Oct. 27, 1936. A. W. SIMON 2,058,732

TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

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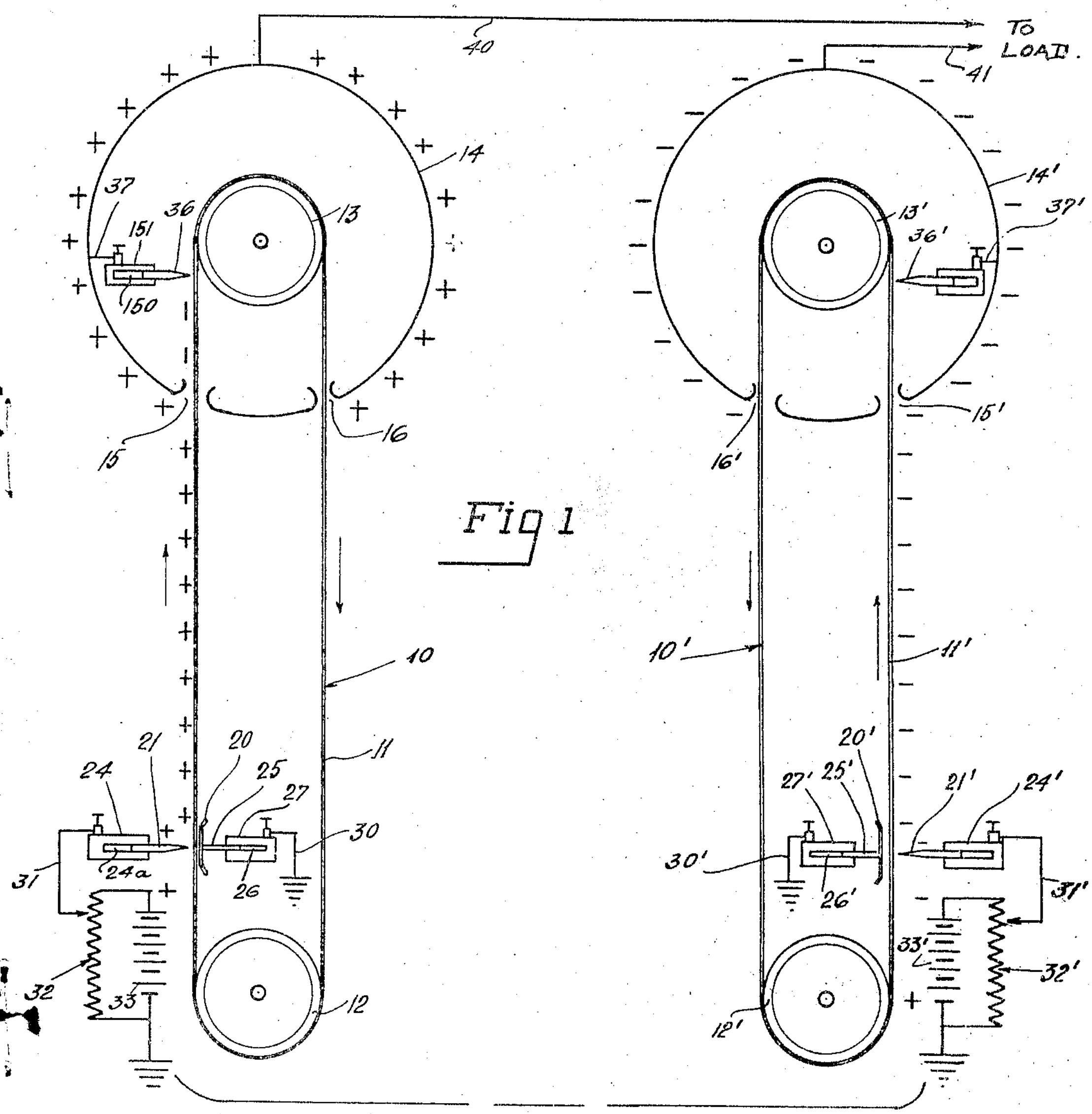
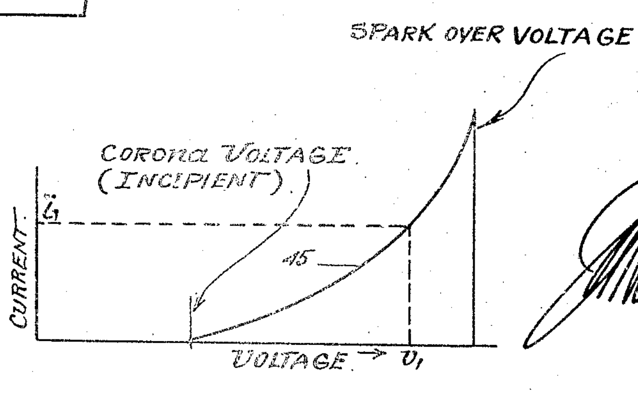


Fig 1

Fig 2.



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TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

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Fig. 3.

