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J. B. THOMAS ET AL

3,059,394

ELECTROSTATIC PRECIPITATOR

Filed Sept. 8, 1959

3 Sheets-Sheet 1

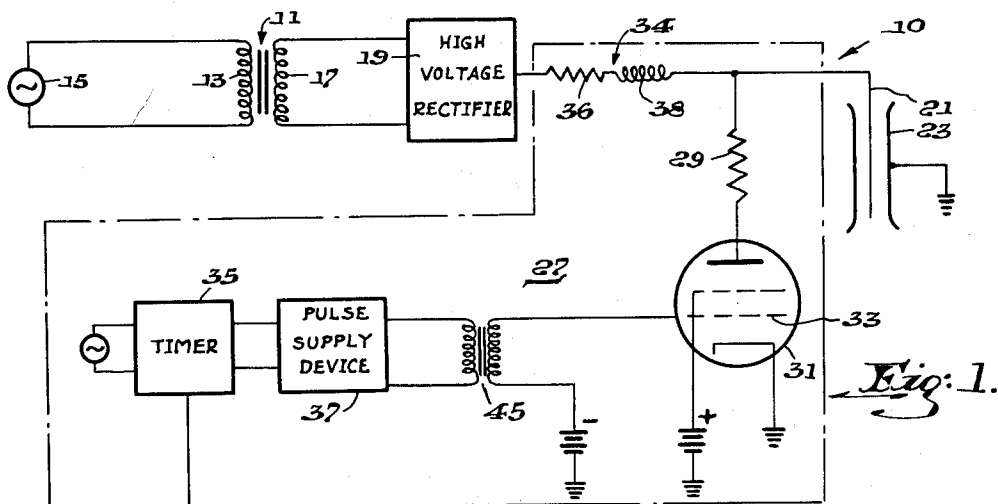


Fig. 1.

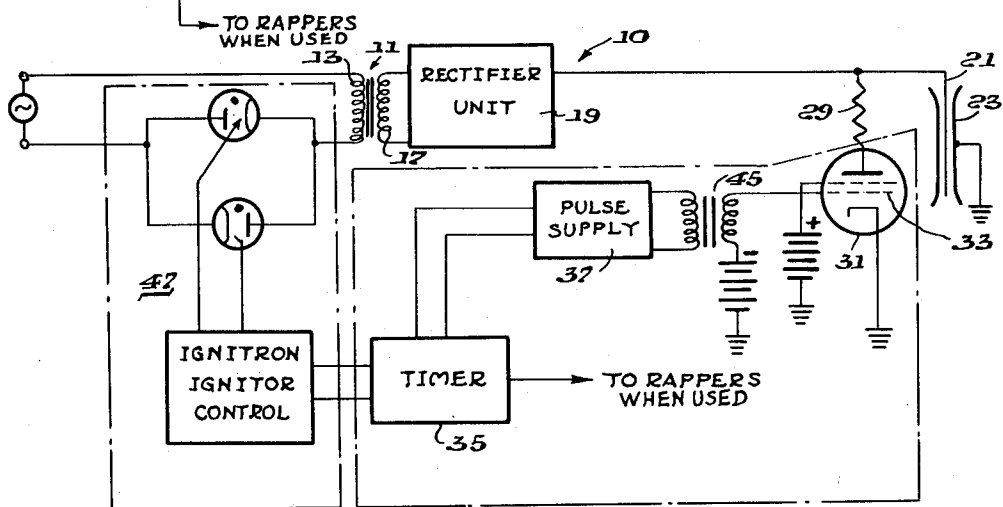


Fig. 2.

INVENTORS,
JOHN W. DRENNING,
JOHN B. THOMAS.

BY
Fred P. Kostka
their
ATTORNEY.

