

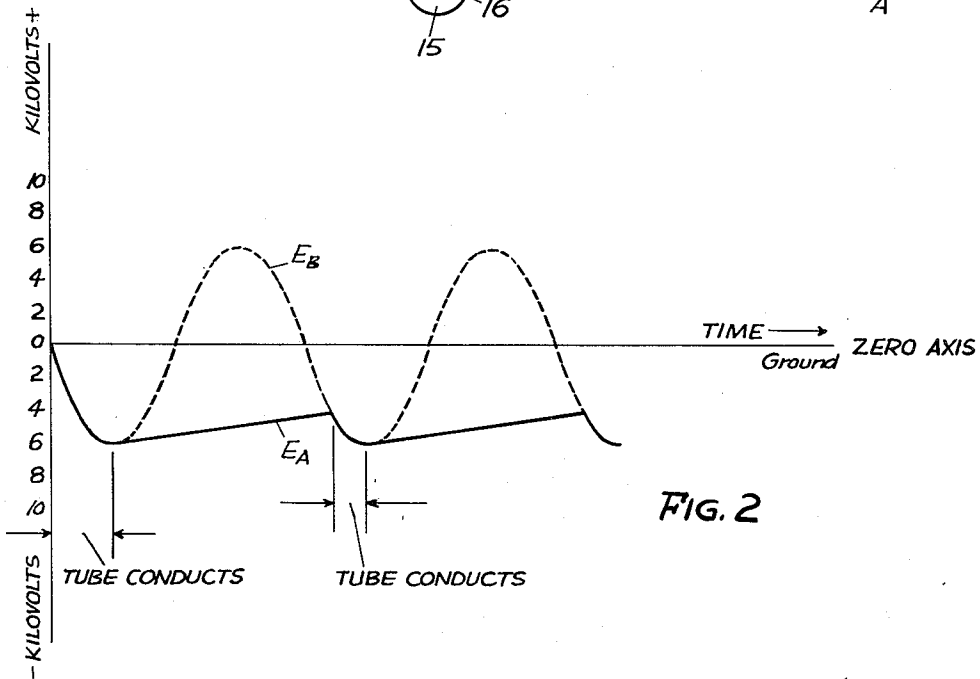
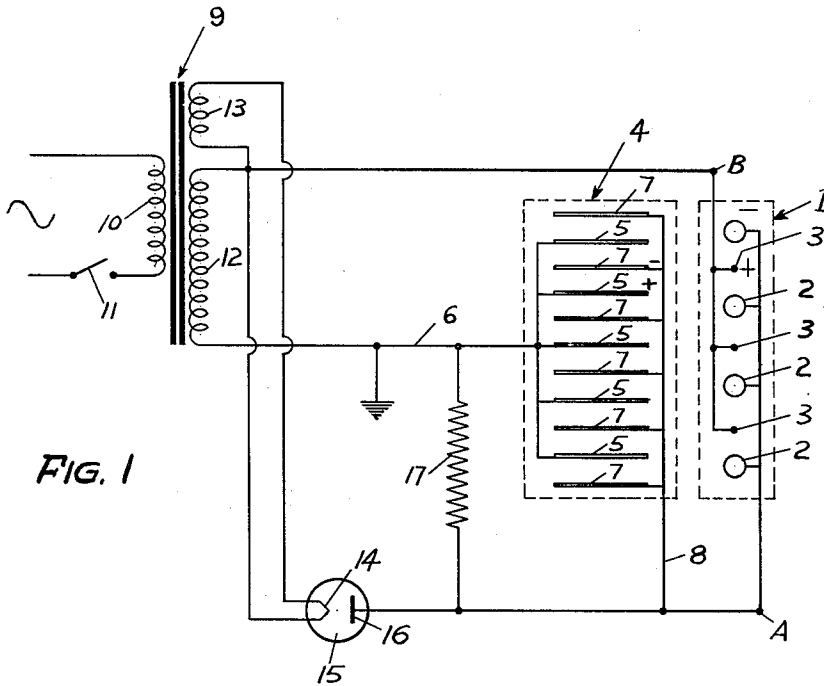
May 27, 1952

