No. 796,011.

PATENTED AUG. 1, 1905.

G. W. PICKARD.

APPARATUS FOR ELECTROSTATIC SEPARATION.

APPLICATION FILED AUG. 2, 1904.

3 SHEETS—SHEET 1.

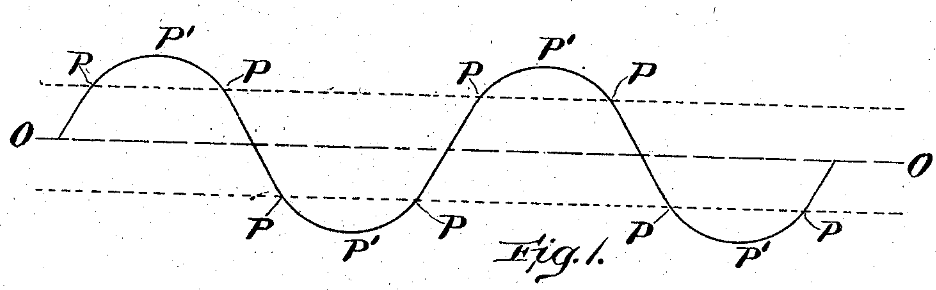


Fig. 1.

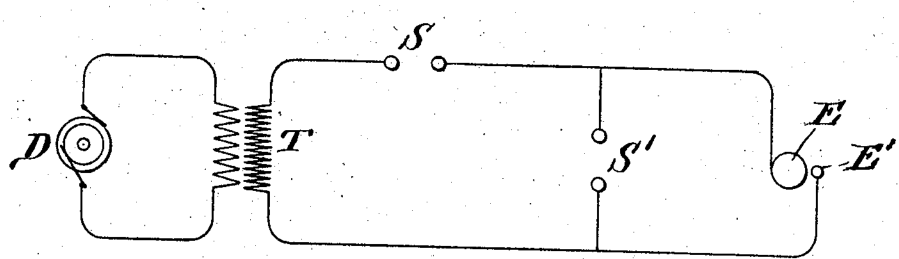


Fig. 2.

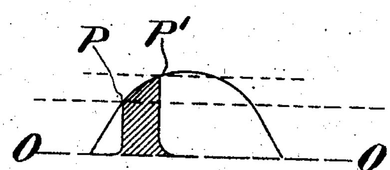


Fig. 3.

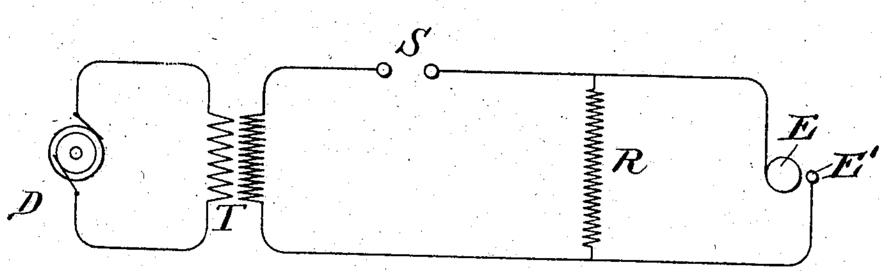


Fig. 4.

Witnesses:
H. Planifot [signature]
F. M. Seymour

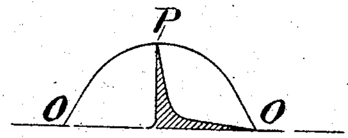


Fig. 5.

