L. W. CHUBB.

METHOD OF AND APPARATUS FOR PRODUCING ASYMMETRIC POTENTIAL WAVES.

APPLICATION FILED JULY 14, 1915.

1,308,041.

Patented July 1, 1919.

3 SHEETS—SHEET 1.

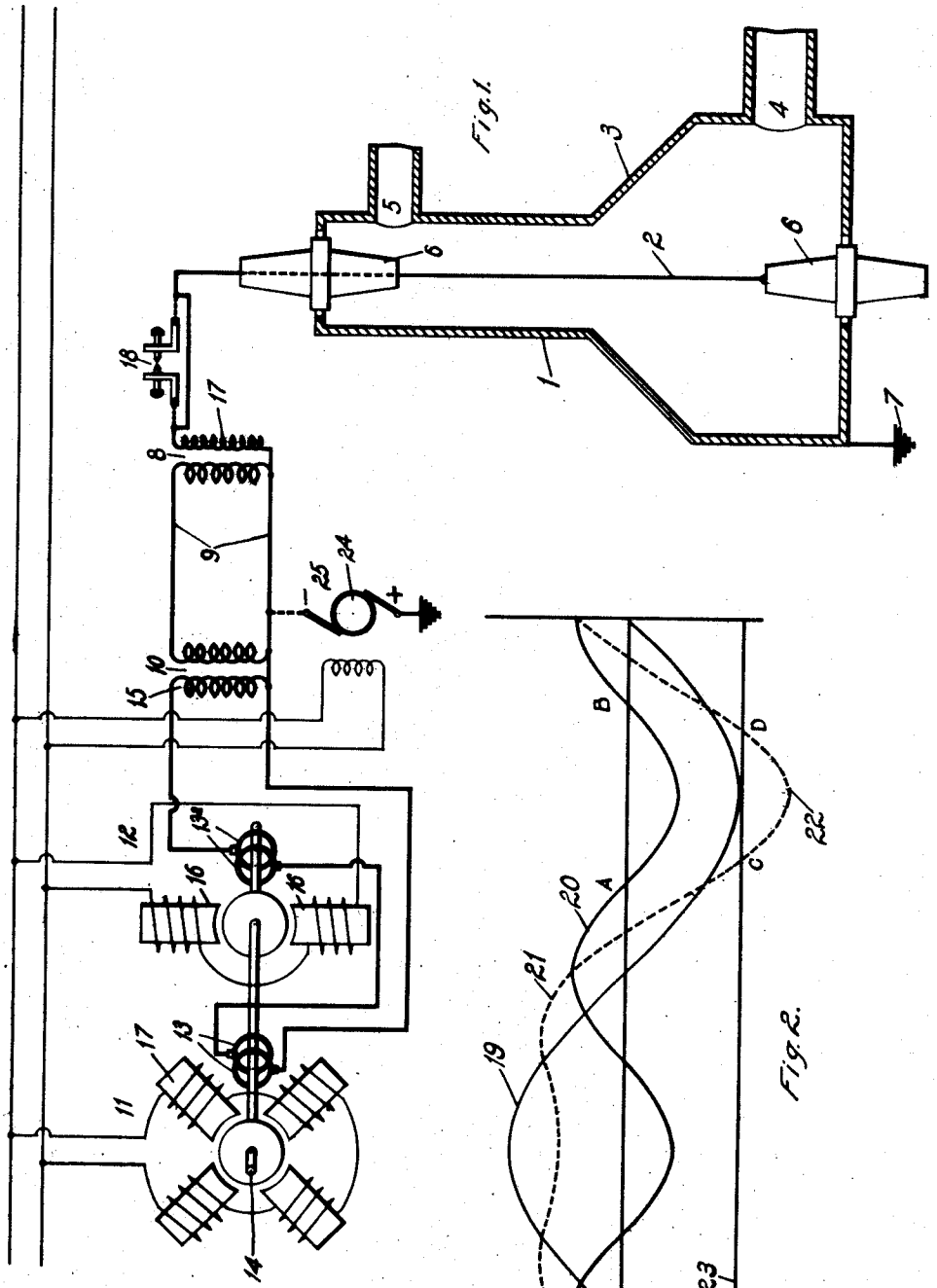


Fig. 2.

