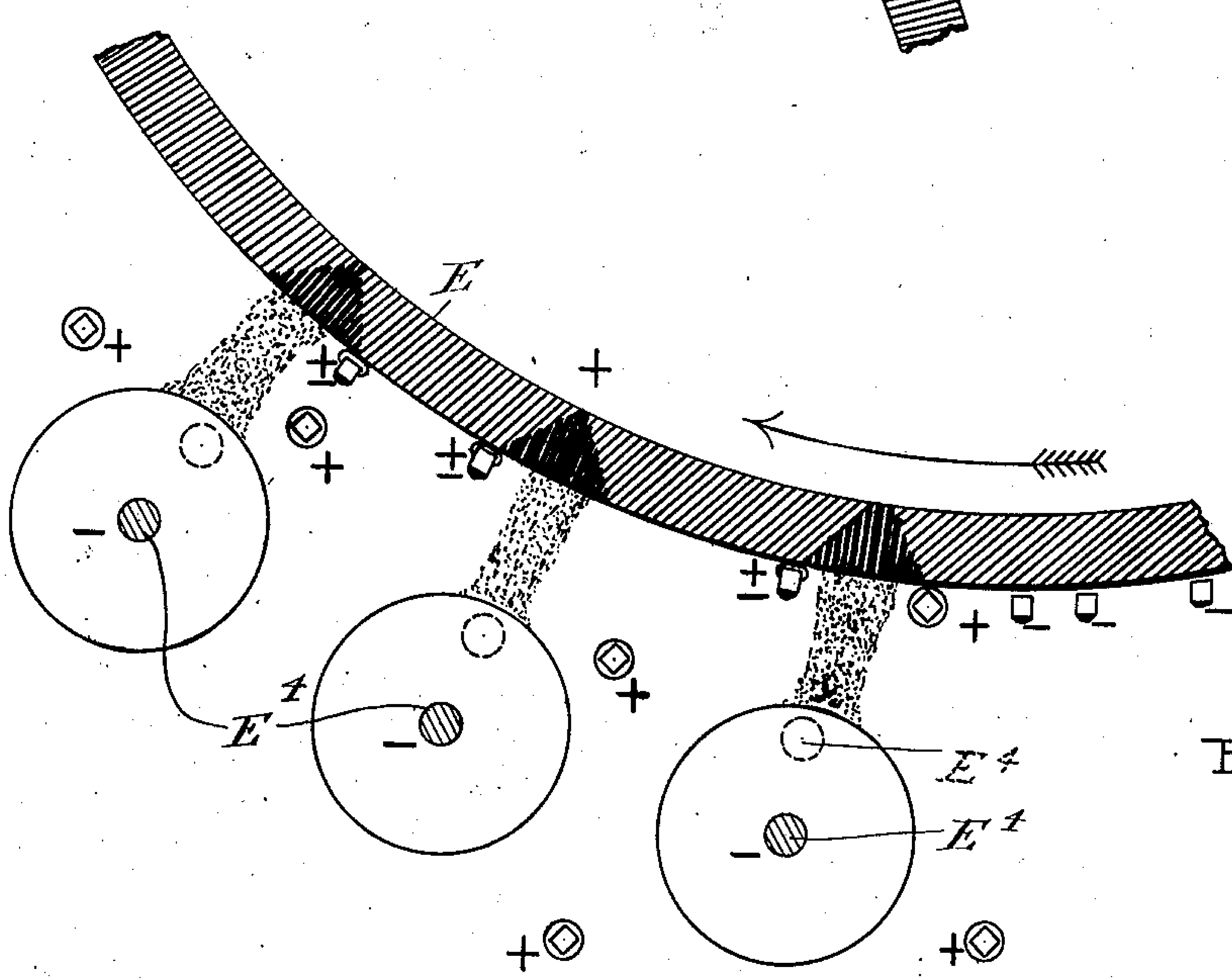

Fig. 8.

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METHOD OF ELECTRICAL SEPARATION.