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3 Sheets-Sheet 2

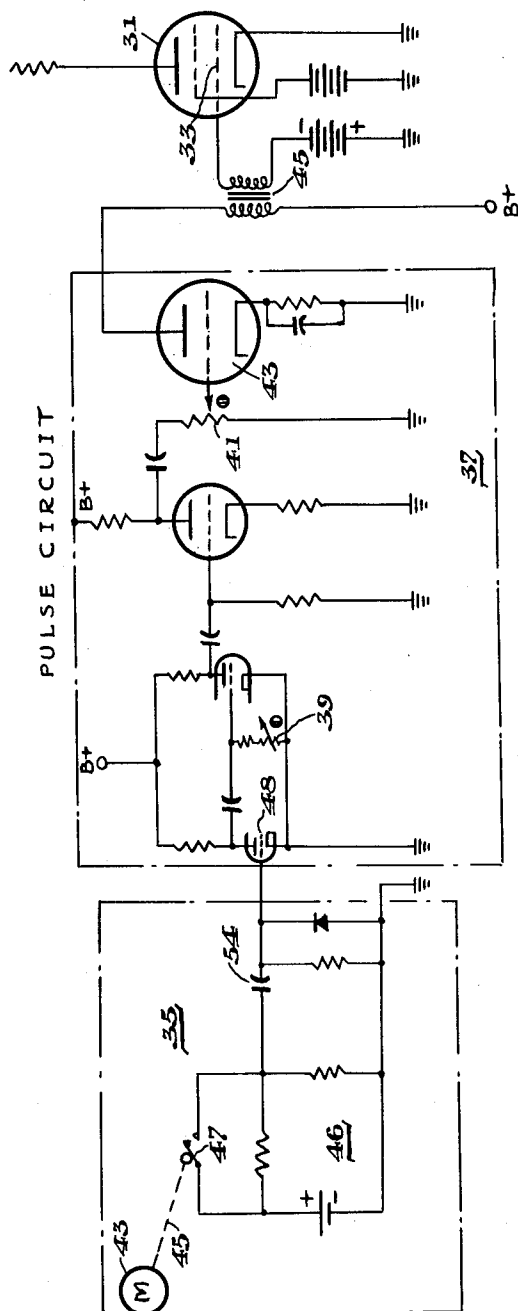


Fig. 3.