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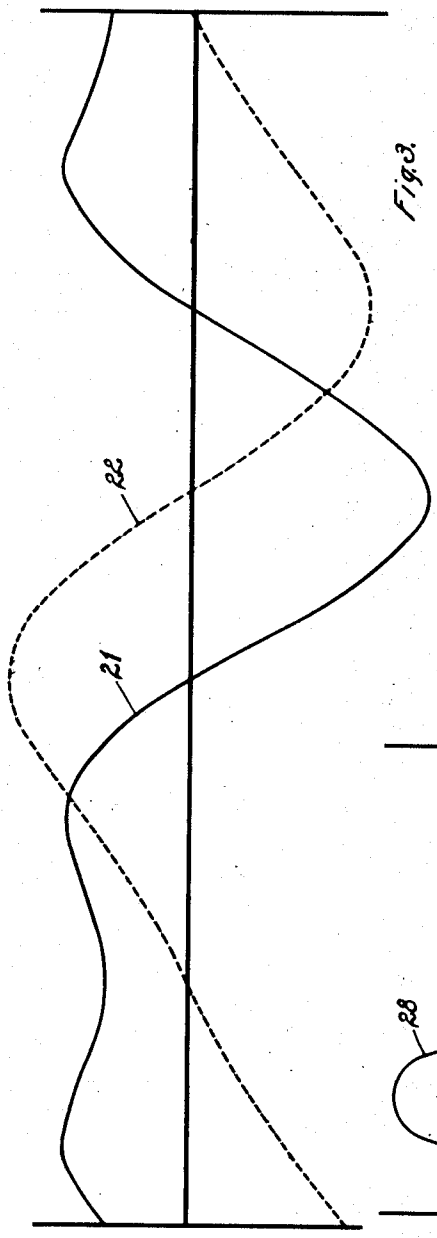


Fig. 3.

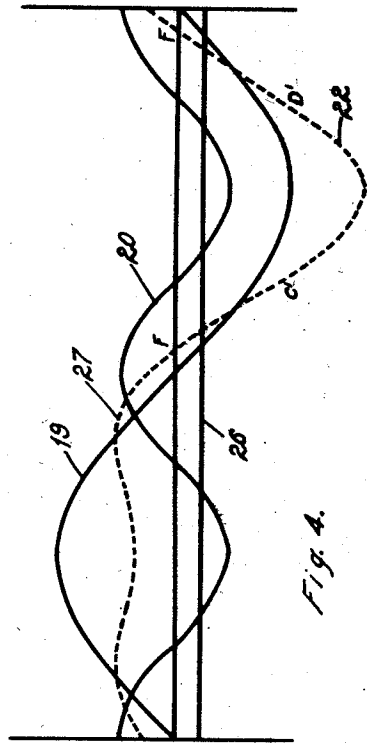


Fig. 4.

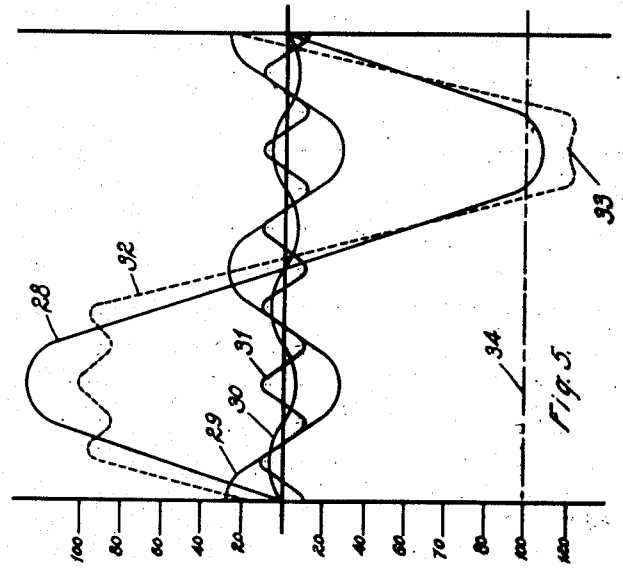


Fig. 5.