No. 859,998. **Specification of Letters Patent.** **Patented July 16, 1907.**

Application filed December 20, 1906. Serial No. 348,720.

To all whom it may concern:

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

My invention relates to the art of electrical separation, concentration, or classification, of the ingredients of heterogeneous mixtures of solid comminuted matter such as, for instance, the miscellaneous components of ore bearing rock or earth in which, as is often the case, there may be several substances of graduated value which to be effectively and economically recovered must be separately classified or concentrated and freed from the earth, rock or other gangue wherewith they are associated in nature.

My invention consists in an improved method by which these results can be accomplished and by which the segregation or concentration of several elements in a mixture may be successively effected.

My method involves to some extent the practice of the process shown and described in Letters Patent of the United States No. 805,694 dated Nov. 28, 1905, granted to Philip Henry Wynne; and in the apparatus which I have found to be best adapted for the performance of my new process, I employ the devices and method shown and described in Letters Patent No. 796,012 to Greenleaf W. Pickard, dated August 1, 1905.

In conducting a long series of experiments and demonstrations with an apparatus constructed and operated according to the specifications of the above mentioned Wynne and Pickard patents, and containing also the structural peculiarities set forth and described in Letters Patent of the United States No. 801,380 to Charles H. Huff, dated Oct. 10, 1905, I modified and varied the conditions of operation, both in respect to the potentials employed and to the duration of the potential accessions which characterize the Wynne process of electrostatic separation. During this series of observations I found that under some of the electrical and time conditions a portion of the materials adhered to the electrode so persistently that it proved difficult effectively to remove such particles from the electrode by means of mechanical brushes or scrapers, and I was at first led to regard this adhesion as more or less detrimental to the proper conduct of the process.

I have been informed that processes and apparatus for electrostatic separation have been contrived and operated wherein the electrical conditions are such that some ingredients of the mixture to be segregated or concentrated are made to adhere to an electrode by reason of their property of dielectric hysteresis, and while the electrical conditions of the Wynne process under which I was operating are radically different from those which must be maintained for the purpose of the aforesaid hysteresis process of separation, I supposed or rather assumed at first, that the adhesion of some particles under some conditions during the performance of the Wynne process might be due to the hysteresis of such particles. On closer observation, however, this hypothesis failed of verification.

During the performance of the Wynne process there had appeared under some conditions a clearly defined band of pale violet light between the two electrodes of the apparatus, this band of light being located in coincidence with the concentrated and effective electrostatic field, and I observed that when this band of violet light was manifested, poorly-conductive particles manifested their most pronounced tendency to adhere to the electrode; and moreover, on experimenting with crystalline quartz particles, which possess substantially no hysteresis whatever, I found that these particles adhered just as persistently to the main electrode as poor-conductors which are decidedly hysteretic. Further, on imposing conditions of atmosphere pressure which so varied the dielectric strength of the air surrounding the electrode, that the band of violet light no longer appeared, meanwhile maintaining the same conditions of potential as under ordinary atmospheric conditions had produced the band of light, I found that inferior conductors which, under the ordinary atmospheric conditions had adhered to the main electrode, no longer manifested any tendency so to do but fell therefrom as inertly as though no electrical conditions whatever had been imposed. Under these conditions if dielectric hysteresis had been responsible for the phenomenon of adhesion, the dielectric particles would have clung to the electrodes just as emphatically as under the ordinary atmospheric conditions. I discovered during the course of these investigations that the highly concentrated electrical field produced by the Wynne or Pickard apparatus ionized the air directly in or near the region of highly concentrated field, and by ionizing the gas further exerted the convective effect of the field so as to produce a transference of the ions from one electrode to the other in a jet of almost inconceivably high velocity. This jet in the form of apparatus used (two parallel electrodes, one a cylinder and the other a glass covered wire) was in form a thin sheet or band extending across from one electrode to the other. Each one of the ions in this jet is, in effect, a minute fraction of the charge on the electrode from which the jet proceeds, or, perhaps, more accurately speaking, serves as a carrier for a small portion of the said charge, and is effective therefore, to transfer from one electrode to the other an infinitesimal fraction of the charge on the electrode.