INVENTORS
JOHN W. DRENNING,
JOHN B. THOMAS

BY *Fred P. Kootka*
their
ATTORNEY

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3 Sheets-Sheet 3

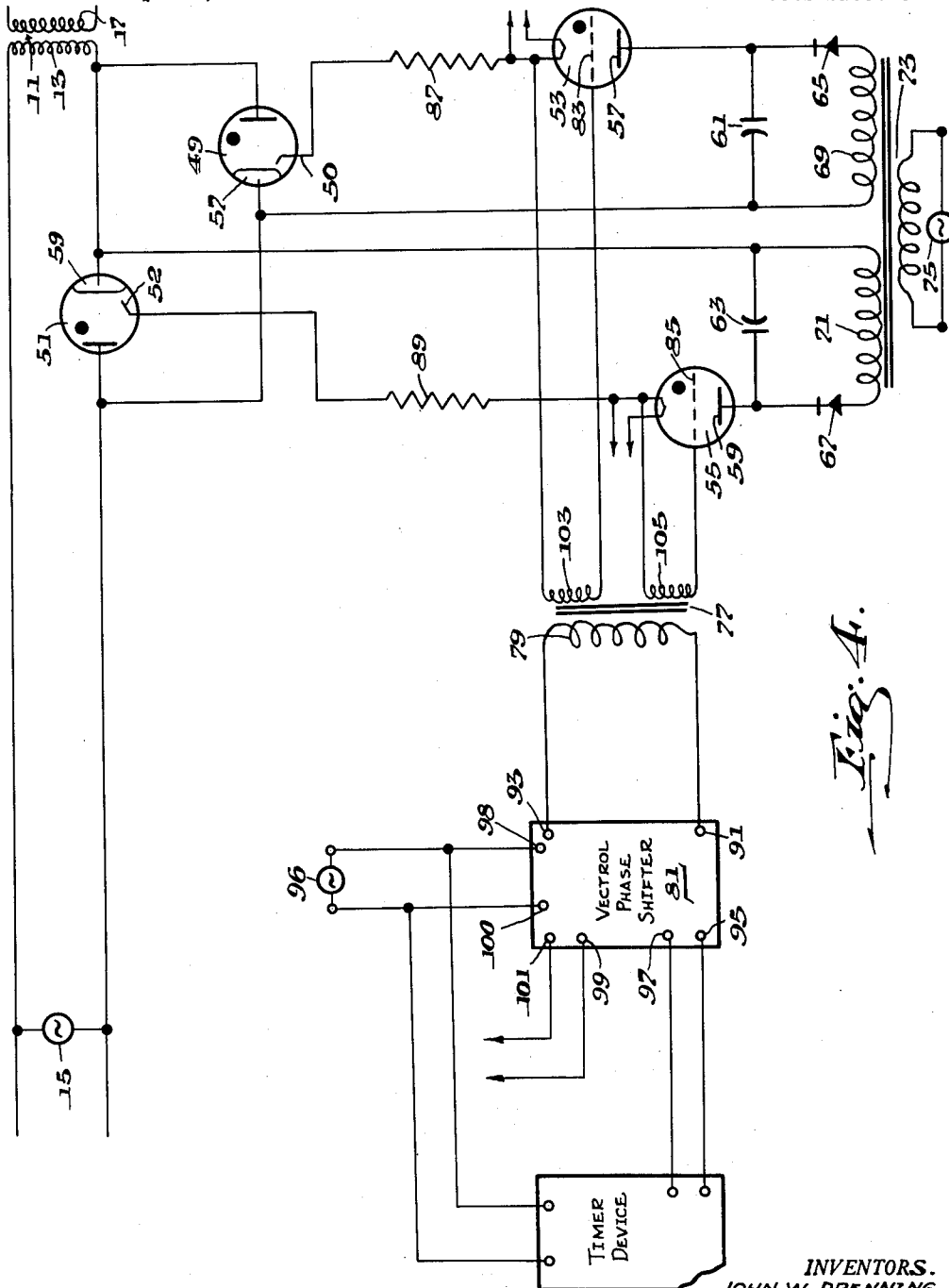


Fig. 4.

INVENTORS.
JOHN W. DRENNING,
JOHN B. THOMAS.
BY *Fred P. Kostka*
their
ATTORNEY.

1

3,059,394

ELECTROSTATIC PRECIPITATOR

John B. Thomas, Plainsboro, N.J., and John W. Drenning,
Baltimore, Md., assignors to Koppers Company, Inc.,
a corporation of Delaware

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7 Claims. (Cl. 55-105)

This invention relates generally to electrostatic precipitators and more particularly to a method and apparatus for removing material deposited on electrodes in electrostatic precipitators.

Conventionally entrained particles may be removed from a gas stream by the use of electrostatic precipitators. Such precipitators comprise electrodes suspended in the gas stream of which one, the discharge electrode, is connected to a high voltage source of direct current so as to produce a current flow therethrough. In this manner, the entrained particles are electrostatically charged by ionization of the gas. The electrostatically charged particles are repelled by the discharge electrodes having the same polarity as that of the charged particles and are attracted to the collecting electrodes having the opposite polarity from that of the charged particles. The charged particles then adhere in the form of an agglomerate on the collecting electrodes.

It has been found, the agglomerate clings to the electrodes with greater tenacity while current is flowing to the discharge electrode than when there is no current flow. This may be due in part to the fact that current has to flow through the material deposited on the electrodes in order to complete an electrical circuit between the discharge and collecting electrodes and this current flow through the material results in what has been described as a "pasting" effect on the deposited particles.