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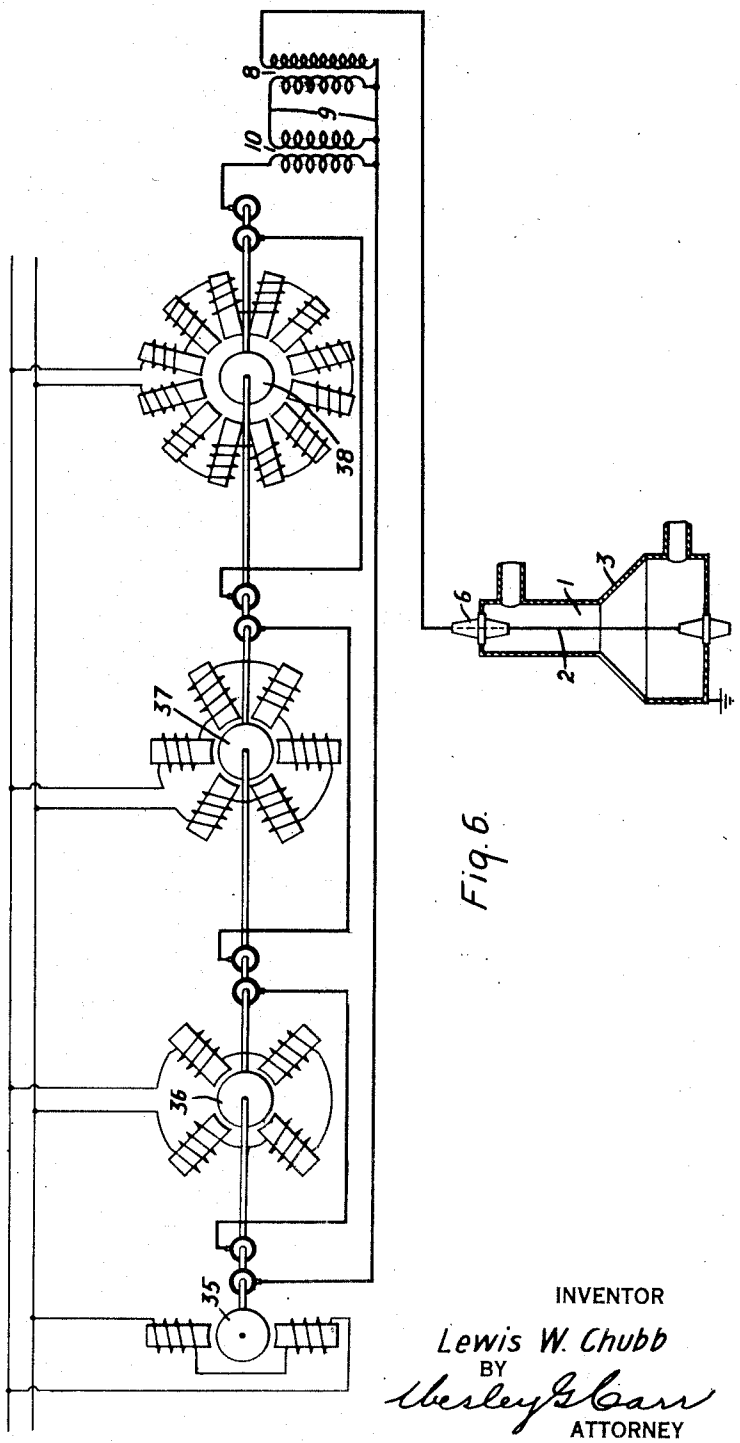


Fig. 6.

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UNITED STATES PATENT OFFICE.

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METHOD OF AND APPARATUS FOR PRODUCING ASYMMETRIC POTENTIAL WAVES.