Inventor:
G. W. Pickard
by A. Stetson
Attorney

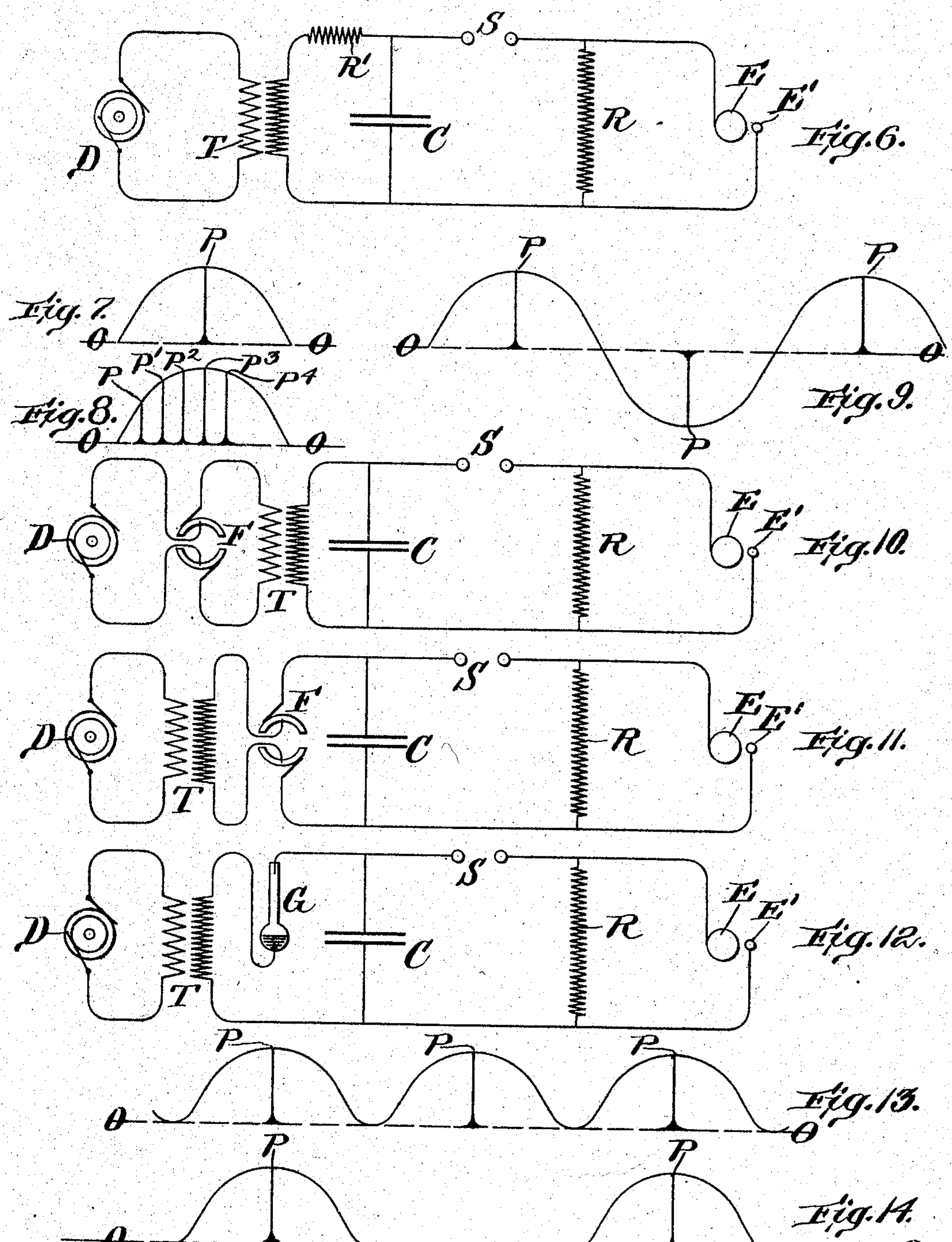
No. 796,011. PATENTED AUG. 1, 1905.

G. W. PICKARD.

APPARATUS FOR ELECTROSTATIC SEPARATION.

APPLICATION FILED AUG. 2, 1904.

3 SHEETS—SHEET 2.



Witnesses:
A. H. Frankfort
F. M. Seymour

Inventor:
G. W. Pickard
by A. Steuart
Attorney.

ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D.C.

No. 796,011. PATENTED AUG. 1, 1905.