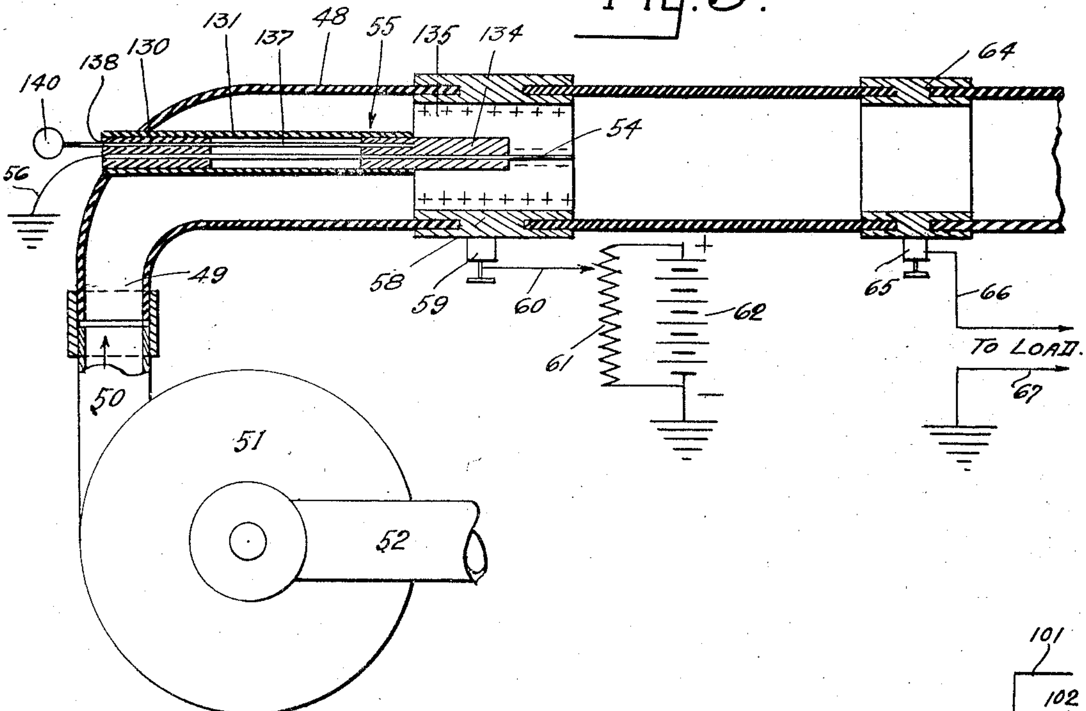
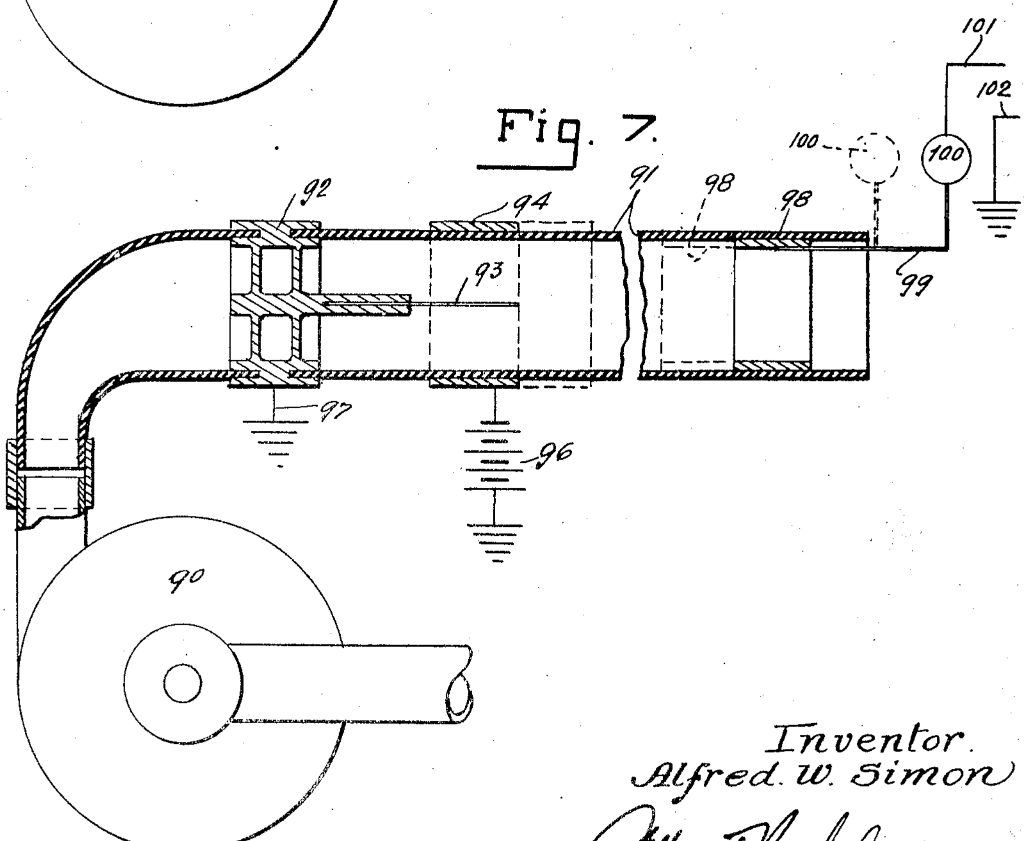


Fig. 7.



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TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

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Fig. 4.