1,308,041. Specification of Letters Patent. Patented July 1, 1919.

Application filed July 14, 1915. Serial No. 39,886.

To all whom it may concern:

Be it known that I, LEWIS W. CHUBB, a citizen of the United States, and a resident of Edgewood Park, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Methods of and Apparatus for Producing Asymmetric Potential Waves, of which the following is a specification.

My invention relates to apparatus for, and methods of, producing asymmetric wave forms to be impressed upon an electrical circuit by combining certain component wave forms which may be produced in a usual manner.

My invention refers particularly to apparatus for, and methods of, producing high-potential electrical impulses or discharges in one direction only, by employing alternating currents to generate asymmetric wave-forms made from a combination of certain component alternating-current waves having substantially characteristic sine wave-forms.

My invention is specially adapted for service conditions requiring the use of high-potential electrical discharges in one direction only, which conditions may be so severe as to substantially preclude the use, in a satisfactory manner, of commutating devices or mechanical rectifiers. One service for which my invention may be utilized relates to systems employed for causing the deposition of finely-divided particles of matter originally held in suspension in bodies of gas or vapor, by the application of electrical discharges.

Under certain conditions, it has been found that the most satisfactory results may be obtained when the body of gas or vapor from which the suspended particles are to be precipitated is subjected to silent or non-disruptive electrical discharges emanating from a discharge electrode. It is usually preferred that the discharges result by reason of the discharge electrode being impressed with a negative potential of suitable value. It is not essential that the negative discharges from the discharge electrode continue uninterruptedly, but their periods of persistence may vary, within certain limits, depending upon other conditions obtaining in the system.

For example, it may be desired to generate a non-disruptive electrical discharge or corona at the discharge electrode of a smoke precipitating apparatus, and the like, by applying a maximum potential which is of such a value as to be in excess of that which may be maintained when a positive potential is applied to said discharge electrode. Therefore, it will be appreciated that difficulty will be encountered in attempting to accomplish the aforementioned electrical results by the use of a direct-current voltage of the requisite value. Heretofore, for such service, a high-potential alternating-current transformer and a rectifier have been employed, the rectifier usually being a mechanical rectifier, the operation of which is, of necessity, quite unsatisfactory because of the difficulties involved in constructing movable electrical contacts to withstand such high voltages.

As a substitute for the above-mentioned alternating current transformer and mechanical rectifier, which are utilized to produce negative-corona discharges by applying, to the discharge surface, negative potentials of such values as are in excess of those which may be maintained when positive potentials are applied thereto, I have invented the present means of accomplishing the desired result, said means being totally devoid of all moving contacts and elements which heretofore have limited the field of application of electrical precipitating systems.

One object of my invention is to provide means whereby an electrical discharge in one direction only may be generated by combining component electrical impulses of substantially sine-wave form that may be impressed in entirety on the working or discharge circuit. None of these electrical impulses needs necessarily, of itself, to have a potential value which approximates that at which the corona discharges are generated. Moreover, no moving elements are embodied in the working circuit, thus insuring uninterrupted and satisfactory operation of the system. Again, I may vary or regulate the periods of persistence of the electrical discharges, within certain limits, and also the amounts of energy represented by the positive and negative pulses of the resultant wave form, it being understood that either positive or negative discharges or corona emanations may be expeditiously produced with my apparatus.

For a better understanding of the nature and scope of my invention, reference may be had to the following description and the accompanying drawings in which Figure 1 is a diagrammatic representation of an electrical precipitating system embodying a form of my invention; Figs. 2, 3 and 4 are diagrams illustrative of the electrical and magnetic conditions obtaining within the system shown in Fig. 1; Fig. 5 is a diagram illustrating the electrical conditions which may obtain in a modified form of the electrical system shown in Fig. 1, and Fig. 6 is a diagrammatic view showing a combination of alternators for generating the component waves of Fig. 5.