It has been conventional to remove the deposited particles from the discharge electrode as by rapping or vibrating the collecting electrodes. Heretofore, during such rapping, a high difference in potential was maintained between the discharge and collecting electrodes to produce optimum current flow therebetween. This caused the particles to cling tenaciously to the electrodes. Thus, it was necessary conventionally to produce high intensity vibrations in the electrodes with an impulse hammer which sharply rapped the electrodes to overcome the forces tending to hold the material deposited on the electrodes so that material deposited on the electrodes was removed therefrom. In the process, however, the agglomerates were often broken up by these high intensity vibrations to such an extent that some of the particles were re-entrained in the gas stream and carried out of the precipitator, thus reducing the overall gas cleaning action and efficiency of the precipitator. Furthermore, the vibrations had to be of such high intensity that damage, such as metal fatigue, was often caused to the electrodes or the supporting structure.

In order to overcome these problems, it was proposed to reduce momentarily the potential of electrical energy supplied to the precipitator, thus to reduce the current flow between the discharge and collecting electrodes whereby the forces tending to hold material deposited on the electrodes was reduced such that the forces, if any, required to dislodge agglomerates of particles from the collecting electrode were substantially reduced. One

2

such arrangement is disclosed in a U.S. Patent No. 2,976,951 in the name of John Lagarias and assigned to the assignee of the instant invention.

While the arrangement disclosed in the above application is satisfactory, under some circumstances it has been found that the gas loading conditions and the other factors in precipitator operation are such that substantially instantaneous potential reduction is required to remove the agglomerated particles from the wall of the collecting electrode.

In accordance with the present invention, it is proposed to substantially instantaneously reduce the potential of the electrodes by providing means intermediate the electrical source of the high direct current potential for periodically reducing the potential at the discharge and collecting electrodes.

In carrying out the invention, this is accomplished generally by providing a circuit which is operative to periodically short circuit the high voltage supply to the electrodes. As is well known electrostatic precipitators conventionally include a power unit comprising a transformer for raising the potential from a conventional alternator and a rectifier connected to the transformer for converting the secondary high voltage alternating current to high voltage direct current. The discharge electrode is connected directly to the rectifier. By the present invention, a grounding circuit is connected between the rectifier and the discharge electrode. The grounding circuit is periodically rendered effective by a switching means so that upon operation of the switch, the high voltage direct current potential is substantially cut off from the discharge electrodes and the latter grounded.

In the drawings:

FIG. 1 is a schematic circuit diagram of a typical precipitator system embodying the present invention.

FIG. 2 is a schematic circuit diagram of a second embodiment of the invention.

FIG. 3 is a schematic circuit diagram of a timing unit and pulse forming device which may be employed in the embodiments of 1 and 2.

FIG. 4 is a schematic diagram of the primary switching device employed in FIG. 2.

Referring now to the drawings, in FIG. 1 there is illustrated one embodiment for reducing the voltage at the precipitator.

The precipitator 10 comprises generally a transformer 11 of which the primary 13 is connected to a suitable source of alternating current 15 and of which the secondary 17 is connected to a high voltage rectifier 19 for converting the stepped-up alternating current voltage to a direct current voltage. The high voltage direct current is applied to discharge electrode 21 which serves to electrostatically charge the particles entrained in a gas stream flowing between the walls of the collecting electrodes 23. As mentioned before, the charged particles are attracted to the collecting electrode walls and deposited thereon in more or less the form of an agglomerate layer. This layer must be periodically removed in order that the gas cleaning process may be efficiently carried out on a continuous basis.

In accordance with the present invention, such removal of the layer of agglomerated particles is accomplished upon a voltage reduction at the discharge electrode which, as previously discussed, decreases the re-

3

tention charge on the collecting electrode walls such that the layer drops off the walls. To this end, there is employed a voltage interrupting circuit generally designated as 27 for periodically grounding the high potential direct current such that it is in effect short circuited between the discharge electrode 21 and ground. In this manner, the voltage is momentarily reduced at the discharge electrode 21 and also at the walls on the collecting electrode 23 such that the electrostatic adhering forces are materially reduced and the layer tends to gravitationally drop off. Under some circumstances depending on the condition of gas particularity, particle characteristics, gas velocity, etc., such reduction of the voltage may be sufficient to remove the particles from the wall. However, if the collecting electrodes are not adequately cleaned by voltage reduction alone, it may be necessary to employ a rapping device (not shown) which, because of the reduced voltage, may be applied at a relatively low intensity. Such low intensity rapping is more fully described in the aforementioned U.S. patent application to which reference is made for a more complete explanation.