As a result of my investigations very briefly summarized above, I have invented a process of electrical separation which I proceed to describe in connection with an apparatus appropriate thereto which is shown in the accompanying drawings.

In these drawings, which are diagrammatic for the purpose of clear illustration,—Figure 1 shows an apparatus for electrical separation, which depends primarily upon the effect of a jet of ionized air upon the particles of a heterogeneous mixture of solids; Fig. 2 shows an apparatus in which my process of separation through the medium of the ionized jet is coupled with and modifies the process of electrostatic separation characteristic of the Wynne invention; Figs. 3, 4, 5 and 6 are diagrams illustrative of the electrical conditions produced by the apparatus shown in Fig. 2; Fig. 7 is a diagrammatic representation on a large scale of a portion of the electrodes showing conventionally the mode of operation of my improved method in one of its phases; and Fig. 8 is a similar detail on a large scale showing the operation of my process in another of its phases.

Referring to Fig. 1, E is an electrode, cylindrical in form and composed superficially, at least, of a good conductor such as steel, brass, or copper. The electrode E is mounted upon a shaft e and is rotated in a direction indicated by the arrow. H is a delivering hopper from which the comminuted mixed solid material M is delivered in a thin stream upon the surface of the electrode E. In Fig. 1 I have shown the hopper H as delivering the material M upon the rising surface of the electrode E. The line of delivery of material should be so arranged with respect to the character of the surface of the electrode E and its speed of rotation, that any tendency of the material to slip down the electrode surface in a direction opposite to its direction of rotation will be overcome by the movement of the electrode itself, and all the particles be conveyed upon and with the rotating surface. E° is an electrode opposed to the electrode E and is preferably composed of fine copper wires inclosed each in a dielectric envelop, such as described in the Huff patent above mentioned. The electrodes E and E° are intermittently connected respectively with the two terminals of a source of electrical energy. The energizing apparatus shown in Fig. 1 is the same as that shown and described in the Pickard patent above mentioned, and consists of a primary source G which may be an ordinary alternating current generator. The circuit of this generator includes the primary P° of a transformer coil, the secondary of which, S°, is connected to the terminals of a condenser K°, a resistance $r°$ being interposed to damp or muffle any oscillations which may be produced by the secondary. Thus, as set forth in the said Pickard patent, the condenser K° becomes the immediate source of electrical energy for the electrodes in the separator. The wire 14 leads to a spark gap I° which in this branch separates the condenser K° from the electrode E°, and the wire 13 of the other branch leads directly to the surface of the larger electrode E. A non-inductive resistance R° serves as a bridge between the electrode connections to deplete the electrodes of potential the instant after they are charged by the break-down of the spark gap I°.

In order to avoid the effect of transporting alternating charges by the stream of ions, the apparatus should be such as to excite the electrodes with recurrent charges of the same sign, plus or minus, as by a commutator or rectifier x. A complete description of this operation will be found in the Wynne and Pickard patents above mentioned. Its result is to produce at the electrodes E and E° periodic accessions of potential which are separated in time by intervals of substantially no potential.

The electrode E being set in motion and the supply of material M being delivered continuously from the hopper H, and the electrical apparatus being put in operation, the material M distributed in a thin layer on the electrode E moves into the field produced by the electrodes E and E°. This field, by reason of the design and construction of the electrodes and their close proximity, is practically concentrated to a thin band extending from the wire electrode E° to the surface of the larger electrode E.