G. W. PICKARD.

APPARATUS FOR ELECTROSTATIC SEPARATION.

APPLICATION FILED AUG. 2, 1904.

3 SHEETS—SHEET 3.

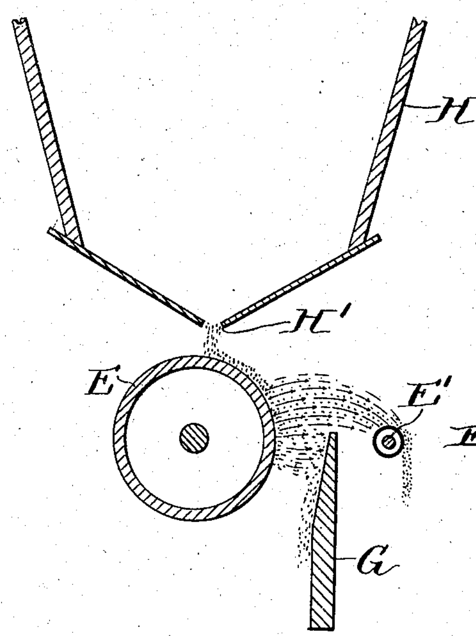


Fig. 15.

Witnesses:
Hvan Oldenneel
D N Hurlbut

Inventor:
G. W. Pickard
by Albert Stetens
Attorney

ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

GREENLEAF WHITTIER PICKARD, OF AMESBURY, MASSACHUSETTS, ASSIGNOR TO CHARLES HENRY HUFF, OF BROCKTON, MASSACHUSETTS.

APPARATUS FOR ELECTROSTATIC SEPARATION.

No. 796,011. Specification of Letters Patent. Patented Aug. 1, 1905.

Application filed August 2, 1904. Serial No. 219,242.

To all whom it may concern:

Be it known that I, GREENLEAF WHITTIER PICKARD, a citizen of the United States, residing at Amesbury, in the county of Essex and State of Massachusetts, have invented new and useful Improvements in Apparatus for Electrostatic Separation, of which the following is a specification.

My invention relates to the art of electrostatic separation or concentration, as of metallic ores, from the comparatively valueless earths or rocks wherewith they are mingled; and it consists of the combination with electrodes and associated apparatus adapted to electrostatic separation of mixed materials of electrical apparatus whereof the effect, as I have discovered, greatly enhances the separative efficiency of the electrodes.

Otherwise viewed, my invention has for its object the regulation, both as to potential and duration of charge, of the electric energy applied to and at or between a pair of electrodes, so that the charge of the electrode may be adapted to varying requirements, such as are met with, for instance, in the great diversity of materials and conditions of electrostatic separation.

A typical example of electrostatic separation apparatus is described in United States Letters Patent to C. E. Dolbear, No. 685,508. The elementary components of such an apparatus are, first, electrodes for developing and properly concentrating a static field; second, means for supplying to one or both of said electrodes the mass of comminuted mixed material destined to be separated, and, third, means for separately collecting the separated components of the material after they have been subjected to the differentiating influence of the electrode-field. As these component parts of an electrostatic separator are fully and sufficiently described in the said Dolbear patent, I will content myself, for the purposes of the following description of my invention, to reference to the said patent without showing and describing at large herein such an apparatus. For the sake of simplicity I show in the drawings hereto annexed only a conventional representation of a pair of electrodes and wish this representation to be understood to imply all the essential elements of an electrostatic separator typified by the aforesaid Dolbear apparatus.