G. E. ANDREWS
ELECTRICAL PRECIPITATOR

2,598,337

Filed June 5, 1948

3 Sheets-Sheet 1



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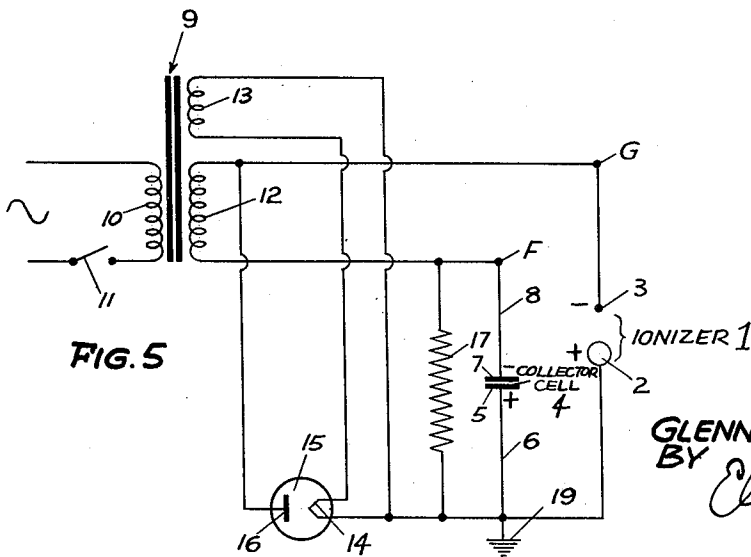
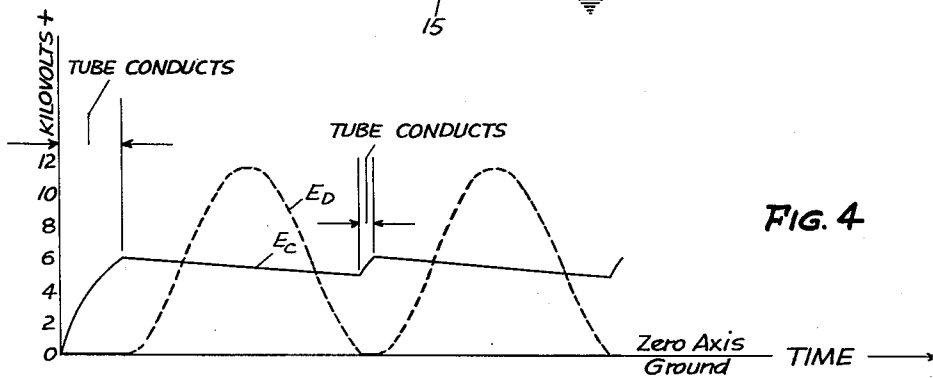
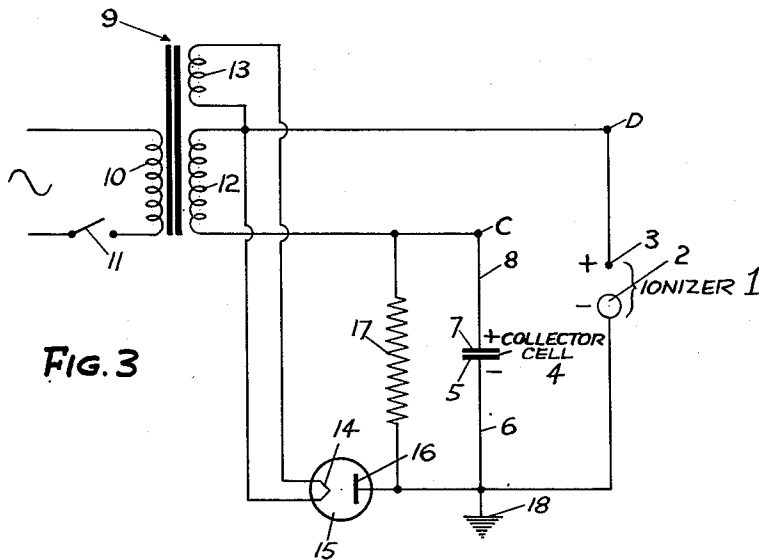
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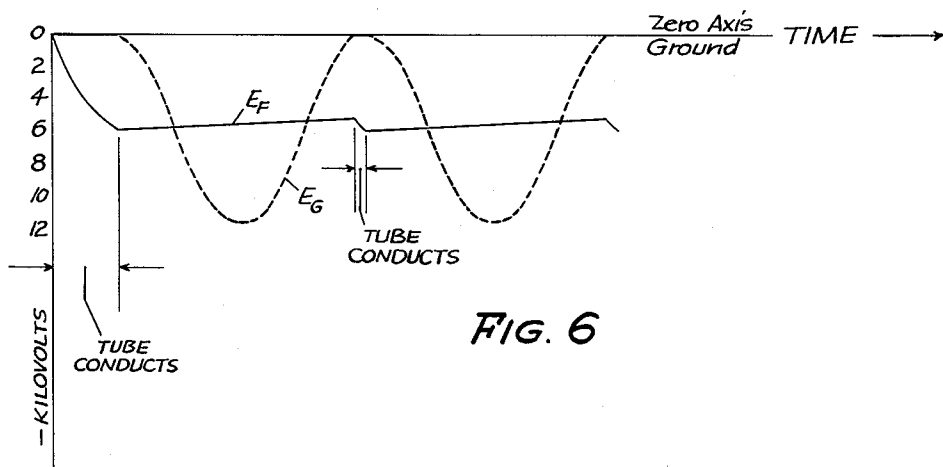


FIG. 6

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2,598,337

ELECTRICAL PRECIPITATOR

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Application June 5, 1948, Serial No. 31,275

20 Claims. (Cl. 183—7)

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This invention relates to electrical precipitators for separating dust and smoke from atmospheric air, flue gases and the like, and more particularly to a circuit for energizing such precipitators.