When the potential difference between the two electrodes E, E° is raised sufficiently, say to 15,000 volts, the band of violet light will manifest itself in the concentrated field, indicating that the ionization of the air has reached that stage necessary for the passage of a spark discharge. The dielectric envelop surrounding the electrodes E° (Fig. 1) operates to prevent too great a quantity of electricity passing in each spark, and thus the discharge is drawn out into a band of very minute and closely spaced spark discharges. The jet, however, is produced under electrical conditions in which the potential differences are very much less than those required for the manifestation of visible light in the concentrated field, and even under such electrical conditions my process of electrostatic separation may be carried on, although I prefer to employ the apparatus under conditions of structure and adjustment which insure the appearance of the violet illumination. The result of the jet of ionized air is to convey a charge to the particles on the electrode E. Those ingredients of the mass M which are of superior conductivity, by reason of their more or less intimate contact with the electrode E deliver their charge to the electrode, or, to speak more correctly;—the charge on the conductive particles of the mass M received from the jet proceeding between the two electrodes is almost instantly neutralized by the charge of opposite sign residing on the electrode E. The non-conductive particles, however, as they resist conduction through their mass and also manifest much less surface leakage than the conductive particles, receive the charge from the ionized gaseous jet only on their exposed sides, and consequently carry each a local charge characterized by potential different from that of the electrode E, whether the latter be actually charged or be for the time inert. Consequently the inferior conductors of the mass adhere to the electrode E and continue to adhere thereto after the rotation of the electrode E has carried them out of the field between it and the electrode E°. As the mass M is carried on the electrode over its descending limb, the conductive particles which received but immediately surrendered the charge conveyed to them by the ionized gaseous jet, are inert and free to fall from the electrode as soon as the inclination of the surface on which the particles rest becomes sufficiently steep, as at m'; the inferior conductors on the contrary, each of which continues to carry its local charge on the surface not in contact with the electrode E, adhere thereto and may be removed by any means found effective for the purpose. The localization of the field is such that the electrode E is to all practical intents and purposes charged only at the point immediately opposite the electrode E°, so that after the particles of the mass M have been conveyed through this concentrated field they rest upon a surface which, electrically considered, is inert. This may be demonstrated by providing, as shown in Fig. 1, an electrical screen, such as the sheet metal plate N which, for the greater part of its surface, is parallel and close to the surface of the electrode E and electrically connected thereto as by a wire *n*. Such a screen will effectively prevent the appearance or manifestation of potential on the surface of the electrode shielded by it; the behavior, however, of the particles is not perceptibly different whether the screen be in place as shown or not.

The operation of the Wynne process requires conditions under which the conductive particles of the mixed mass assume the charge of the electrode in contact with which they rest so that they are vigorously repelled from that electrode. When, however, the electrical conditions are adjusted in respect to potential and duration of charge so that this repellent effect is not perceptible, that is to say, if manifested at all, serves only to barely neutralize the effect of gravitation, nevertheless by the operation of the ionized gaseous jet the inferior conductors are locally charged in the manner above described, whereas the conductors being completely superficially charged by the said jet have their charge neutralized by their contact with the electrode on which they rest. Thus, in Fig. 1, I have shown the electrodes E° as directly over the top of the rotating electrode E so that if the electrical conditions were such as to bring into play the auto-repulsion of the Wynne process, the conductive particles would only hop a little way from the surface of the electrode E and return thereto. In practice, however, I find that by either diminishing the potential differences or by reducing the time duration of the potential accessions until no convective response by conductive particles is perceptible, nevertheless the separative effect due to the adherence of the inferior conductors after their subjection to the ionized gaseous jet is carried on with certainty and success.

As the ordinary mechanical devices such as brushes or scrapers have given trouble in removing adhering particles from an electrode, I employ the electrical stripper shown in Fig. 1. This consists of a wire electrode which may be covered similarly to the electrode E°, or preferably, a grid of such electrodes as shown at E^4. The exciting apparatus for these electrodes need not contain any interrupting and depleting devices but may, as shown, consist merely of the wires, 3, 4, connected to the terminals of the secondary S^4, which is provided with the oscillation suppressing resistance r^4, the primary P^4 being in the circuit of the alternating generator G. By this means the duration of the potential accessions at the electrode E^4 is protracted far beyond the duration of the potential accessions of the electrodes excited by such apparatus as that described above in connection with the electrode E°. When, therefore, the adhering poorly conductive particles come within the field of the electrode E^4, they are subjected to the direct influence of the charge on the electrode for so long a time that even though they are composed of highly resistant substances, they become charged with potential similar in sign to that of the electrode E, and are repelled therefrom in the manner characteristic of the Wynne process and apparatus, this auto-repulsion being sufficiently emphatic first to neutralize, and then to overcome, the effect of charge conveyed by the ionized gaseous jet. The stripping electrode may, if desired, be excited by a source of substantially steady potential, such as an electrostatic machine.