It has been discovered by Philip Henry Wynne that electrostatic separation or concentration (the terms may be used interchangeably) is more effectively carried on by employing a potential at the electrodes or in the working electrostatic field, which varies rapidly and emphatically, as contrasted with a steady potential, or one which is maintained as uniform as is practicable under working conditions. For some purposes and for some classes of material excellently economical separation can be obtained by employing as the immediate source of electrical energy a high-frequency, alternating-current dynamo with a suitable transformer to bring the maximum potential of the static field up to an effective pressure; but the progressive rise and fall of potential which characterizes such a cycle is by no means suited to the great majority of conditions if maximum efficiency of separation is to be secured. During the potential phases or such portions of them as actually accomplish the separation of particles at the electrodes there is a protraction of the static charge, which brings about or is liable to bring about undesirable effects whereof the exact nature is not wholly clear, but whereof the consequences, practically considered, are felt in imperfect or inadequate separation of differentiated particles of matter. Whatever may be the immediate causes of this imperfect performance, it is at least certain that they proceed from protraction of the electrostatic charge, which has time to communicate itself to particles in the mass under treatment which it is not desired at the particular stage in question to have responsively subjected to the electrostatic influence.

In the drawings hereto annexed, Figure 1 represents diagrammatically a normal characteristic phase curve of potential variation. Fig. 2 shows diagrammatically an apparatus for regulating the time duration of charge at the electrodes of a separator. Fig. 3 shows diagrammatically the curve of potential variation produced at the electrodes by the apparatus of Fig. 2. Fig. 4 represents another form of apparatus for regulating the time element of charge at separator-electrodes Fig. 5 represents diagrammatically the general character of potential curve at the electrodes produced by the apparatus shown in Fig. 4. Fig. 6 shows diagrammatically a preferred modification of the apparatus shown in Fig. 4. Fig. 7 illustrates the curve of potential variation at the electrodes produced when the apparatus of Fig. 6 is used. Fig. 8 shows another curve of potential variation of the electrodes, which can be obtained by a different adjustment of the apparatus of Fig. 6. Fig. 9 shows the curve of potential variation at the electrodes produced by the employment of the apparatus of Fig. 6. Figs. 10 and 11 show still further modifications of the apparatus containing a commutator to determine the sign of potential effectuated at the electrodes. Fig. 12 shows an alternative construction employing a rectifier. Figs. 13 and 14 show the curves of potential variation at the electrodes produced when the apparatus of Figs 10, 11, and 12 are employed. Fig. 15 illustrates an arrangement of electrical separator-electrodes and immediately associated apparatus, such as may be employed satisfactorily with the electrical devices shown and described in this specification.

The conditions referred to will more clearly be understood by reference to Fig. 1 of the drawings hereto annexed, wherein O O represent the zero-line of potential and the curve the line representing the phase cycle of potential at the electrodes. At some point—say P—whether on the positive or negative side of the zero-line, the electrode-potential reaches an intensity sufficient to separate a selected portion of the material under treatment. During that portion of the phase represented by P P′ P the electrodes thus possess a separating charge, and it is obvious that under given conditions of material maximum potential P′ and minimum separating-potential P the separating charge will last in time during half, or even more than half, of the complete cycle, and while, as I have stated, for some materials and under some conditions this characteristic potential phase may work tolerably or even properly there are many instances which render this condition undesirable for practical purposes.

Whatever changes may be imposed upon the potential phase at the electrodes, it is essential, of course, that at least a working minimum pressure be always available; and the object which I attain by my invention and improvements is to regulate and reduce the time element in the potential phase as it is effectuated at the electrodes, while retaining all the values of high potential for separating purposes.