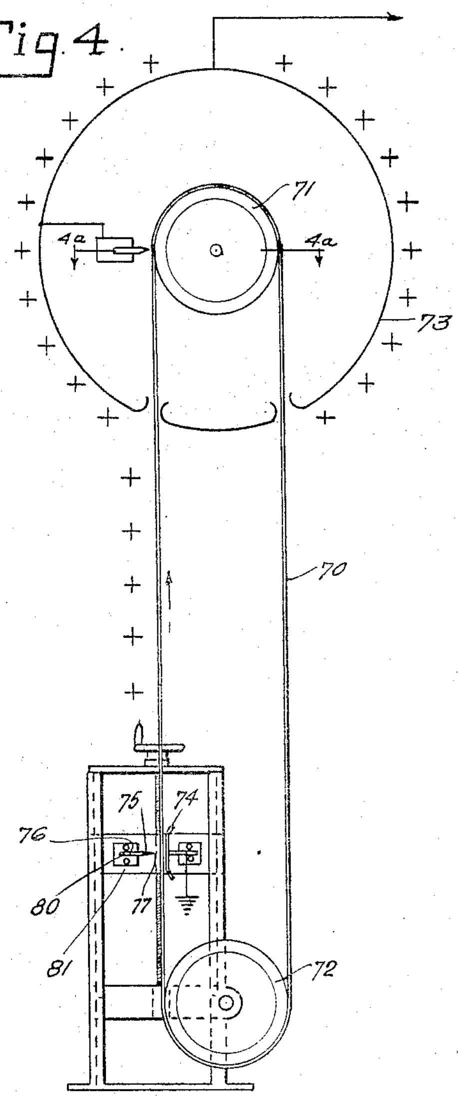


Fig. 5.

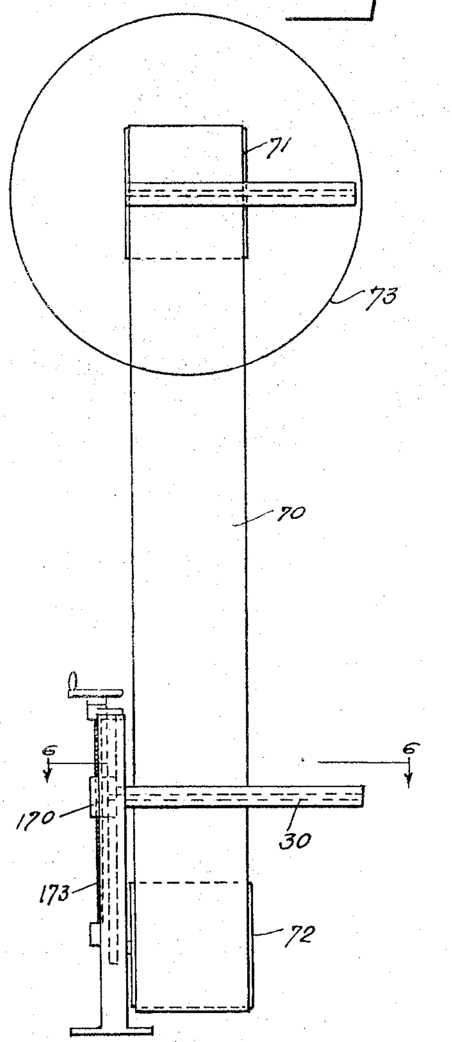


Fig. 4a.

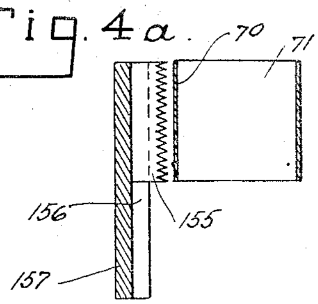
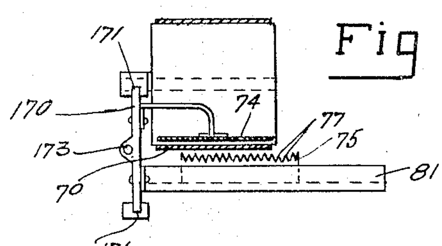


Fig 6



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TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