Poorly conductive ingredients of the mass M are shown as falling from the electrode E at *d* and a partition or separator D^3 may be employed to perpetuate the separation of these particles from the others.

It is frequently the case that even after the operation of the electrical stripper there are some very minute particles still adhering to the electrode, and these are readily removed by a brush or scraper such as B and fall as at *d′* into whatever receptacle is provided for them.

While my above described process of separation through the deposition of local charges by the action of the ionized gaseous jet upon inferior conductors in a mass may, under many conditions, be effective for electrical separation or concentration without the aid of other agencies; I believe, however, that the modification of the Wynne process by my ionization process and the combining of the two processes or agencies will be found preferable and effective over a larger range of material conditions than either process employed solely. Moreover, the coöperation of the two processes results in a mutual improvement of functional performance so that the auto-repulsion process of Wynne is enhanced in its effects by the super-position or co-ordination of my process of local charge by ionization of the intervening gas, and, conversely, my process is enhanced and improved in its effects and functions by the coöperative employment of the principle of the Wynne process.

In Fig. 2 I have shown an apparatus whereby the fundamental principles of the Wynne process and of my ionizing process coöperate. By this coöperation it is possible and commercially practicable to effect a serial and graduated classification of the heterogeneous ingredients of a mixed mass with much greater certainty and rapidity than heretofore.

In Fig. 2 H represents a hopper slotted at the bottom from which the material M is delivered in a thin and substantially continuous stream to the surface of the cylindrical electrode E which is mounted upon a shaft *e* and caused to rotate in the direction of the arrow shown. The opposed electrodes E′, E^2, E^3, E^4 consist each of a wire or wires each of which may be inclosed in a dielectric envelop as of glass, the several members of each of these opposed electrodes being constructed substantially in accordance with the specifications of the Huff patent, No. 801,380, wherein the electrode marked E′ is similar to a single one of the members of the opposed electrodes shown herein. The several electrodes E′, E^2, E^3, E^4 are spaced apart, so that the field of either does not affect the field produced by another. The close proximity of the members of these opposed electrodes to the surface of the main electrode E so concentrates the field that substantially all the lines of force of each field are collected immediately between the main electrode and the opposed electrode. Suitable screens or dividers D′, D², D³ are provided to maintain and preserve the separation of successively selected ingredients of the material M by the successive action of the electrodes E′, E², E³, E⁴. If the proportions of the apparatus are such that the electrodes E′, E², etc. have to be placed in comparatively close proximity to each other, the screens D′, D² etc., may be made of metal and electrically connected with the electrode E, so as to act as electrical screens to prevent interference of one local field with another.

The exciting apparatus peculiar to each of the electrodes (with the exception in the specific instance here shown of the electrode E⁴) is the same in substance as that shown and described in the Pickard patent No. 796,012. The exciting devices for the several electrodes are arranged in parallel between the lead wires 1 and 2 of the common generator G which is conventionally shown herein as an alternating current generator. The primary coils P′, P², P³, P⁴ are arranged in parallel, and the secondary transformer coils S′, S², S³, S⁴ have their terminals 3 connected with the main electrode E, and their terminals 4 connected through the modifying apparatus with the electrodes E′, E², E³, E⁴, respectively. A full description of the exciting apparatus intimately associated with the electrodes E on the one hand and E′, E², E³, E⁴ on the other will be found in the Wynne and Pickard patents above mentioned, and I will, therefore, merely enumerate the parts without extended explanation. r', r^2, r^3, r^4 are resistances in the secondary circuit interposed for the purpose of damping or suppressing oscillatory effects which might be produced by reason of the coaction of the capacities of the condensers K′, K², K³ and the inductances represented by the secondary coils S′, S², S³. I′, I², I³ are the spark gaps which close the secondary circuit when the potential therein reaches a point at or near the crests of the potential waves which, as hereinabove stated, should be all characterized by the same sign. R′, R², R³ are non-inductive resistances interposed to short-circuit the electrode E on the one hand and electrodes E′, E², E³ on the other. I have indicated the provision of means for adjusting the total resistance of the resistances R′, R², R³ in the shape of movable contact points C′, C², C³.