Referring to Fig. 1, the electrical precipitating apparatus or separator 1 comprises a discharge electrode 2 and a coöperating collecting electrode 3 in the form of a flue or smokestack into which the body of gas or vapor to be precipitated is introduced. The smokestack is provided with an opening 4 at its lower portion in order to admit the gases or vapors from which the suspended particles are to be removed, and is provided with an outlet 5 at its upper portion for the emission of such gases after having been subjected to the corona discharges emanating from the discharge electrode 2. It will be noted that the discharge electrode 2 is thoroughly electrically insulated from the electrode 3 by means of insulators 6, the electrode 3 being, in turn, connected to ground 7. As mentioned above, it is preferred, in this instance, that the discharge electrode 2 shall emanate negative corona or non-disruptive electrical discharges. It will be understood that the discharges from the electrode 2 need not necessarily be continuous, but good results may be obtained if such discharges are intermittent only. Under certain conditions, it may be desired to vary or regulate the periods of persistence of the corona discharges from the discharge electrode 2 and, to this end, I have invented means which will be hereinafter disclosed. Moreover, the amounts of energy represented by the positive and negative pulses of the resultant wave may be varied, as, for instance, the amount of energy represented by a negative potential pulse may be in excess of that represented by a positive potential pulse.

In order to impress the discharge electrode 2 with the desired potential impulses, it is connected through a high-potential transformer 8, a distributing circuit 9, and a second transformer 10 to the alternators 11 and 12. The alternator 11 is shown, in this particular instance, as being a four-pole machine having a pair of slip rings 13 mounted upon a shaft 14 which is common to the alternator 12. The alternator 12 is shown as a two-pole machine having slip rings 13^a, the armature windings of the alternators 11 and 12 being connected through the slip rings 13 and 13^a in series relationship and across a primary winding 15 of the transformer 10. Inasmuch as the alternators 11 and 12 have the common shaft 14, which may be rotated at a constant speed by any suitable prime mover (not shown), the potential impulses generated by the alternator 11 have twice the frequency of those generated by the alternator 12, as a result of the respective four-pole and two-pole field structures. The poles 16 of the alternator 12 are so positioned with respect to the pole pieces 17 of the alternator 11 that the maximum value of the positive pulsation generated by the alternator 12 occurs when the wave generated by the alternator 11 possesses zero value on initiating a positive pulsation. By means of the simple structure shown in Fig. 1, it being presumed that the armatures are suitably wound, as is well known in the art, it will be apparent that the alternating-current potential wave generated by the alternator 12 will be of fundamental frequency and that the alternating-current potential wave generated by the alternator 11 will be of double fundamental frequency. By reason of this cyclic variation between the alternating-current wave-forms generated by the two alternators, both wave-forms simultaneously attain their maximum negative value periodically or when the negative pulsation developed by the alternator 12 reaches its maximum negative value. It is presumed that the alternators 11 and 12 are located at a power house which may be spaced a considerable distance from the precipitator 1 and, to this end, the distributing conductors 9 are utilized in order to transmit power economically to the load point, namely, the electrical precipitator 1.

In proximity to the electrical precipitator 1, the high-potential transformer 8 is installed. a high-potential winding 17 being insulated to withstand the high-potential voltages impressed thereupon. An adjustable spark gap 18 may be inserted in circuit with the high-potential winding 17 and the discharge electrode 2 in order that the said electrode may be impressed with potential accessions of the same sign only which are not separated from one another by those of reversed potential. It will be understood, however, that the insertion of the spark gap member 18 is usually arbitrary and may or may not be desirable, depending upon other conditions.

By referring to Fig. 2, the nature of the electrical conditions obtaining in the system of Fig. 1 is illustrated. An alternating-current wave 19, of substantially characteristic sine-wave form, represents the electrical impulse imparted to the above-mentioned sys-

tem by the alternator 12, and an alternating-current wave 20 of substantially characteristic sine-wave form, but having a frequency double that of the wave 19, represents the electrical impulse imparted to the above-mentioned system by the alternator 11. Again. it will be apparent that because of the proper cyclic variation between the alternating-current waves 19 and 20 the maximum negative values of the two waves will periodically occur simultaneously. The proper cyclic variation is obtained as a consequence of the assembling of the alternators 11 and 12.