As shown in FIG. 1, the voltage interrupting circuit 27 comprises a relatively low resistance 29 connected in the line between the high voltage rectifier 19 and the discharge electrode 21. The resistance 29 is connected to ground by way of a rapidly responsive electronic switching device which, in the embodiment illustrated, is a high vacuum tetrode 31. The tube shown is preferably in the form of a rapidly responsive tetrode such as a Machlett Tetrode Tube, type DP-1.

The tetrode 31 is controlled by way of a pulse supply device 37 which serves to determine the magnitude and duration of the firing potential applied to the grid 33, a timing device 35 for periodically energizing the pulse forming device 37 and thereby the rate of firing of the tetrode 31. As shown in FIG. 3, the pulse circuit 37 is a substantially conventional free running multivibrator of which the square pulse magnitude emitted therefrom and thereby the firing potential on the grid is selectively obtained by way of adjustment of the pulse height potentiometer 41 and the pulse length potentiometer 39.

The pulse timing device 35 includes a motor 43 having a camming shaft 44 operative to periodically open and close a switch 47 of a more or less conventional pulse forming circuit 46 so as to energize the grid 48 of the multivibrator by way of the condenser 54. If necessary, the timing device may be connected to the rappers to synchronize the movement thereof with the voltage reduction.

Upon closing of the switch 47, a pulse of predetermined magnitude is generated by the multivibrator, which pulse is amplified by the tube 43 and applied to the grid 33 by way of pulse transformer 45 so as to trigger the tetrode tube such that the tetrode tube 31 becomes conductive and functions as a switch. In this manner, the resistor 29, which serves as a current resistor, is effectively grounded such that the potential is shunted to ground and does not pass to the discharge electrode 21. Hence, the voltage to the discharge electrode is reduced. It is obvious, of course, that the amount of voltage reduction is determined by the magnitude of the resistance 29 and the series impedances 36 and 38.

For the purpose of preventing excessive current flow from the rectifier 19 to the discharge electrode 21 during the grounding of the potential which is in the nature of a short circuit, an impedance 34 is provided between the precipitator transformer 11 and the rectifier 19. While the impedance may be connected as illustrated in the embodiment, it also may be connected between the secondary and the rectifier. As shown, the impedance includes a resistor 36 and inductance 38. It is to be understood, however, that the impedance may comprise either resistance or inductance alone.

4

FIG. 2 illustrates a second embodiment of the invention in which like parts are designated alike. The second embodiment, as in the embodiment illustrated in FIGS. 1 and 3, includes a transformer 11, rectifier 19, discharge electrode 21, collecting electrode 23, and a grounding switch arrangement 27 including a timer circuit 35, pulse supply device 37, and a thyatron 31 which are operative to periodically reduce the voltage as explained heretofore.

For the purpose of reducing the current flow through the rectifier 19, there is employed a primary switching device 47. As schematically illustrated in FIG. 4, the primary switching device includes ignitron tubes 49 and 51 which are connected in inverse parallel such that one tube carries one half cycle of current flow and the other tube the reverse half cycle. The ignitrons, as to be more fully explained below, serve as a primary switch to reduce the total line current a predetermined amount and thereby decrease the potential delivered to the discharge electrode by the rectifier when the voltage reduction arrangement 27 is actuated.

As described above, the ignitrons are connected such that a full wave current corresponding to line frequency passes therethrough when they are rendered conductive. Hence, if the line current is reduced, there results a corresponding decrease in line voltage. It is apparent, therefore, that the total line current to the transformer can be controlled by shifting the firing time of the ignitron with respect to the line frequency.