In precipitators of the type to which the invention relates, the air or other gas to be cleaned is first ionized in a suitable ionizing device, from whence it flows through a suitable precipitating means, where dust and other impurities are separated. The ionizing device comprises at least one pair of ionizing electrodes adapted to have a sufficient potential placed therebetween to ionize the air that passes therebetween. The precipitating means commonly comprises a plurality of spaced, parallel collector plates of substantial area between which the ionized air flows and on which the dust particles and other impurities are collected due to a difference in potential maintained between adjacent plates. The potential across adjacent plates may be on the order of six kilovolts, while the ionizing potential is substantially higher, for example, on the order of 12 kilovolts or more.

In precipitator power supplies of the prior art which employ voltage doubler circuits, a typical example of which is disclosed in the copending MacKenzie application, Ser. No. 692,893, filed August 24, 1946, now Patent 2,476,247, dated July 12, 1949, two capacitances, two discharge resistors, and two rectifier tubes are required, even though one of the two capacitances may be provided by the inherent capacitance of the collector plates. Also, since the filaments of the two rectifier tubes operate at different potentials, two filament windings must be provided on the input or supply transformer.

An object of this invention is to devise a precipitator power supply employing a voltage doubler circuit which requires fewer parts than conventional or prior art power supplies, and yet at the same time does not cause a reduction in the cleaning efficiency of a precipitator using the power supply of this invention.

Another object is to provide a precipitator power supply employing a voltage doubler circuit in which, as compared to prior circuits, one capacitance, one discharge resistor, one rectifier tube, and one filament winding are eliminated without reducing the precipitator cleaning efficiency, thereby reducing the cost of such power supply.

A further object is to decrease the production of ozone by the ionizing device of a precipitator without decreasing the cleaning efficiency of the

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precipitator of which such ionizing device constitutes a part.

A still further object is to devise a novel precipitator power supply wherein a pulsating direct potential is applied to the precipitator ionizing device.

An additional object is to provide an inexpensive precipitator power supply.

The foregoing and other objects of the invention will be best understood from the following description of some exemplifications thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is a schematic representation of an electrical precipitator together with a supply circuit therefor;

Fig. 2 is a set of curves helping to explain the operation of the circuit of Fig. 1;

Fig. 3 is a diagrammatic representation of a modified precipitator power supply;

Fig. 4 is a set of curves helping to explain the operation of the circuit of Fig. 3;

Fig. 5 is a diagrammatic representation of another precipitator supply according to the invention; and

Fig. 6 is a set of curves helping to explain the operation of the circuit of Fig. 5.

Referring to Fig. 1, reference numeral 1 indicates generally an ionizing device of an electrical precipitator comprising a plurality of tubular electrodes 2 and a plurality of spaced, parallel fine wire electrodes 3, one between each two successive adjacent tubular electrodes 2, and between which tubular electrodes and fine wire electrodes an ionizing discharge is adapted to take place.

Adjacent the ionizing device 1 is a precipitating device or collector cell 4 comprising a plurality of collector plates having extensive parallel surfaces and comprising a plurality of ground plates 5 connected to a common grounded lead 6 and a plurality of intervening charged plates 7 connected to a common lead 8.

In order to supply suitable potentials between the ionizing electrodes 2 and 3 of the ionizing device 1 and a substantially lower potential between the charged plates 7 and the ground plates 5 of the precipitating means 4, a transformer 9 is provided having a primary winding 10, the terminals of which are connected across a suitable source of alternating current through a series switch 11, and two secondary windings 12 and 13. One terminal of winding 12 is connected to the common terminal B of the fine wire electrodes 3 of the ionizing device 1, while the

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opposite terminal of winding 12 is connected to grounded lead 6 and the ground plates 5 of collector cell 4.

Opposite terminals of filament winding 13 are connected to opposite ends of the filament 14 of a half-wave rectifier 15, in order to supply heating current to said filament. Rectifier 15 may, for example, be a vacuum tube of the type known as 3B24. To complete connections to the cathode 14 of rectifier 15, one terminal of winding 13 is connected to the ungrounded end of winding 12. Anode 16 of rectifier 15 is connected to common lead 8 of the charged plates 7 of the precipitating device 4 and also to common terminal A of the tubular electrodes 2 of the ionizing device 1. A discharge resistor 17 having a high resistance, on the order of 300 megohms, for example, is connected between anode 16 and ground. There is an inherent capacitance between the opposed plates 5 and 7 of collector cell 4, and this capacitance is connected across resistor 17 by means of leads 6 and 8.