Since the alternating-current waves 19 and 20 are simultaneously impressed upon the discharge electrode 2, through the distributing circuit and transformers described in connection with Fig. 1, the resultant electrical impulse impressed upon the discharge electrode 2 may be represented by an asymmetric alternating-current wave 21 which is the resultant wave of the component waves 19 and 20. It will be readily seen that the asymmetric wave 21 has unequal positive and negative maximum potential accessions, thereby producing resultant periodic accessions of potential 22 of pronounced extent and of the same sign as indicated by the portion of the wave extending between the points A and B in the axis of abscissæ (Fig. 2). Since the potential waves 19 and 20 are of suitable value and each has one set of maximum values coincident in phase, the potential accession 22 of the wave 21 may reach a sufficiently high value to create periodic corona emanations from the discharge electrode 2. For instance, the value of potential at which corona emanations are created may be represented by a line 23 which is parallel to the X-axis of the curves of Fig. 2. The line 23 intersects the asymmetric wave 21 at points C and D, and, consequently, the potential accession 22 extending between the abscissæ C and D represents the corona discharge periodically emanating from the discharge electrode 2 during each cycle of the resultant potential impulses impressed thereupon. Again, the distance C—D represents the time of duration or the period of persistence of the corona emanation from the discharge electrode 2. From the foregoing description, it will be apparent that the potential accessions may occur on the positive side of the X-axis of Fig. 2 by proper manipulation of the component alternating-current waves 19 and 20, but, inasmuch as negative discharges from the electrode 2 are preferred in this instance, I have shown the method employed in procuring periodic accessions of potential 22 which are on the negative side of the X-axis.

The alternating-current wave 19 may be represented by the equation $A_1 \sin \theta$ and the alternating-current wave 20 may be represented by the equation $B_2 \cos 2\theta$. Therefore, the resultant wave 21 may be represented by the equation.

$$A_1 \sin \theta + B_2 \cos 2\theta,$$

it being understood that A_1 and B_2 may represent any suitable value. While the wave 21 has an unsymmetrical form, the magnetic flux traversing the core members of the transformers 8 and 10 has a symmetrical wave form, as shown in Fig. 3. Inasmuch as the equation representing the magnetic flux traversing the core members of the above-mentioned transformers is the integral of the equation of the resultant asymmetric wave 21, it may be represented by the equation—

$$A_1 \cos \theta + \frac{B_2}{2} \sin 2\theta$$

which, on being plotted, constitutes the curve 22 of Fig. 3. It will be seen that the flux curve 22 has symmetrical positive and negative amplitudes and, consequently, the exciting current for the transformers 8 and 10 is likewise symmetrical. In other words, the curve 21 may be considered as the curve of secondary electromotive force and is obviously the differential of the flux curve 22. The flux curve 22 is symmetrical about the X-axis, although the component half waves thereof are not symmetrical about any vertical axis, the disparity between the shapes of the positive and negative secondary electromotive force waves being due to the distortion of the flux wave. Thus, it will be noted in Fig. 3 that the flux wave 22 rises fairly steeply from the Y-axis, producing the first small peak in the positive half wave of the electromotive force curve 21 and that the flux wave 22 then flattens out or decreases its rate of change as it crosses the X-axis, this decrease in the rate of change decreasing the secondary induced electromotive force and producing the valley or depression in the positive wave of the curve 21. The steepness or rate of change of the curve 22 then again increases, producing the second small positive peak of the wave 21. After passing over its first crest, the flux curve 22 falls very steeply to a minimum crest value, producing the pronounced negative peak in the electromotive force wave 21. Those familiar with transformer design will appreciate the desirability of the symmetrical magnetic flux and the symmetrical magnetizing-current waves resulting from the use of my system. It will be noted that the curves in Fig. 3 are not drawn to the same scale, the curve 21 being substantially a duplicate of the curve 21 of Fig. 2.