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Fig 8

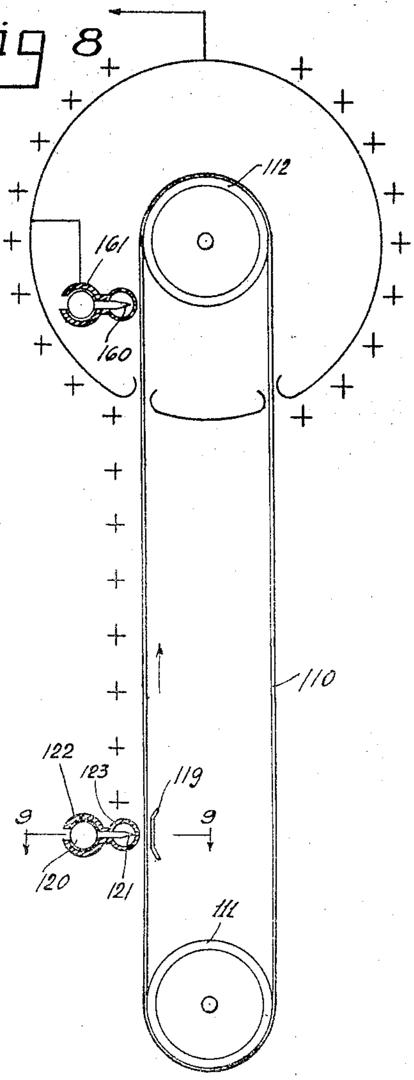


Fig 10

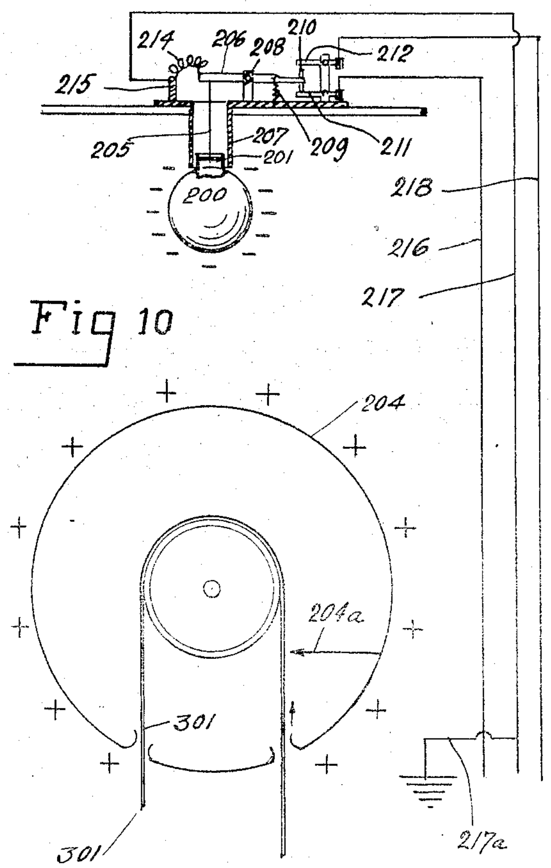


Fig. 9.

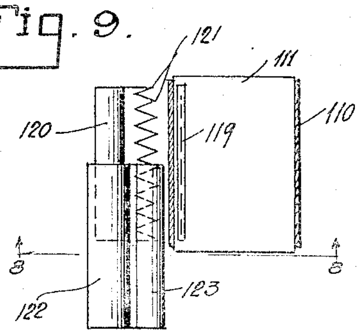
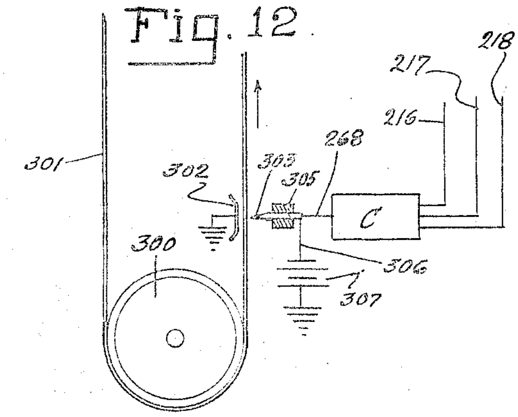


Fig. 12



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TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

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Fig. 13.