To achieve such a reduction in line current and decreased potential to the primary of the precipitator transformer 11, there are provided a pair of thyatrons 53 and 55 of which the thyatron tube 53 is operative to energize the igniter 50 to initiate the firing of the ignitron 49, and the thyatron 55 energizes the igniter 52 to fire the ignitron 51. Connected to the plates 57 and 59 of the thyatrons 53 and 55 respectively and to the igniters 50 and 52 are condensers 61 and 63 respectively. The condensers 61 and 63 are respectively charged by way of rectifiers 65 and 67 connected to secondary windings 69 and 71 of transformer 73 which is connected to a suitable source of alternating current 75. For full wave current operation, the thyatrons are selectively triggered by the application of a firing potential provided by way of a matching and isolation transformer 77 of which the primary winding 79 is connected to the phase shifting device 81. The application of firing potential on the grids 83 and 85 causes the condensers 61 and 63 to discharge through the respective limiting resistors 87 and 89 thereby causing the igniters 50 and 52 to establish an arc such that the tubes 49 and 51 conduct.

As described, the grids 83 and 85 of thyatrons 53 and 55 are both fed from the same phase shift device 81 and are connected so that the signal to the grid 83 is 180° out of phase with the signal on the grid 85. This insures that both tubes 53 and 55 are fired exactly 180° out of phase and each tube carries an equal amount of half cycle current. To insure that energy will always be available from condensers 61 and 63 for firing the igniters 50 and 52, the condensers are arranged so that they will charge on the half cycle of voltage from the transformer 73 which is 180° out of phase from the conducting half cycle of the corresponding igniter. Hence, when the ignitrons 49 and 51 are fired, full wave line current passes to the precipitator transformer.

The phase shifter 81 is a conventional unit which is energized by a source of alternating current 96 connected to input terminals 98 and 100 and having terminals 91 and 93 connected to an output winding to supply the grids 83 and 85, terminals 95 and 97 connected to an input signal winding in which the current flow determines the amount of phase shift, and terminals 99 and 101 connected to a bias winding to set the "no signal" phase shift.

5

The signal and bias windings are provided with low magnitude direct current circuits which serve to control the inductance of a small saturable reactor, which inductance determines the degree of phase shift. In the absence of a signal on the control winding or no current flow there-through, the bias winding is adjusted to supply a firing potential to the thyatron which will in turn permit full-wave conduction of the ignitrons 49 and 51 and therefore apply full potential to the transformer 11.

The phase shift device is connected to the timing device 35 at control winding terminals which time device, as explained above, serves to determine the rate at which the voltage is grounded by way of the supply device, 37, tetrode 31, and resistor 29.

In operation, when the timing circuit switch is in its open position, the phase shifting unit is energized directly from its alternating current source 96 and the bias winding such that the outputs at the windings 105 and 103 of the matching and isolator transformer 11 are substantially 180° out of phase whereupon the thyratons 53 and 55 are sequentially triggered and the condensers are also sequentially discharged to fire the ignitrons 49 and 51 on opposite half cycles. In this manner, the full line current passes directly through the precipitator transformer 11. The pulse supply device 37 and tetrode 31 remain de-energized such that the high potential from the rectifier 19 is applied to the discharge electrode 21.

When the switch 47 is closed, the control windings of the phase shifter 81 are energized. The flow of current through control windings of the phase shifter is adjusted by means not shown such that the thyratons 83 and 85 are de-energized at some selected phase angle of the 60 cycle current flow whereby the ignitors 50 and 52 are extinguished at the same phase. In this manner, the average magnitude of current flow to the precipitator transformer 11 during the period of voltage reduction at the discharge electrodes 21 is controlled so as not to exceed a current flow tending to damage the transformer 11 or rectifier 19. The pulse forming device 37, tetrode 31, and resistor 29, as explained in connection with the embodiment of FIGS. 1 and 3, are operative during the period the switch 47 is closed to ground the high potential and thereby interrupt and reduce the voltage to the discharge electrode 21.

From the foregoing, it is readily apparent that both output voltage of rectifier to the discharge electrode and input potential to the transformer are substantially simultaneously reduced such that the attraction of the entrained particles to the collecting electrodes is reduced and the particles agglomerated thereon may readily be removed.