By varying or adjusting the ohmic resistance of the non-inductive resistances R′, R², R³, the duration of the potential accession and field produced thereby at the electrodes can be regulated, the higher the short-circuiting resistance the longer will the electrostatic field at the electrodes be maintained. x conventionally indicates a rectifier. Thus referring to Figs. 3, 4, 5 and 6, Fig. 3, represents with substantial fidelity the curve of potential accession at the electrodes when the short-circuiting resistances as R′ are comparatively low. Fig. 4 represents the curve say for the electrodes E, E², the resistance R² being greater than that of R′, and Fig. 5 illustrates the still further protraction of charge at the electrodes due to a still further increase in the ohmic resistance in, say, the resistance R³. I have shown in Fig. 2 the electrode E⁴ as connected directly to the secondary S⁴ without any intermediate apparatus. This mode of connection will create a field at the electrode E⁴ whereof the variations in potential are fairly represented by the curve shown in Fig. 6, and such a condition, when the potentials employed are high, is, in substance and effect, the same as would be characteristic of a continuous application of potential without variation in sign.

Let us suppose that the material M contains valuable ingredients a, b and c and a miscellaneous gangue d, and that, according to the definition of the term set forth and explained in the patent to Philip Henry Wynne above mentioned, these several substances differ one from another in conductivity, material a having the highest conductivity and materials b, c and d inferior conductivities in gradation. In order to charge and repel particles of material a, an accession of potential of the utmost brevity is sufficient. Accessions of a duration sufficient to repel from the electrode E the particles of material a will be too brief to effect the repulsion of particles belonging to classes b, c or d, while these latter classes of material are attracted to the electrode E by means of the local charges deposited thereon by the ionized gaseous jet. Consequently, as they pass between the electrodes E and E′, the particles of material a will be affected by and respond to potential accessions such as are represented by the very sharp wave form of Fig. 3, and will leave the large electrode E, fall upon the screen or divider D′ and be collected in a suitable receptacle. The effect of the recurrent brief potential accessions at the electrode E′ is not only to repel the particles which under the time-conditions of charge there maintained are perfect conductors, but also to cause the coherence of the other particles to the electrode E in the manner which I have explained hereinabove, that is to say, the jets of ionized air localized in the field between the electrodes E and E′ cause local charges to lodge, so to speak, on the portions of the inferior conductors which are remote from and not in contact with the surface of the electrode E. As these particles are carried by the electrode E, classes b, c and d, mingled together arrive at the field generated between the electrodes E and E². The potential of this field is characterized by accessions of longer duration than those of the field at the electrode E′ such, for instance, as represented by the curve in Fig. 4, and potential accessions of this duration are adjusted so that they are sufficiently protracted to cause particles of class b to become charged similarly to the electrode E, and be repelled, the local charges due to the ionized gaseous jet being overcome by the opposed potential of the electrode E, and the particles of this class are collected by the screen or divider D². The material now consisting only of classes c and d, continues clinging to the electrode E until electrode E³ is reached when the longer enduring potential accessions, as represented by the curve of Fig. 5, charge the particles of class c by conductive contact with the electrode E and cause them to be repelled from the electrode E. When the residuum material d reaches the electrode E⁴ it is desirable to clean the electrode as thoroughly as possible of all adhering material, and this is done by applying a substantially continuous charge to the electrode E⁴ which by reason of the high potential employed charges all of the particles similarly to the electrode E, and as it were, strips them from the electrode by repulsion. There will be, however, a very fine dust in some instances which is not removed by the cleansing action of the protracted field between the electrode E and electrode E^4. This, however, yields to the action of the mechanical brush of felt scraper B and such fine particles as d' are to all practical intents and purposes thoroughly removed by the action of such a brush. At all events the final residue of fine particles d' may be made so insignificant that its absolutely complete removal is a matter of indifference.