In order to vary the time of duration of the periodic discharges from the electrode 2,

and to increase the amount of energy represented by a pulsation of one sign over that represented by a pulsation of the opposite sign, I have shown, in Fig. 1, a direct-current generator 24 connected to said discharge electrode. Since the electrode 2, in this instance, is subjected to negative-corona discharges, the negative terminal 25 of the direct-current generator 24 is connected to the high-potential winding 17 of the transformer 8 through one of the conductors 9. In this manner, the discharge electrode 2 is continuously subjected to a negative potential, the value of which is affected by the voltage of the direct-current generator 24. In addition thereto, the discharge electrode 2 is impressed with the component alternating- current waves resulting from the alternators 11 and 12.

To illustrate the electrical conditions obtaining under these circumstances, reference may be had to Fig. 4 in which the alternating-current waves 19 and 20 are illustrated as shown in Fig. 2. The negative potential of constant value impressed upon the discharge electrode 2 is represented by the curve 26 of Fig. 4, and the resultant potential wave impressed upon the electrode 2 is represented by the curve 27. It will be seen that, as a result of superimposing the negative-potential curve 26, the period of persistence C′—D′, or the time of duration of the negative accession of potential for the corona emanations, will be substantially in excess of the period of persistence C—D represented in Fig. 2. By varying the value of the negative-potential curve 26, the periods of persistence C′—D′ may be varied within limits. At the same time, the amount of electrical energy represented by the negative pulsation of the wave 27 is in excess of that represented by the positive pulsation of the wave. In this manner, the negative charges imparted to the particles to be precipitated exceed the positive charges imparted thereto.

With reference to modified forms of asymmetric potential waves which may be impressed upon the discharge electrode 2, without undue complication of the required apparatus, I have shown a modified form of an asymmetric curve in Fig. 5. A curve 28, which may be represented by the equation $C_1 \sin \theta_1$, constitutes the fundamental wave generated in the modified circuit. A curve 29, which may be represented by the equation $C_2 \cos 2\theta_1$, constitutes a component wave having a frequency double that of the wave 28. A third curve 30, which may be represented by equation $C_3 \sin 3\theta_1$, constitutes a triple-frequency impulse, or, for a matter of convenience, may be considered as a second fundamental curve of the nature of the curve 28 but having a frequency three times that of the said first fundamental curve. A fourth curve 31, which may be represented by the equation—$C_4 \cos 6\theta_1$, constitutes a component curve which has double the frequency of the curve 30 and six times the frequency of the fundamental curve 28.

A curve 32, having an asymmetric wave form, comprises the resultant curve of the curves 28, 29, 30 and 31. It will be noted that the negative-potential accession 33 of the curve 32 substantially exceeds in value that of the curve 28. If the voltage at which corona is produced upon the discharge electrode 2 is represented by the curve 34, it will be noted that the lobe or negative-potential accession 33 substantially exceeds the value of the corona voltage, and the period of persistence thereof endures a substantial time. As one means for producing the several impulses represented in Fig. 5, I employ the combination of alternators shown in Fig. 6.

An alternator 35 generates the fundamental alternating-current wave 28, an alternator 36 generates the double-frequency wave 29, an alternator 37 generates the triple-frequency wave 30 and an alternator 38 generates the sextuple-frequency wave 31. The armature windings of the several alternators are connected in series relationship so as to impress the resultant asymmetric potential wave upon the discharge electrode 2. Those familiar with the art will appreciate that the same results may be economically obtained by employing armatures having multiple windings thereupon which are subjected to the influences of several forms of pole structures. This structure is old in the art and, consequently, is not described in detail.

While I have shown only one embodiment of my invention, it will be understood that many modifications may be made without departing from the spirit and scope of the appended claims.

I claim as my invention:

1. The method of producing electrical discharges in one direction only which consists in superimposing upon a discharge circuit a plurality of relatively low-potential, alternating-current-potential impulses of substantially sine-wave form and of different frequencies which are so cyclically displaced as to produce resultant asymmetrical potential waves having periodic accessions of potential in one direction only that are in excess of the potential values at which said circuit discharges.