Speaking with reference to the curve which graphically represents the phase cycle produced by a high-frequency alternating-current dynamo, my invention has the result of cutting out from the separator-electrodes more or less of the potential-ordinates at will, leaving only such portion of the crest of the cycle wave as may be found desirable for any stated conditions of material, &c. With reference to the working electrodes or field useful for electrostatic separation of solid material my invention is characterized by means for producing a suddenly-applied and suddenly-released potential at the electrodes. In Fig. 2 is exhibited diagrammatically an apparatus for accomplishing this result. D represents a dynamo of the high-frequency alternating-current class. T is a transformer—the primary in the dynamo-circuit, the secondary in the electrode-circuit. E E′ represent two electrodes conventionally represented, separated from each other by a suitable air-space. These electrodes may be considered, for illustrative purposes, to be such as are suitable for electrostatic separation, though the details of apparatus usually associated therewith need not be shown. One electrode, as E′, is wired or otherwise made one electrically with the secondary of transformer T. The other electrode, as E, is normally sundered from the transformer-coil by the interposition of a spark-gap S. Another spark S′ has its terminals connected with E and E′, respectively, and is in shunt with the electrode. Assume the spark-gaps S and S′ to be adjusted so that their breaking-potentials are P and P′, respectively, P′ being greater than P. As the transformer pressure curve rises and approaches potential P the electrodes E E′ are unaffected thereby, the circuit being open at S; but when potential P is reached the spark-gap S breaks and closes the electrode-circuit, creating a potential difference equal to P at the opposed electrode-surfaces. Still in the progress of the phase produced in the transformer the potential rises until it reaches P′, where spark-gap S′ breaks and cuts out the electrodes, whose potential drops back almost instantaneously to zero. This performance is illustrated by Fig. 3, wherein a phase curve is represented by O P P′ O. If the electrodes E E′ were connected electrically at all times with the transformer, this potential phase would correspond with this full curve; but, as we have seen, until the phase curve reached potential P the electrodes were isolated, and that when potential P was reached the electrode connections were suddenly closed and the charge applied; and, further, that when potential P′ was reached the electrodes were again cut out and potential suddenly withdrawn. The shaded portion of the curve in Fig. 3 illustrates the condition at the electrodes. It now becomes obvious that when it is desired to shorten the period of potential application to the electrodes this may be accomplished by adjusting the spark-gaps S and S′, Fig. 2, so that they have very nearly the same breaking-potentials, or even so that the spark-gap S shall have a higher breaking-potential than S′.

While with delicate handling an apparatus constructed as shown in Fig. 2 will yield good results and enables the operator to control the time period of electrode charge, nevertheless as spark-gaps are unreliable contrivances in the matter of nice adjustment I prefer to accomplish my desired result with a different arrangement. (Shown in one form, though not, I believe, its best form, in Fig. 4.)

As before, Fig. 2, we have the transformer T, and electrodes E E′, normally isolated by a spark-gap S. Here, however, I insert a non-inductive resistance—say a carbon rod—at R, in shunt with the electrodes E E′. Assuming a minimum applied potential P, the spark-gap S is adjusted so as to have a corresponding breaking-potential. The inaccuracy of spark-gap adjustment does not enter as an appreciable factor, because having determined upon a minimum applied potential for the electrodes—say sixty thousand volts—an error of a few hundred volts in the spark-gap adjustment will make practically no difference to the separating efficiency of the electrodes. When the transformer phase rises to potential P, the spark-gap closes and the electrodes E E′ are charged; but straightway the resistance R cuts out the electrodes more or less rapidly, according to its adjusted resistance, and the electrodes are left inert until the rise of potential in the next phase, or rather half phase.

With an arrangement such as shown in Fig. 4 the release of potential at the electrodes is not so sudden as its application. The capacity of the transformer-coil here has its effect and the potential is let down through the resistance R through a curve, which while far more abrupt, especially in its initial phase, than the normal transformer-phase curve, is nevertheless relatively gradual as compared with the rise of potential at the electrodes.