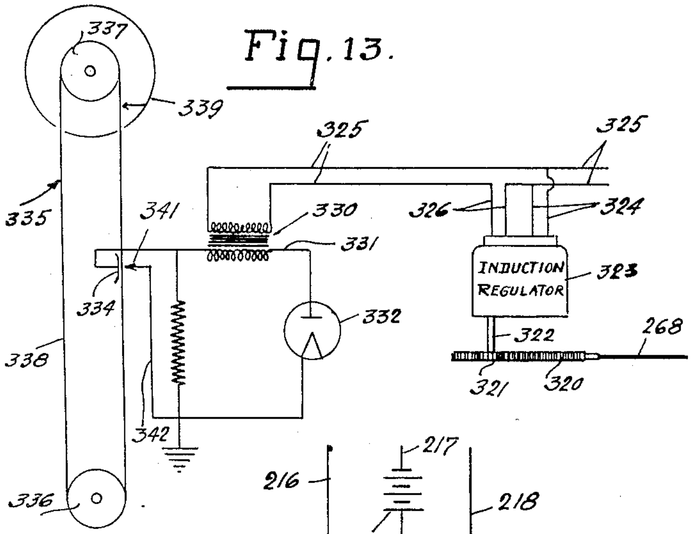


Fig 14

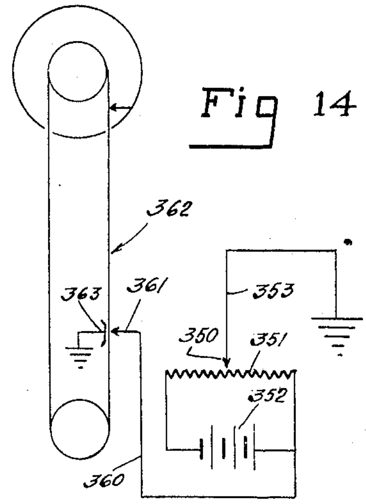


Fig 11a

Fig 11

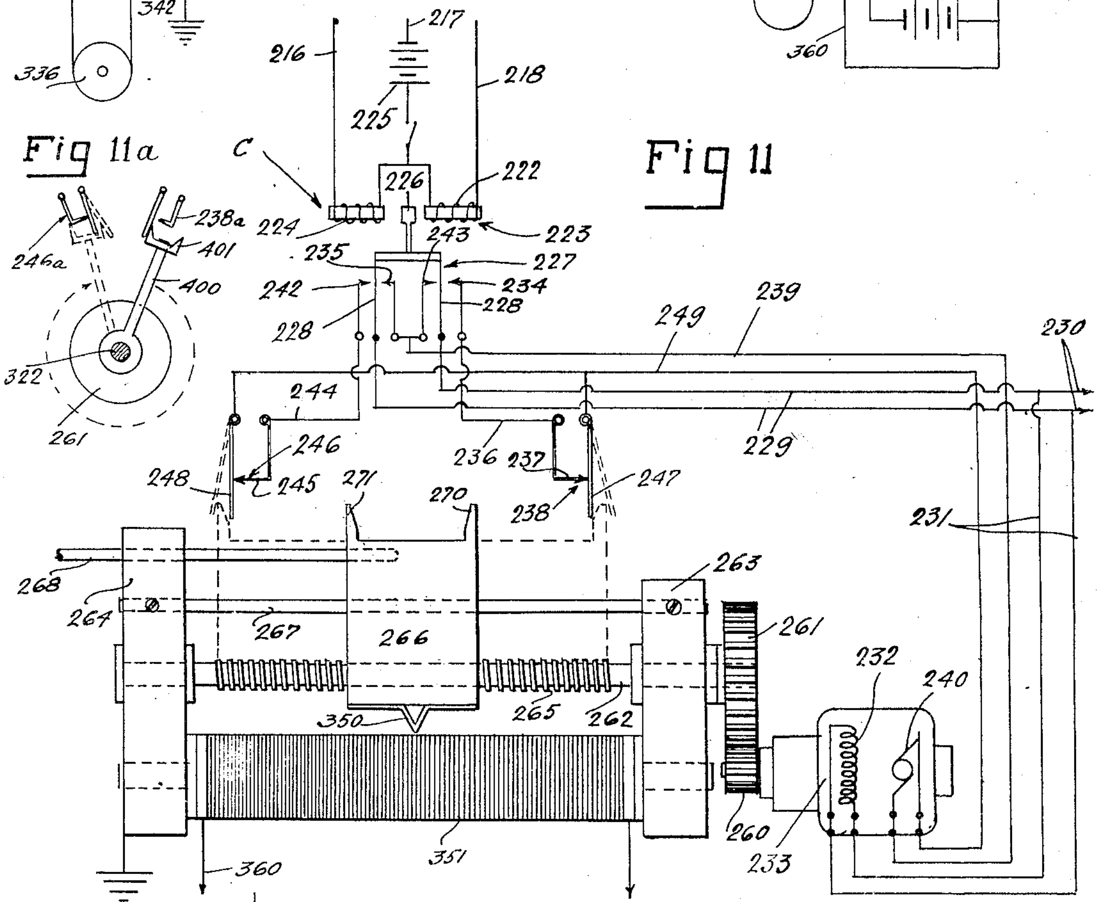
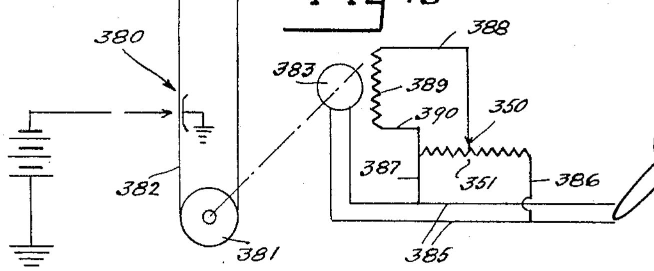


Fig 15



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Patented Oct. 27, 1936

2,058,732

UNITED STATES PATENT OFFICE

2,058,732

TERMINAL VOLTAGE REGULATION FOR ELECTROSTATIC GENERATORS

Alfred W. Simon, Chicago, Ill., assignor of two-sixths to James T. Barkelew and one-sixth to Forrest J. Lilly, both of Los Angeles, Calif.

Application December 4, 1934, Serial No. 755,933

39 Claims. (Cl. 171—329)

This invention relates generally to electrostatic generators, and more particularly to methods of and means for regulating the terminal voltage of electrostatic generators.

In the old and well known rotating disc type of static machine, such as the Toepler-Holtz, Wimshurst, etc., as well as the more modern traveling belt types, no provision is made for controlling the voltage generated. The terminals of these machines, usually provided with a pair of spark spheres, are allowed to charge up either until spark-over occurs, or, with the spheres widely separated, the corona leakage from the machine balances the rate of charging of the spheres.

A machine of this nature in normal operation thus periodically charges up from zero to maximum voltage, and then suddenly drops back to zero voltage as spark-over occurs, or, if operated with spark-over spheres widely separated, or without a spark gap, the voltage generated is determined by the corona losses. In neither instance is the machine designed for maintenance of its terminal voltage at a definite and constant value when a load is applied thereto, as is desirable in commercial uses of the generator.

It is therefore an object of the present invention to provide a method of and means for maintaining the terminal voltage of an electrostatic generator at a desired or constant value under load conditions.

In accordance with the preferred form of the present invention the electric charge carrier, whether of rotating mechanical disc, traveling belt, or gas blast type, is allowed to transport electric charge to the collector until the collector is at the desired potential, and then the charge transported to the collector by the carrier is regulated until the rate of charge input into the collector (electric current input), just balances the rate of outflow of current from the collector, i. e., equals load plus leakage current. This method of charging up the collector, or collectors, until the desired potential is reached, and then regulating the current input to the collectors to balance the current output at that potential, will be seen to allow independent variation of voltage and current, since the collector voltage can be adjusted to any desired value within the range of the machine and then held constant at that value.

This method of voltage and current control is the underlying principle of the invention. There are, however, several general methods of carrying it into effect, and several subdivisions of each of the latter.

A first general typical method of carrying the principle of the invention into effect is by variation of the amount of charge carried per second by the carrier to the collectors. A second general typical method is by regulation of the charge per second that is appropriated from the carrier by the collectors. Several variations of each of these methods will be set forth in the body of the specification, together with other methods in accordance with the broad invention, detailed consideration of which will lead to a full understanding of the broad invention.

It is a further object of the invention to provide for automatic regulation of the potential of the high voltage electrode of the electrostatic generator.