Fig. 7 is a conventional illustration on a large scale of the combined and coöperative action of the Wynne principle of auto-repulsion by brief potential accessions and of the underlying principle of my method of local charges deposited by the conveyance of ions upon the exposed surfaces of inferior conductors. In this figure I have illustrated those particles which are, under the conditions imposed, sufficiently good conductors to receive a charge from the electrode E by reason of their effective conductive contact therewith, by circles and those particles which under these conditions behave as non-conductors, by squares, and have shown these alternately arranged upon the surface of the electrode E. As the effect of the glass envelop around the electrode E′ is to concentrate the field as though the wire E′ were at the dotted line position marked E′, the field is localized between the virtual position of the electrode E′ and the electrode E, and is so concentrated that at all other regions upon the electrode E substantially no charge resides. As the conductors and non-conductors pass in succession into this concentrated field, the conductors represented by the circles respond to the dominant influence of the electrode E and receive its charge by immediate conduction, and, as explained in the Wynne patent aforesaid, become electrically one with the electrode E, and as they are mechanically separate from that electrode, are immediately repelled from its surface. The degree of concentration of field is susceptible of wide variations to meet changing conditions of practice. The inferior conductors on the other hand are slow to receive a charge by conduction from the electrode E so that the ions conveyed by the gaseous jet in the field are, as it were, deposited upon the surfaces of the non-conducting particles which face toward the electrode E′. In Fig. 7 I have indicated this locally deposited charge by a spot or coating on the outer faces of the square particles. If for illustration, we assume that the electrode E carries a positive and the electrode E′ a negative charge, these locally deposited charges on the poorly-conducting particles will be negative, and therefore, whether they rest for the time being upon a positively charged area of the electrode E, or pass out of the field, so that they rest upon a substantially neutral surface, the potential of these poorly-conducting particles is different from that of the surface on which they rest, and consequently they cling thereto; their adherence is pronounced and their contact intimate because in practice the particles themselves are very small and the linear distance between the locally resident negative charge and the surface of the electrode E is very small, resulting in an instant and effective attraction.

In Fig. 8 there is illustrated on a large scale similarly to Fig. 7 that phase of my improved process which is manifest at the field produced by the electrode E^4 in Fig. 2. Here, assuming that all of the particles which can be selected for repulsion by the operation of the principle of the Wynne process, have been removed from the electrode, only the poorest conductors are conveyed into the field between the electrode E^4 and the electrode E. Here the duration of the potential accessions is protracted so that to all intents and purposes it is continuous, and the particles, which have theretofore behaved as though absolutely non-conductors, are subjected to the field for a long enough time to enable the charge on the electrode E to be communicated by conduction to the particles. When these particles have become enveloped, so to speak, by the charge peculiar to the electrode E, the locally deposited charges on the particles themselves which have caused them to cling to the electrode E are neutralized and then the particles are repelled from the electrode just as the superior conductors were repelled while passing through the fields produced by the earlier electrodes in the series. I have illustrated the square particles whose low conductivity has been dominated by the protraction of the potential to which they are subjected as square particles surrounded by circles. Assuming that the electrode E carries a plus charge and the electrode E^4 a minus charge, the poorly conductive particles shown as square come into the field with a locally deposited negative charge on their outer faces and though the stream or jet of ionized gas in the concentrated field tends to maintain or increase the localized charge, the intimate contact between these particles and the electrode E enables the protracted charge upon the latter to overcome the feebler influence of the ionized gaseous jet and to bring each one of the particles to a condition of positive charge, and the instant this is accomplished the positively charged particle leaves the electrode E. I have shown some of the square particles as completely enveloped by a circle and other particles carrying a local negative charge on one side and the growing positive charge on the opposite side, thereby illustrating the progressive over-balance of the negative ions by positive ions.