Now referring to Fig. 2, solid line curve E_A represents the potential of terminal or point A with respect to the zero axis or ground, while dashed line curve E_B represents the potential of terminal or point B with respect to the same zero axis. E_B traces a substantially sinusoidal path of six kilovolts peak value when switch 11 is closed, since the potential of point B with respect to ground is the voltage across secondary winding 12 of supply transformer 9. When switch 11 is closed to energize the circuit, during the first half-cycle when point B goes negative, rectifier 15 begins to conduct, since point B is connected to cathode 14, and charging current flows through condenser 4 and rectifier 15, charging condenser 4 to substantially the peak voltage appearing across winding 12, which may be six kilovolts, plates 7 (point A) being charged negatively with respect to plates 5 or ground. Whenever tube 15 conducts, point B has the same potential as anode 16 or point A. When the sinusoidal voltage E_B reaches its negative peak and begins to go in the positive direction, rectifier 15 ceases to conduct because E_B no longer overcomes the opposing voltage E_A across condenser 4, rectifier 15 remaining off and the charge on condenser 4 leaking off very slowly through resistor 17 until an instant in the next negative half-cycle of supply voltage E_B is reached at which E_B becomes equal to E_A , at which instant rectifier 15 again begins to conduct to restore the charge which has leaked off condenser 4 through resistor 17, bringing the potential of point A back up in the negative direction to substantially the full peak voltage of source 12.

During steady-state conditions, the above-described leaking-and-recharging process repeats; if the frequency of the source is 60 cycles, condenser 4 is recharged 60 times per second to substantially the peak voltage of the source. Since the resistor 17 has a high value of resistance, the draining-off of the charge on condenser 4 takes place quite slowly, this discharge being somewhat exaggerated in slope in Fig. 2 for the sake of clearness. Since this rate of discharge is rather low, and since the discharge tends to take place exponentially with respect to the zero axis or ground, the portion of the curve E_A corresponding to the discharge of condenser 4, between the times of conduction of tube 15, is substantially linear as indicated.

The voltage E_A with respect to the zero axis or ground is the voltage on collector cell 4, and

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during steady-state conditions, as shown, is substantially constant at six kilovolts direct current, with charged plates 7 negative with respect to ground plates 5. Therefore, the collector cell 4 functions in the conventional manner.

The voltage E_A with respect to E_B is the voltage supplied to the ionizing device 1, points A and B being located at opposite electrodes of said ionizer. During steady-state conditions, E_A with respect to E_B varies from zero, while tube 15 is conducting, to approximately 12 kilovolts, when E_B reaches its positive peak of six kilovolts with respect to ground while E_A is held at substantially six kilovolts negative with respect to ground by the non-conduction of tube 15 and the only extremely slow leaking-off of the charge on condenser 4, as described above. Thus, the ionizer voltage E_A with respect to E_B rises to a high value of short duration at the frequency of the supply voltage, which in the example given means 60 times per second. At these voltage peaks on the ionizer, point B and fine wire electrodes 3 are positive with respect to point A and tubular electrodes 2. The ionizer voltage E_{AB} is therefore a pulsating direct voltage, with the fine wire electrodes 3 positive with respect to the tubular electrodes 2.

When E_{AB} is approximately 12 kilovolts, ionization of the air molecules occurs. It may be seen that this occurs during short time intervals or in "bursts" repeated at a rate of 60 times per second, since E_{AB} reaches the ionizing potential only in the vicinity of the positive peaks of E_B . However, it has been found that this non-continuous ionization or ionization in bursts does not decrease the cleaning efficiency of the precipitator, but in fact increases it slightly. With an airstream velocity of 300 feet per minute, or five feet per second, a particle in the air stream moves about one inch in the direction of air flow between pulses of ionizing voltage, which occur at intervals of approximately $\frac{1}{60}$ second. In this case, a dirt particle can be a maximum of one-half inch away from the plane of the ionizing wire at the occurrence of succeeding ionizing pulses or "bursts." The existence of this maximum condition does not appreciably interfere with efficient ionization, because under ordinary conditions some ionization of particles occurs when such particles are $\frac{1}{2}$ -inch away from the plane of the ionizing wire, and particularly because such particles are subjected to ionization when they are on each of the two opposite sides of such plane.

Another characteristic of the ionizing means, perhaps more important than that just discussed, which keeps the ionizer operating efficiently even when operating in "bursts" as in this invention, is the fact that the ions produced by ionization of the gas molecules diffuse in all directions, transversely of the airstream as well as upstream and downstream thereof, and moreover move very far in $\frac{1}{60}$ sec., compared to the distance traveled by the dust particles in the same time. Therefore, the ions travel throughout very large volumes of gas during each of the "bursts" of ionization, thus producing substantially continuous and complete ionization of the dust particles in the gas by addition to such particles, even though the gas moves between "bursts;" the dust particles are charged positively in the ionizer if the fine wire electrodes are positive with respect to the tubular electrodes.