Various specific forms of the invention will be set forth in the following specification, reference for this purpose being had to the accompanying drawings, in which:

Fig. 1 is a diagram indicating one form of electrostatic generator provided with potential control devices in accordance with the present invention;

Fig. 2 is a diagram showing the relation between voltage and current in such a system as Fig. 1;

Fig. 3 shows a gas blast type of electrostatic generator provided with potential control devices in accordance with the present invention;

Fig. 4 is a diagram showing a form of belt type electrostatic generator provided with potential control devices in accordance with the present invention;

Fig. 4*a* is a section taken on line 4*a*—4*a* of Fig. 4;

Fig. 5 is a view looking toward the right at the generator shown in Fig. 4;

Fig. 6 is a section taken on line 6—6 of Fig. 5;

Fig. 7 is a diagrammatic view of a gas blast type of electrostatic generator provided with certain potential control devices in accordance with the present invention;

Fig. 8 is a diagrammatic view of an electrostatic generator provided with variational forms of potential control devices in accordance with the present invention;

Fig. 9 is a section taken on line 9—9 of Fig. 8;

Fig. 10 is a diagrammatic view showing the upper or high potential portion of an electrostatic generator of the belt type and also the electrostatic pick-up device of my automatic potential regulation system;

Fig. 11 shows the automatic control unit operated by the electrostatic pick-up shown in Fig. 10;

Fig. 11a shows a modification of a portion of Fig. 11;

Fig. 12 shows illustratively the lower portion of an electrostatic generator of the belt type to which is applied one form of potential control means as controlled by the electrostatic pick-up device of Fig. 10 and the automatic system of Fig. 11;

Fig. 13 is a diagrammatic view showing a variational method by which the electrostatic pick-up of Fig. 10 and automatic control system of Fig. 11 may be applied to potential control of the electrostatic generator;

Fig. 14 shows a further variational system for accomplishing the same purpose; and

Fig. 15 is a diagram showing a further variational scheme of automatic potential regulation.

The systems first to be discussed involve the method of variation of the quantity of electric charge carried per second by the carrier toward the collectors. Fig. 1 illustrates a method and means for accomplishing this result, in the instance of a belt-type static machine, by regulation of the potential difference applied between inductor electrode and ionizer electrode. In that figure there is shown a machine comprising two units 10 and 10′ which are identical except for being arranged with opposite electric polarities. A description of one unit will accordingly suffice for both, and for convenience parts on the second unit corresponding to those described and given numerals on the first unit will be designated by the same numerals but with primes annexed.

Numeral 11 designates the flexible, dielectric belt of the first unit, which passes around a lower driving drum 12 and an upper drum 13. There is shown around upper drum 13 a hollow electrically conductive shell 14 which serves as the upper terminal electrode of that unit. This electrode 14 is provided with ports 15 and 16 for entrance and exit of the charge carrier belt 11.

On opposite sides of belt 11, just above the point where it leaves lower drum 12, are an inductor electrode 20 and an ionizing electrode 21. The ionizing electrode 21 involves a point or points, as shown, or a knife edge, or a wire, or other equivalent conformation having a very small radius of curvature, placed adjacent one surface of the belt. The inductor electrode 20 presents a surface to the other side of the belt which is much larger in area and avoids sharp points, or conformations of small radius of curvature, on that surface. For instance, the inductor may comprise a substantially flat plate parallel to the belt, but curved away from the belt at its edges, as indicated in Fig. 1. In the instance of Fig. 1, ionizer electrode 21 is mounted to be movable towards and from the belt in a slide mounting 24, this mounting member being of electrically conductive material and being in electrically conductive relation with ionizer electrode 21. Inductor electrode 20 is shown provided with an integral slide element 25 extending perpendicularly thereto and is similarly movable toward and from the belt by sliding of element 25 within a slide way 26 provided in a mounting member 27, member 27 being in electrically conductive relation with the inductor. In the present instance the inductor is grounded, and the ionizer electrode is raised to a high potential above ground, although these relations may be reversed, without altering the action of the machine. As shown, however, mounting member 27, and therefore inductor 20, is grounded by a ground wire 30, while ionizer electrode 21 is connected by means of a wire 31 to the moving arm of a potentiometer resistance 32 which is bridged across battery 33. In the present instance the negative side of this battery is grounded. It will be obvious that the potential difference between inductor 20 and ionizing electrode 21 will depend upon the setting of potentiometer 32.

It is well known that the field set up between a point and a flat plate placed on opposite sides of a belt causes a discharge from the point of gaseous ions of polarity the same as the polarity of the point, and that these ions impinge on the belt and are carried away therewith. In the arrangement shown in Fig. 1, the ionizing point 21 will be positively charged, and therefore the belt will receive a positive charge which it will carry upwardly toward the terminal electrode 14. The positive charge on the belt is collected therefrom within terminal 14 by means of a collector comb 36, which may comprise a point, or series of points, or the equivalent, placed adjacent the belt. This collector 36 is shown connected to terminal 14 by an electrical connection 37. It will be understood by those skilled in the art how collector 36 appropriates the charge from the belt and conveys it to terminal 14. Thus terminal or collector 14 accumulates a positive charge from the positively charged belt-carrier 11.

The other unit of the generator, at the right hand side of the figure, is arranged with the positive pole of its battery 33′ connected to ground, so that its ionizing electrode 21′ becomes negatively charged, and therefore "sprays" a negative charge on the upwardly rising side of belt 11′. The collector or terminal 14′ accordingly accumulates a negative charge, as indicated.