Each of the above described preferred forms of the invention for reduction of voltage is accomplished by rapidly responsive electronic devices such that substantially instantaneous voltage reduction at the precipitator electrodes may be achieved. However, it will be understood that other electrical or electro-mechanical devices such as high voltage vacuum relays, conventional relays, and mechanical cam actuated timing mechanism may be also employed.

For example, a high voltage vacuum relay may be used as a substitute for the tetrode tubes employed. Furthermore, if the particle conditions are favorable, an electro-mechanical arrangement such as a variable speed motor for periodically driving a rotating blade in contact with a stationary shoe connected to the grounding resistor may also be suitable. The latter arrangement may include a cam operating switch for actuating the primary switching arrangement.

What is claimed is:

1. An electrostatic precipitator comprising a transformer connected to a source of alternating current, a rectifier connected to the secondary of said transformer for converting said alternating current to high voltage direct current, a discharge electrode connected to said rectifier, means connectable to ground connected intermediate said

6

rectifier and said discharge electrode, switch means for periodically connecting said connectable means to ground substantially instantaneously reducing the voltage at said discharge electrode, means for reducing the current flow through said rectifier a predetermined amount, said current reducing means being connected between said source of alternating current and said transformer and means interconnecting said current reducing means and said switch means for simultaneous actuation thereof whereby the output voltage of the rectifier to the discharge electrode and the input voltage to the transformer are substantially simultaneously reduced.

2. The invention as defined in claim 1 in which said switch means comprises an electronic tube normally biased so as to be non-conductive and means for periodically overriding said bias on firing said electronic tube at a predetermined rate so as to connect said groundable means to ground.

3. The invention as defined in claim 2 in which said firing means comprises a pulse forming device and a timing device for energizing said pulse forming device.

4. The invention as defined in claim 1 in which the current reducing means includes means for selectively determining the magnitude of current flow reduction.

5. The invention as defined in claim 1 in which said switch means comprises a tetrode tube normally biased so as to be non-conductive, pulsing means in the form of a multivibrator having a pulse magnitude and duration selectively adjusted to override said bias so that said tetrode tube becomes conductive, and means for selectively energizing said multivibrator at a predetermined rate.

6. In an electrostatic precipitator having a transformer connected to a source of alternating current, a rectifier connected to the secondary of said transformer for converting said alternating current to high voltage direct current, a discharge electrode connected to said rectifier, a collecting electrode located in spaced relationship to said discharge electrode and circuit means connected between said rectifier and said discharge electrode for periodically short circuiting said discharge electrode to instantly reduce the voltage thereof, the improvement comprising means for reducing the current flow through the rectifier during the periodic short circuiting by the circuit means, said current reducing means being connected between said source of alternating current and said transformer and including means for separating and subsequently recombining the half cycles and reverse half cycles of the alternating current passing therethrough and means interconnecting said current reducing means and said circuit means operative concurrently with said circuit means for automatically shifting the phase relationship of said half cycles and reverse half cycles to reduce the net line voltage and net line current to said transformer a predetermined amount whereby the output voltage of said rectifier to the discharge electrode and the input voltage to said transformer are substantially simultaneously reduced.

7. An electrostatic precipitator comprising a transformer connected to a source of alternating current, a rectifier connected to the secondary of said transformer for converting said alternating current to high voltage direct current, a discharge electrode connected to said rectifier, a collecting electrode located in spaced relationship to said discharge electrode, means for grounding connected intermediate said rectifier and said discharge electrode, switch means connected to said grounding means for periodically connecting said grounding means to ground substantially instantaneously reducing the voltage at said discharge electrode, means connected between said source of alternating current and said transformer for separating and subsequently recombining the half cycles and reverse half cycles of the alternating current passing therethrough and means interconnecting said separating and recombining means and said switch means and being operative concurrently with said switch means to shift the phase

relationship of said half cycles and reverse half cycles to reduce the net line voltage and net line current to said transformer a predetermined amount whereby the output voltage of said rectifier to said discharge electrode and the input voltage to said transformer are substantially simultaneously reduced.

5

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