In addition, though the production of ions from the gas molecules is not continuous but

takes place during pulses of short duration at a rate of 60 times per second, the ions produced during each burst, if they are not removed from the area of action by effective combination or otherwise, wander around haphazardly in said area between bursts because of the substantially field-free condition existing between such bursts. During this haphazard or random wandering, ionization of some dust particles may take place, even between ionization bursts, thus helping to insure uniform and complete ionization of all the dust particles. Moreover, even if ionization does not occur in this manner between bursts, beneficial action still results. Because of the large number of ions produced during each burst and because of their wanderings between bursts, just prior to each such burst they are dispersed throughout large volumes of the gas, so that when an electrostatic field is applied between the opposite ionizing electrodes at the beginning of a burst, the ions are already in existence and immediately begin to move toward one or the other of the opposite ionizing electrodes through a large volume of the gas, colliding with and ionizing dust particles on the way, without the necessity of a relatively long time elapsing from the beginning of the burst before sufficient ions can be produced and dispersed through the gas.

It has been found that the above-described effects act, either alone or in combination, to produce substantially continuous and complete ionization of the dust particles entrained in the air stream passing through the ionizer of this invention, even though the ionizer is supplied with pulsating direct voltage and ionization of the air molecules occurs only in short bursts at a periodicity of approximately $\frac{1}{60}$ second. The cleaning efficiency of a precipitator using the power supply of this invention has been measured as 85 per cent. by the so-called blackness test.

Due to the fact that ionization occurs only in bursts, there is less ionizing time with this invention than with the continuous ionization of prior devices. This means that less ozone is produced by the ionizing means of this invention, a result which is very desirable. Also, if desired, it is possible with this invention to increase the peak voltage, and therefore the ionization, without increasing the total ozone production over that of the prior devices. If the peak voltage is increased, the ozone production is increased also. However, with the present invention ozone is produced only in "bursts" and not continuously, so that the total or "integrated" ozone can be held down to a value not greater than that produced by prior devices, while at the same time increasing the ionization over such devices.

From the above description, it may be seen that a precipitator power supply has been devised which does not cause a reduction in the cleaning efficiency of a precipitator using such supply. Such a power supply acts in effect as a voltage doubler circuit, and yet requires only one capacitance, one discharge resistor, one rectifier tube, and one filament winding on the input transformer, as compared to two of each of these elements required by conventional circuits.

The circuit of Fig. 1 has been found particularly useful for electrical precipitators of the type designed for home or room use. Fig. 3 disclosed a modified circuit which is useful for precipitators of the type designed for industrial use, in which the tubular electrodes 2 of the ionizer 1 are grounded. In Fig. 3, elements the same as

those of Fig. 1 are denoted by the same reference numerals.

Now referring to Fig. 3, the tubular electrodes 2 of ionizer 1 are connected to anode 16 of rectifier 15, as in Fig. 1, but now electrodes 2 are grounded at 18. As before, ground plates 5 of the collector cell 4 are connected together by lead 6, but now lead 6 is connected to ground 18 and the anode 16. Charged plates 7 of the collector cell 4 are connected to a common lead 8 which is connected to terminal or point C at one end of secondary winding 12, discharge resistor 17 being connected between anode 16 and this same end of winding 12, or directly across the condenser 4. Fine wire electrodes 3 of the ionizer 1 are connected to terminal or point D at the end of winding 12 opposite to terminal C. As in Fig. 1, filament winding 13 is connected to the upper end D of winding 12 and also across filament 14 of rectifier 15.

The operation of the circuit of Fig. 3 will be understood from an examination of Fig. 4. In Fig. 4, the solid line curve E_c represents the potential of point C with respect to the zero axis or ground, while the dashed line curve E_D represents the potential of point D with respect to ground. If the potential of point C were taken as a zero axis of reference, E_D would be sinusoidal about such an axis with a peak voltage of 6 kilovolts, since the voltage E_D with respect to E_c is the voltage across winding 12.

When switch 11 is closed, during the first half-cycle when point C goes positive with respect to point D or cathode 14, or when point D goes negative with respect to point C, rectifier 15 begins to conduct, and charging current flows through condenser 4 and rectifier 15, charging condenser 4 to substantially the peak voltage appearing across winding 12, which may be 6 kilovolts, plate 7 (point C) being charged positively with respect to plate 5 or ground. During this time of conduction of tube 15, and whenever said tube conducts, the potential of point D has the same value as anode 16, which is zero or ground in this case. When the sinusoidal voltage represented by the initial rising portion of curve E_c reaches its positive peak, or when E_D reaches its negative peak with respect to E_c and begins to go in the positive direction, rectifier 15 ceases to conduct because E_c with respect to E_D is no longer sufficiently positive to overcome the opposing voltage E_c across condenser 4. Rectifier 15 remains off and the charge on condenser 4 leaks off very slowly through resistor 17 until an instant in the next negative half-cycle of the swing of point D with respect to point C is reached at which E_c with respect to E_D becomes equal to E_c , at which instant rectifier 15 again begins to conduct to restore the charge which has leaked off condenser 4 through resistor 17, bringing the potential of point C back up to substantially the full peak voltage of source 12. When tube 15 again conducts as described, the potential of point D again drops to that of anode 16 or zero. Between times of conduction of tube 15, E_D varies as illustrated, since E_D with respect to E_c is a sinusoidal wave of 6 kilovolts peak amplitude.