Output leads 40 and 41 are shown electrically connected to terminals 14 and 14′, respectively. The power load is connected across these leads 40 and 41 in the event the generator is to be used as a source of continuous power, as for example to operate an X-ray tube. In such event it is not actually essential that the terminal electrodes 14 and 14′ be employed, since the load can be connected immediately to collector combs 36 and 36′; the use of the large terminal electrodes 14 and 14′ is, however, of considerable advantage, in that they act as accumulators or reservoirs of electric charge and thus prevent sudden changes in the voltage across the load due to changes in the load device or due to other causes, which, if they occur too rapidly, might be difficult for the control mechanism to follow instantaneously. For this reason it is also of advantage to add to the electrical capacity of the terminals by connecting in parallel with them Leyden jars or other forms of condensers to assure stability. The provision of the large terminal electrodes 14 and 14′ also suits the generator to the method of operation which involves charging the terminal electrodes up until arc-over occurs therebetween. Large terminal electrodes also enable higher operating voltages without corona or brush discharge.

Now it will be evident that the charge density on the belt produced by the ionizing electrode, or, as is sometimes said, the amount of charge "sprayed" on the belt by the ionizing electrode, is proportional to the field intensity between ionizing electrode and inductor, and hence upon the potential difference between those electrodes, which in the instance here considered depends upon the adjustment of potentiometer **32**. The rate at which charge is transported by the carrier belt from ionizer to collector therefor depends upon the regulation of potential difference between ionizer and inductor. The relations between various factors involved are shown in the diagram of Fig. 2. In this diagram the voltages between ionizer and inductor are taken as abscissa, and the corresponding electric currents carried by the belt toward the collector (quantity of charge per second) are taken as ordinates. The voltage-current curve **45** shown in the diagram is characteristic of such a system as that shown, namely, a point and plate, and is also characteristic of such systems as a fine wire and plate, a wire and concentric cylinder, etc., which may be employed in modified forms of the machine. As shown by this diagram, there is no current flow accomplished by the carrier belt until the voltage reaches the incipient corona value. From this point the current gradually rises, as shown by the curve, until the voltage between ionizer and inductor reaches a spark-over value; and when spark-over occurs, the electrostatic field between ionizer and inductor of course breaks down and charging of the belt (the electric current of the diagram) falls immediately to zero. The operating voltage range of the machine is accordingly between the incipient corona voltage and the voltage for spark-over and for proper operation the voltage must be so regulated at all times as to be within these limits.

The present method of operating the generator to supply a load current at a substantially constant terminal voltage is first to adjust the ionizer-inductor voltage to allow the high voltage terminals to charge up to the desired terminal voltage, and then to regulate the ionizer-inductor voltage to maintain the inflow of current to the terminals (rate of transportation of electric charge by the carrier belt) to equal the outflow of electric current from the terminals, this outflow current being made up of load current plus leakage. In this way a load current of any value can be drawn from the terminals at any terminal voltage desired, within the range of the generator. It will be evident, therefore, that this method of regulation permits independent variation of load current and terminal voltage.

The generator shown in Fig. 1 is a two unit machine, involving two terminal electrodes charged positively and negatively, respectively. It is equally possible to operate the generator as a one unit machine, the load being connected, for instance, across the terminal **14** of one unit and ground. It will be obvious that the method of voltage regulation of the present invention applies to such a one unit type of machine in precisely the same way as described for the double unit machine.

A single unit gas blast type of machine is shown in Fig. 3. Numeral **48** designates a dielectric insulating tube, of pyrex glass or other suitable material, connected at its inlet end **49** with a tube **50** leading from a suitable fan or blower, designated at **51**. The opposite end of tube **48** is shown discharging to atmosphere, although if desired the tube may be arranged for closed circulation simply by connecting the outlet end of tube **48** with the blower inlet pipe **52**.

Supported within tube **48** is an ionizing electrode, being in the present instance a concentric wire **54** projecting forwardly in the tube from a mounting generally designated at **55**. The details of the mounting here shown will be discussed at a later point in the specification, it being sufficient here to note that there is provided an ionizing electrode in the form of a forwardly projecting, concentric wire. This ionizing electrode is electrically grounded, as indicated at **56**. Mounted in tube **48**, around ionizing electrode **54**, is a cylindrical inductor **58**. This inductor is shown with a binding post **59**, to which is connected a wire **60** leading to the moving arm of a potentiometer **61** which is connected across a suitable source of high potential, as battery **62**. One side of this battery, here the negative side, is grounded, as indicated. Potentiometer **61** and battery **62** represent any suitable source of electromotive force, the potential of which can be regulated. Mounted in tube **48**, at some distance beyond the inductor and ionizing electrodes, is a collector **64**, and this collector may be simply another conductor passing through the wall of the insulation tube beyond the inductor in the direction of gas circulation, although a comb type collector, substantially as used in the usual rotating disc static machine, may be used to advantage. The form here shown is simply a conductive cylinder in the wall of tube **48**. The collector is shown provided with a binding post **65**, to which is connected a lead **66** which goes to the load. The generator here illustrated being of the single unit type, the other side **67** of the load will be connected to ground, as indicated.