2. The method of producing electrical discharges in a discharge circuit which consists in superimposing upon a discharge circuit a plurality of alternating-current-potential impulses of different frequencies, each impulse independently having such value as to preclude the formation of non-disruptive electrical discharges but said impulses being

cyclically so displaced with respect to one another as to produce resultant recurrent potential impulses that are in excess of the discharge potential of said circuit.

3. The method of producing recurrent electrical discharges in one direction only in a discharge circuit, which consists in superimposing upon said circuit a plurality of alternating-current-potential impulses of substantially sine-wave form and of different frequencies, the value of each impulse independently being less than the non-disruptive discharge potential of said circuit and said impulses being so cyclically displaced as to produce resultant alternating impulses of asymmetric wave form which recurrently exceed, in one direction only, the discharge potential of said circuit.

4. The combination with a discharge electrode adapted to emanate non-disruptive electrical discharges in one direction only, of means for impressing upon said electrode a plurality of alternating-current-potential waves of different frequencies which are so cyclically displaced with respect to one another as to produce periodic accessions of potential of the same sign and in one direction only, whereby said non-disruptive discharges may be effected.

5. The combination with a discharge electrode adapted to emanate non-disruptive discharges in one direction only, of means for impressing upon said electrode alternating-current-potential waves of fundamental and double fundamental frequency, said waves being so cyclically displaced that their maximum amplitudes occur at substantially the same time but in one direction only to produce an alternating asymmetric wave having periodic accessions of potential of the same sign that are in excess of the discharge potential on said electrodes.

6. The said combination with a discharge electrode adapted to emanate non-disruptive electrical discharges in one direction only, of means for impressing upon said electrode alternating-current-potential waves of different frequencies, the value of the potential of each wave being below that conducive to said non-disruptive discharge but said waves being so cyclically displaced with respect to one another that recurrent periodic accessions of potential in excess of said non-disruptive-discharge potential are impressed upon said electrode in one direction only.

7. The combination with a discharge electrode adapted to emanate electrical discharges in one direction only, of means for impressing upon said electrode a plurality of odd and even harmonic alternating-current-potential waves, which are cyclically displaced with respect to one another in order to produce a resultant asymmetric potential wave having periodic accessions of potential in one direction only that are in excess of the discharge potential of said electrode.

8. The combination with a discharge electrode adapted to emanate periodic non-disruptive electrical discharges, of means for impressing upon said electrode a plurality of alternating-current-potential waves of different frequencies which are displaced cyclically to produce periodic potential excesses of the same sign, whereby said non-disruptive discharge from said electrode may be effected, and means to modify the periods of persistence of said periodic non-disruptive discharges.

9. The combination with a discharge electrode adapted to emanate electrical discharges in one direction only, of means for impressing upon said electrode a plurality of alternating-current waves of different frequencies, said waves being cyclically displaced with respect to one another so as to produce periodic accessions of potential which, in one direction, produce said electrical discharges, and means for increasing the amount of energy represented by a pulsation of one sign over that represented by a pulsation of the opposite sign.

10. The combination with a discharge electrode adapted to emanate periodic electrical discharges of the same sign only, of means for impressing upon said electrode a constant potential of the same sign as said discharges and a plurality of sine-wave potential-producing means for impressing on said electrode periodic accessions of potential having the same sign.

11. The combination with a discharge electrode adapted to emanate non-disruptive electrical discharges in one direction only, of means for impressing upon said electrode a plurality of alternating-current-potential waves of fundamental and double frequency which are cyclically displaced in order to produce an alternating asymmetric wave having periodic accessions of potential, in one direction only, that are in excess of the discharge potential of said electrode and additional means for impressing upon said electrode a constant potential having the same sign as the said electrical discharges.

In testimony whereof I have hereunto subscribed my name this 28th day of June, 1915.

LEWIS W. CHUBB.