During steady-state conditions, the above-described leaking-and-recharging process repeats; condenser 4 is recharged 60 times per second to substantially the peak voltage of the source. Again, as in Fig. 1, the portion of curve E_c corresponding to the discharge of condenser 4, between the times of conduction of tube 15, is substantially linear as illustrated.

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The voltage E_c with respect to the zero axis or ground is the voltage on collector cell 4, and during steady-state conditions, as shown, is substantially constant at six kilovolts direct current, with charged plate 7 positive with respect to ground plate 5. Therefore, collector cell 4 functions in the conventional manner.

The voltage E_b with respect to the zero axis or ground is the voltage applied to ionizer 1. During steady-state conditions, E_b varies from zero, while tube 15 is conducting, to approximately 12 kilovolts, when E_b reaches its positive peak of six kilovolts with respect to E_c while E_c is held at substantially six kilovolts positive with respect to ground by the non-conduction of tube 15 and the only extremely slow leaking-off of the charge on condenser 4, as described above. Thus, as in Fig. 1, the ionizer voltage E_b rises to a high value of short duration at the frequency of the supply voltage, or 60 times per second. At these voltage peaks on the ionizer, point D and fine wire electrodes 3 are positive with respect to ground and tubular electrodes 2. The ionizer voltage E_b is therefore a pulsating direct voltage, with the fine wire electrodes 3 positive with respect to the tubular electrodes 2.

As in Fig. 1, ionization occurs in "bursts" repeated at a rate of 60 times per second, since E_b reaches ionizing potential only in the vicinity of positive peaks of E_b . However, as previously explained, this non-continuous ionization or ionization in "bursts" does not decrease the cleaning efficiency of the precipitator. The advantage of decreased production of ozone, explained above in connection with Fig. 1, is obtainable with the Fig. 3 modification also. As in Fig. 1, the dust particles are charged positively.

Fig. 5 discloses a modification which has certain advantages as compared to the embodiments of Figs. 1 and 3. Parts the same as those previously described are denoted by the same reference numerals.

Now referring to Fig. 5, the tubular electrodes 2 of ionizer 1 are connected to cathode 14 of rectifier 15, which is grounded at 19. Ground plates 5 of collector cell 4 are connected together by lead 6, which is connected to ground 19 and cathode 14. Charged plates 7 of the collector cell 4 are connected to common lead 8 which is connected to terminal or point F at the lower end of secondary winding 12, discharge resistor 17 being connected between cathode 14 and this same end of winding 12, or directly across the condenser 4. Fine wire electrodes 3 of ionizer 1 are connected to terminal or point G at the upper end of winding 12, or at the end thereof opposite to terminal F. Filament winding 13 is connected across filament 14 of the rectifier 15, while anode 16 of said rectifier is connected to the upper end G of winding 12.

It can be seen that the filament 14 in Fig. 5 is at ground potential. This is in sharp contrast to the Fig. 1 embodiment, in which the filament point B goes to a peak of approximately six kilovolts on both sides of ground, and also to the Fig. 3 embodiment, in which the filament point D goes to a peak of approximately 12 kilovolts with respect to ground. Since the filament 14 in Fig. 5 is at ground potential, it is very much simpler to insulate the filament winding 13 in this embodiment than in the embodiments of Figs. 1 and 3, in which latter embodiments the filament winding must be insulated in such a way as to withstand rather high voltages with respect to ground. Thus, a decided advantage is pro-

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vided by the Fig. 5 embodiment. For this embodiment, it is possible to use a tap on the primary winding 10 to supply the filament 14, rather than a separate filament winding, if desired, since the filament 14 operates at ground potential and since it is possible to ground one side of the primary winding.

The operation of the circuit of Fig. 5 will be understood from an examination of Fig. 6. In Fig. 6, the solid line curve E_F represents the potential of point F with respect to the zero axis or ground, while the dashed line curve E_G represents the potential of point G with respect to ground. Similarly to Fig. 4, if the potential of point F were taken as a zero axis of reference, E_G would be sinusoidal about such an axis with a peak voltage of six kilovolts, since the voltage E_G with respect to E_F is the voltage across winding 12.