The general character of the potential curve at the electrodes is illustrated in Fig. 5, wherein O P O is the normal transformer-phase curve and the included shaded portion the electrode-potential curve. In order to eliminate even this delayed restoration of electrode-potential to zero, I employ the following arrangement, which I believe is typical of the best form in which my invention may be embodied. In Fig. 6 there is shown diagrammatically this typical form of apparatus. The transformer T is, as before, the source of electrical energy; E E′ represent the electrodes; S, the spark-gap, and R the non-inductive resistance, substantially as shown in Fig. 4; but between the transformer-coil and the electrode-circuits I interpose a condenser C, connected across in parallel with the resistance R and electrodes E E′. With this arrangement the condenser C becomes to all practical intents the source of potential for the electrodes, and the transformer T is cut of all immediate influence over the electrodes. A resistance R′ is interposed between the transformer and the condenser C to damp and prevent the occurrence of oscillating disturbances in the circuit-inclosing transformer T and condenser C. As the potential phase created by the transformer rises to potential P, at which the spark-gap S is set to break, the condenser is charged, the electrodes remaining unaffected. When potential P is reached, the spark-gap S breaks, the electrodes E E′ are excited, and the function of the resistance R follows in the series of occurrences, cutting out the electrodes; but the condenser C is, unlike the transformer-coil, susceptible of almost instantaneous discharge, and the potential at the electrodes drops to zero without any appreciable detention.

Referring to Fig. 7, the contrast between the phase curve O P O at the transformer and the sharp rise and fall from zero to P and back again at the electrode is graphically represented.

I believe it to be preferable to restrict the application of potential at the electrodes to a single momentary excitation, as illustrated in the foregoing figures of the drawings. If, however, a situation should develop which required a more rapid succession of isolated excitations than the recurrent phase cycle of the source of potential can administer, the apparatus—such as, for instance, that shown in Fig. 6—can be adjusted to deliver this result. Assuming that the source of potential is characterized by a definite phase, if the spark-gap be adjusted to break at a potential considerably below the maximum of the phase the electrode will be excited, and thus discharged, as before described, while the potential phase is still increasing. Then as the phase curve is still rising above the breaking-potential the spark-gap will close the electrode-circuit a second time and afterward even a third time, if the apparatus be properly adjusted. By this means the electrode excitations will be made to occur in closely-successive impulses grouped according to the adjustment of spark-gap, resistance to recharge, and discharging resistance.

In Fig. 8 there is illustrated graphically such a condition as just described. The spark gap being adjusted to break at potential P, the electrode impulses begin while the potential phase is on the increase and recur at P' P^2 P^3 P^4. This condition is one which probably will not be found desirable for most cases of electrostatic separation; but it may be secured if required for special purposes.

I have shown for purposes of illustration a source of potential having a rapidly-alternating phase, such as proceeds from a high-frequency alternating-current dynamo. With such a source of potential the apparatus described will excite the electrodes, alternating positively and negatively, according to a phase curve somewhat as shown in Fig. 9.

Practically I believe that the arrangement above described in connection with a high-frequency alternating-current dynamo is the best available apparatus for the general purposes indicated. My invention may, however, include other forms of electrical generators. An influence-machine or a storage battery may be employed and the potential derived immediately therefrom be maintained as nearly constant or uniform in phase, if the expression may be used, as possible. The spark-gap control over the electrode will thus assert itself, and the recurrent excitations succeed each other as rapidly as the potential can be restored by the machine or battery.

If it be desired to have the electrode excitations characterized by potential all of one sign, various devices may be employed to secure this result. A commutator in synchronous relation with the dynamo may be inserted either in the primary or secondary circuit of the transformer, or a rectifier may be introduced between the transformer and the condenser of Fig. 6.

In Figs. 10 and 11 the commutator F is shown conventionally in the primary of transformer T in Fig. 10 and in the secondary in Fig. 11. In Fig. 12 a rectifier G is shown as introduced in the circuit of the secondary of transformer T, its office being to oppose effective resistance to impulses in one direction while offering easy passage to those in the other. The phases of potential at the condenser C produced by the arrangements of either Fig. 10 or Fig. 11 and their modification at the electrodes E E′ are illustrated by Fig. 13. All the excitations at the electrodes are thus made of one sign, + or −, as desired. The conditions peculiar to the arrangement of Fig. 12, wherein the rectifier is employed, may be represented as in Fig. 14.

It has been discovered that certain problems in electrostatic separation are better solved by potential excitations all of one sign, sometimes positive and sometimes negative, so that the employment of commutators or rectifiers has its practical value.