What I claim and desire to secure by Letters Patent is:

1. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, and thereafter separately collecting the diverse components.

2. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, and thereafter separately collecting the diverse components.

3. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential, there subjecting the mixture to an intermittent ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received

from the jet, leaving the inferior conductors locally charged, and thereafter separately collecting the diverse components.

4. The process of separating the components of mixed solid material which consists in placing the mixture on a conductive electrode, there subjecting the mixture to an ionized gaseous jet from an opposed electrode, depriving the superior conductors of the charge received from the jet by conductive contact with the conductive electrode, leaving the inferior conductors locally charged, and thereafter causing the superior conductors to leave the conductive electrode.

5. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors.

6. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors.

7. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential, there subjecting the mixture to an intermittent ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors.

8. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

9. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

10. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential, there subjecting the mixture to an intermittent ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

11. The process of separating the components of mixed solid material which consists in placing the mixture on a conductive electrode, there subjecting the mixture to an ionized gaseous jet from an opposed electrode, depriving the superior conductors of the charge received from the jet by conductive contact with the conductive electrode, leaving the inferior conductors locally charged, thereafter causing the superior conductors to leave the conductive electrode, and finally correcting the local charge of the inferior conductors by subjecting them to the influence of an electrostatic field.

12. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and finally subjecting the inferior conductors to the influence of an electrostatic field for a time sufficient to charge them fully.

13. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and finally subjecting the inferior conductors to the influence of an electrostatic field for a time sufficient to charge them fully.

14. The process of differentiating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential, there subjecting the mixture to an intermittent ionized gaseous jet, meanwhile depriving the superior conductors in the mixture of the charge received from the jet, leaving the inferior conductors locally charged, then removing the superior conductors from the locally charged inferior conductors, and finally subjecting the inferior conductors to the influence of an electrostatic field for a time sufficient to charge them fully.

15. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the material to an ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet.

16. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential-accessions separated by intervals of substantially no potential, there subjecting the material to an ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet.

17. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet.

18. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential there subjecting the mixture to an intermittent ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet.

19. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to

an ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

20. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential-accessions separated by intervals of substantially no potential, there subjecting the material to an ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

21. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field, there subjecting the mixture to an ionized gaseous jet for a time insufficient to more than locally charge inferior conductors, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

22. The process of separating the components of mixed solid material which consists in introducing the mixture to an electrostatic field characterized by brief potential accessions separated by intervals of substantially no potential, there subjecting the mixture to an intermittent ionized gaseous jet, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet, and thereafter correcting the local charge of the inferior conductors by subjecting them to the influence of a second electrostatic field.

23. The process of separating the components of mixed solid material which consists in placing the material on a conductive electrode, there subjecting the material to an ionized gaseous jet from an opposed electrode, conducting a repelling charge to the superior conductors in the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixtures, leaving the inferior conductors locally charged by the jet, and finally correcting the local charge of the inferior conductors by subjecting them to the influence of an electrostatic field.

24. The process of separating the components of mixed solid material, which consists in introducing the mixture to an electrostatic field, there subjecting the material to an ionized gaseous jet, conducting a repelling charge to the superior conductors of the mixture, thereby overcoming the charge received from the jet and removing the superior conductors from the mixture, leaving the inferior conductors locally charged by the jet, and finally subjecting the inferior conductors to the influence of an electrostatic field for a time sufficient to charge them fully by direct conduction.

Signed by me at Boston, Suffolk county, Massachusetts this seventeenth day of December 1906.

HENRY AZOR WENTWORTH.

Witnesses:
ODIN ROBERTS,
JOSEPH T. BRENNAN.