From a comparison of Figs. 3 and 5, it may be seen that these circuits are exactly the same with a single exception, which is that the rectifier 15 is poled oppositely in the two circuits. Therefore, when switch 11 in Fig. 5 is closed to energize the circuit, voltage variations of a character exactly similar to those described in connection with Fig. 4 take place, so that the curves of Fig. 6 resemble those of Fig. 4; however, since the rectifier is poled oppositely in Fig. 5 with respect to Fig. 3, the curves of Fig. 6 are disposed oppositely from the zero axis with respect to the curves of Fig. 4. Thus, in Fig. 5, the rectifier connections are such that when rectifier 15 conducts to charge condenser 4, E_F goes negative with respect to ground, and the charge on said condenser leaks off slightly through resistor 17 between the periods of conduction of tube 15. Since the zero line E_F for the sinusoidal input voltage (E_G with respect to E_F) is thus negative with respect to ground, E_G has the shape shown in Fig. 6 and is a pulsating direct voltage which is negative with respect to ground; E_G with respect to E_F is a sinusoidal wave of six kilovolts peak amplitude, the input voltage across winding 12. The leaking-and-recharging process repeats, and condenser 4 is recharged 60 times per second to substantially the peak voltage of the source.

The voltage E_F with respect to the zero axis or ground is the voltage on collector cell 4, and during steady-state conditions, as shown, is substantially constant at six kilovolts direct current, with charged plate 7 negative with respect to ground plate 5. Therefore, collector cell 4 functions in the conventional manner.

The voltage E_G with respect to the zero axis or ground is the voltage applied to ionizer 1. During steady-state conditions, E_G varies from zero, while tube 15 is conducting, to approximately 12 kilovolts, when E_G reaches its negative peak of six kilovolts with respect to E_F while E_F is held at substantially six kilovolts negative with respect to ground by the non-conduction of tube 15 and the only extremely slow leaking-off of the charge on condenser 4, as described in connection with Fig. 4. Therefore, the ionizer voltage E_G rises to a high value of short duration at the frequency of the supply voltage, or 60 times per second. At these voltage peaks on the ionizer, point G and fine wire electrodes 3 are negative with respect to ground and tubular electrodes 2. The ionizer voltage E_G is therefore a pulsating direct voltage, with the fine wire electrodes 3 negative with respect to the tubular electrodes 2. As in the embodiments previously described,

ionization occurs in "bursts" repeated at a rate of 60 times per second, since E_g reaches ionizing potential only in the vicinity of negative peaks of E_g . However, as previously explained, this non-continuous ionization or ionization in "bursts" does not decrease the cleaning efficiency of the precipitator.

Since in Fig. 5 the ionizer voltage (the voltage on the fine wire electrodes with respect to that on the tubular electrodes) is negative, negative ionization takes place, or in other words, the dust particles are charged negatively. Negative ionization ordinarily produces more ozone than positive ionization. However, it is possible to get adequate ionization at somewhat lower voltages than those described in connection with Figs. 1 and 3, so that the ozone generation may be kept down in Fig. 5 to a value not appreciably in excess of that produced by positive ionization. Thus, in Fig. 5 also, the advantage of fewer circuit elements with undiminished precipitator cleaning efficiency is obtained, as in Figs. 1 and 3, without any noticeable undesirable effects.

In Fig. 5, as in Fig. 3, the tubular elements 2 of the ionizer are grounded, which is particularly desirable for industrial units.

Of course, it is to be understood that this invention is not limited to the particular details as described above, as many equivalents will suggest themselves to those skilled in the art. For example, instead of the commercial 60-cycle alternating current input mentioned, the circuit could if desired be modified to operate at a higher frequency as a radio-frequency power supply, by supplying the primary winding of the input transformer from a radio-frequency oscillator. In this case, an air-core input transformer would preferably be used. The circuit connections and operation would otherwise be exactly similar to those described above. Also, in the circuit of Fig. 1 the rectifier could be oppositely poled if desired, in which case, the operation would be represented by curves of the shape shown in Fig. 2 but reversed with respect to the zero axis. Various other variations will suggest themselves. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of this invention within the art.

What is claimed is:

1. An electrical precipitator for purifying gas comprising a plurality of ionizing electrodes between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, a rectifier and filter circuit connected to said source for deriving from said source a substantially constant potential different from ground for energizing said charged plates, and means for applying to said electrodes to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying between zero and a peak of substantially twice the value of said first-named potential.

2. An electrical precipitator for purifying gas comprising a plurality of ionizing electrodes between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including a rectifier and the capacitance inherent in said plates energized by said source

and connected to said charged plates, and means for applying to said electrodes to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying between zero and a peak of substantially twice the value of said first-named potential.

3. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including the capacitance inherent in said plates for deriving from said source a substantially constant potential of a predetermined polarity relative to ground for energizing said charged plates, means for applying to one of said electrodes to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying with respect to ground between said first-named potential and a potential substantially equal to the absolute value of said first-named potential but of a polarity opposite to said predetermined polarity, and means connecting the other of said electrodes to said charged plates.

4. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including the capacitance inherent in said plates for deriving from said source a substantially constant potential of a predetermined polarity relative to ground for energizing said charged plates, means for applying to one of said electrodes to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying with respect to ground between zero and a potential substantially equal to twice the absolute value of said first-named potential and of said predetermined polarity, and means connecting the other of said electrodes to ground.

5. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including the capacitance inherent in said plates for deriving from said source a substantially constant potential different from ground for energizing said charged plates, and means for applying between said two electrodes to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying between zero and a peak of substantially twice the value of said first-named potential.

6. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes

being a tubular metallic member, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including the capacitance inherent in said plates for deriving from said source a substantially constant potential of a predetermined polarity relative to ground for energizing said charged plates, means for applying to said fine wire electrode to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying with respect to ground between said first-named potential and a potential substantially equal to the absolute value of said first-named potential but of a polarity opposite to said predetermined polarity, and means connecting said tubular electrode to said charged plates.

7. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates comprising alternate charged and ground plates upon which impurities in said gas are collected, a source of alternating current, circuit means including the capacitance inherent in said plates for deriving from said source a substantially constant potential of a predetermined polarity relative to ground for energizing said charged plates, means for applying to said fine wire electrode to energize the same a pulsating unidirectional potential derived from said first-named potential and said source, said last-named potential varying with respect to ground between zero and a potential substantially equal to twice the absolute value of said first-named potential and of said predetermined polarity, and means connecting said tubular electrode to ground.

8. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a one-way conducting device across said source, whereby said capacitance is charged from said source through said device, means connecting one of said electrodes to one terminal of said source, and means connecting the other of said electrodes to one of said groups of plates.

9. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a one-way conducting device across said source, whereby said capacitance is charged from said source through said device, a discharge resistor connected between said two groups of plates, means connecting one of said electrodes to one terminal of said source, and means connect-

ing the other of said electrodes to one of said groups of plates.

10. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a one-way conducting device across said source, whereby said capacitance is charged from said source through said device, means connecting one of said electrodes to said source, and means connecting the other of said electrodes to one of said groups of plates and said device.

11. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a one-way conducting device across said source, whereby said capacitance is charged from said source through said device, means connecting said wire electrode to one terminal of said source, and means connecting said tubular electrode to one of said groups of plates.

12. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a one-way conducting device across said source, whereby said capacitance is charged from said source through said device, a discharge resistor connected between said two groups of plates, means connecting said wire electrode to one terminal of said source, and means connecting said tubular electrode to one of said groups of plates and said device.

13. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, means connecting one of said electrodes to one terminal of said source and the cathode of said rectifier, and means connecting the other of said electrodes to the group of charged plates and the anode of said rectifier.

14. An electrical precipitator for purifying gas

comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a ground of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, means connecting one of said electrodes to one terminal of said source and the cathode of said rectifier, and means connecting the other of said electrodes to the group of ground plates and the anode of said rectifier.

15. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, means connecting one of said electrodes to one terminal of said source and the anode of said rectifier, and means connecting the other of said electrodes to the group of ground plates and the cathode of said rectifier.

16. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates upon which impurities in the gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, a discharge resistor connected between said two groups of plates, means connecting said wire electrode to one terminal of said source and the cathode of said rectifier, and means connecting said tubular electrode to the group of charged plates and the anode of said rectifier.

17. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates upon which im-

purities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, a discharge resistor connected between said two groups of plates, means connecting said wire electrode to one terminal of said source and the cathode of said rectifier, and means connecting said tubular electrode to the group of ground plates and the anode of said rectifier.

18. An electrical precipitator for purifying gas comprising at least two ionizing electrodes of opposite polarity between which an ionizing discharge is adapted to occur, one of said electrodes being a fine wire and the other of said electrodes being a tubular metallic member, a plurality of spaced, parallel collector plates upon which impurities in said gas are collected, said plates comprising a group of charged plates alternating with a group of ground plates, a source of alternating current, means connecting the inherent capacitance between said charged and ground plates in series with a diode rectifier across said source, whereby said capacitance is charged from said source through said rectifier, a discharge resistor connected between said two groups of plates, means connecting said wire electrode to one terminal of said source and the anode of said rectifier, and means connecting said tubular electrode to the group of ground plates and the cathode of said rectifier.

19. An electrical precipitator comprising a first collector plate, a second collector plate spaced from said first collector plate, means for producing a unidirectional voltage connected across said plates, a first ionizing electrode, a second ionizing electrode, and a circuit connecting said means and a source of alternating potential in series across said ionizing electrodes.

20. An electrical precipitator comprising a first collector plate, a second collector plate spaced from said first collector plate, a source of unidirectional voltage connected across said plates, a first ionizing electrode, a second ionizing electrode, and a circuit connecting said collector plates and a source of alternating potential in series across said ionizing electrodes.

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