The electrodes which form the active instruments of the separator are shown conventionally in the Figs. 1 to 14, inclusive. While my electrical devices may be combined with various forms and arrangements of electrodes, I prefer a form such as shown in Fig. 15 in cross-section, wherein H is a hopper, H′ its slot, wherethrough comminuted material descends to the electrode E. E is a cylinder having a metallic surface, and E′ a copper wire inclosed in a glass tube. G is a partition, preferably of dielectric material, which serves to divide the separated portions of the material acted on by the electrode-field. The two electrodes are electrically connected, as shown in the other figures of the drawings.

It should be borne in mind that the phase-diagrams used for illustration do not pretend to represent with perfect fidelity any actually-produced wave form, but that they are employed to show a simple form of wave, which will be approached more or less nearly in actual practice. Whatever be the precise form of phase curve, my invention will be found applicable to the situation.

In the practice of electrostatic separation my invention places at the service of the operator electrode impulses or excitations which are reduced to infinitesimal time intervals. If, for instance, the potential be derived from an alternating-current dynamo having a frequency of fifty per second, the electrode excitations can be reduced by my invention to two or three millionths of a second, so that the electrodes are unexcited and inert during all of the time except this minute fraction. All the disturbances which result from prolongation of electrode excitation and which require time to develop are eliminated, and very nearly perfect separation of materials results.

I claim—

1. The combination with the elementary components of an electrostatic separator, of a source of potential having a normal characteristic phase curve, and means to exclude from the electrodes of the separator all of the potential created by the source except a selected portion thereof represented by an area which is only an included fraction of the normal phase-curve area.

2. The combination with the elementary components of an electrostatic separator of a source of potential having a normal characteristic phase curve, and means to exclude from the electrodes of the separator all of the potential created by the source except a selected portion thereof represented by an area included between intermediate ordinates of the phase curve.

3. The combination with the elementary components of an electrostatic separator of a source of potential having a normal characteristic phase curve, means to exclude from the electrodes of the separator the potential at the initial and final stages of the phase cycle, and means to expose the said electrodes to a portion of the potential duration represented by a part of the phase-curve area included between two of its intermediate ordinates.

4. The combination with the elementary components of an electrostatic separator of a source of potential, a spark-gap normally insulating the separator-electrodes from the source, the spark-gap to connect the said electrodes momentarily with the source of potential.

5. In an apparatu . ıor exciting static elec-

trodes, a source of potential, electrodes normally insulated from the source by a spark-gap, the spark-gap, to connect the electrodes momentarily with the source of potential and a shunt, to deplete the electrode-potential after its establishment by the spark-gap.

6. In an apparatus for exciting static electrodes, a source of potential, electrodes normally insulated from the source by a spark-gap, the spark-gap, to connect the electrodes momentarily with the source, and a non-inductive resistance shunting the electrodes to deplete the electrode-potential after its establishment by the spark-gap.

7. In an apparatus for exciting static electrodes, a source of potential, consisting of a condenser, electrodes normally insulated from the condenser by a spark-gap, the spark-gap, to connect the electrodes momentarily with the condenser, and a resistance, to discharge the electrodes and condenser after the establishment of said connections.

8. In an apparatus for exciting static electrodes, a source of alternating potential, electrodes normally insulated from the source by a spark-gap, the spark-gap to connect the electrodes momentarily with the condenser, a shunt to deplete the electrode-potential after its establishment by the spark-gap, and means for rectifying one of the alternate phases of potential.

9. The combination with the elementary components of an electrostatic separator, of a source of potential, a spark-gap normally insulating the separator-electrodes from the source, to connect the said electrodes momentarily with the source of potential, and means for deënergizing the electrodes after the circuit-closure by the spark-gap.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

GREENLEAF WHITTIER PICKARD.

Witnesses:

A. H. Frumfurt,

A. Stetson.