A vigorous circulation of the gas in the insulating tube is maintained by the blower or pump. As is evident from Fig. 1, the direction of the circulation is from the inductor **58** to the collector **64**. The potential difference between inductor **58** and ionizing electrode **54** is adjusted to such a value, in the present instance by regulation of potentiometer **61**, that gaseous ionization or corona is produced at the surface of ionizing electrode **54**, and such that gaseous ions so produced, which are of the same polarity as inductor **58** (here positive ions) are drawn in and held by ionizing electrode **54**, while the ions of opposite polarity (here negative ions) are attracted toward inductor **58**. The attraction of the negative ions to move toward inductor **58**, however, is overcome by the gas blast, and these ions are therefore moved up the tube toward collector **64**. This selective differentiation between the ions of opposite polarities is of course due to the considerable difference in the intensity of the field adjacent the small ionizing electrode **54** and adjacent the comparatively large area inductor **58**, the force exerted on the negatively charged ions to move toward the latter electrode of course being very much smaller than the force exerted on the positively charged ions to move toward the small ionizing electrode **54**. Thus, instead of traveling across the tube and lodging on the inductor, the ions of polarity opposite to that of the inductor are carried along the tube in the direction of the circulation of the gas.

The effect of the inductor continues now unabated and more negative ions are continually formed and carried along the tube, so that there is produced a continuous stream of electric charges of one sign passing along the length of the tube. In so passing up the tube this electric charge of course does work in moving against the attractive force of the inductor, and this work must appear as increased potential of the charges as they travel along the tube. The charge from this current of gas is collected from the gas current by means of collector **64**, and the potential of this collector accordingly rises proportionately to the quantity of charge which it collects from the gas stream. It is now possible to connect a load across collector **64** and ground, as indicated in Fig. 3. Of course, if two such units as shown in Fig. 3 are provided, the load may be connected across their respective collectors, after the manner of the connections shown for the belt type machine in Fig. 1.

The current and potential relations will now again be as shown in the diagram of Fig. 2, and the machine may be regulated in precisely the same manner as explained previously in connection with Fig. 1. The potential difference applied across inductor and ionizing electrode is adjusted until the gaseous ionization is produced, whereupon collector **64** immediately begins to charge up. When the potential of the collector has reached the desired value, the potential difference between inductor and ionizing electrode is then regulated until the quantity of charge passing up the tube per second, or in other words the rate of electric current input to collector **64**, just balances the load current plus leakage losses, which constitutes the output of the machine. Thus again the machine is capable of independent adjustment of current and terminal voltage.

The quantity of charge given to the carrier may also be regulated in several different manners by shifting the ionizing and inductor electrodes relatively to each other or to the carrier.

In Fig. 1, for instance, ionizing electrode **21** is shown mounted to slide perpendicularly towards and from the carrier belt in slide way **24a** in its mounting member **24**, while the rearward perpendicular extension **25** of the inductor plate **20** is arranged to slide in way **26** provided in mounting member **27**. It will be evident that the strength of the electrostatic field between ionizer and inductor is adjustable by moving either the ionizer or inductor towards and from the belt, or, more broadly considered, by moving the ionizer and inductor electrodes relatively to each other. And this may be accomplished, either by moving either one of the two alone, the other remaining stationary, or by adjustment of the position of both. The principle of operation of the machine with this adjustment means is essentially the same as before, the electrodes being moved toward each other sufficiently closely to produce gaseous ionization and charging of the upwardly rising belt, and being sufficiently close to each other (of course, avoiding spark-over) that the charge on collector or terminal electrode **14** continues to build up and the terminal voltage of the collector continues to rise until the final desired terminal voltage is reached. Inductor and ionizing electrodes **20** and **21** are then relatively separated from each other and adjusted at such a distance that the rate of charge input to terminal electrode **14** just balances the load current and leakage losses which constitutes the output from the terminal electrode.

In the case of a two unit machine such as shown in Fig. 1, each unit must be adjusted as described above independently of the other.

Figs. 4, 5 and 6 show a variational manner of adjusting the quantity of charge given to the belt carrier by movement of a charging electrode. The belt **70** is shown passing around upper and lower drums **71** and **72**, the upper drum being surrounded by collector sphere **73**. An inductor plate **74** is shown adjacent the inner surface of the rising sides of the belt, and an ionizing or charging comb **75** is shown adjacent the outer surface of the belt immediately opposite inductor **74**. Comb **75** is shown to consist of an electrically conductive bar **76** extending transversely of the belt and provided with discharge points **77** lying closely adjacent but out of contact with the surface of the belt. Of course, any equivalent for points **77**, such as a knife edge, etc., may be used in place of specific points. Bar **76** is arranged to slide transversely in a way **80** provided in a mounting member **81**. A suitable source of electromotive source will be understood to be applied across ionizing comb or electrode **75** and inductor plate **74**. It will now be evident that the width of belt **70** which will receive charge will depend upon the transverse position of comb **75** with respect thereto. When the comb is in position squarely opposite the belt, the entire width of the belt will receive charge, and this position is the maximum charging position. When the belt is displaced somewhat to one side, as shown in Fig. 6, the active width of the belt is reduced to the extent covered by the comb, and the total charge given to the belt evidently reduced accordingly. Thus in this instance the charge per second carried by the carrier belt is regulated by adjustment of the active width of the belt, which in turn is controlled by transverse adjustment movement of the ionizing comb or electrode.

Fig. 7 shows a typical application of the method of relative movement of inductor and ionizing electrode as applied to the gas blast type of generator. In this figure a blower **90** is arranged to maintain a blast of gas in a dielectric tube **91**. Placed in tube **91** is an ionizing electrode support **92** which carries an ionizing wire electrode **93** in a central position within tube **91**. The inductor electrode in this instance is a cylinder **94** placed around tube **91** and arranged to be movable longitudinally thereon. A suitable source **96** of electromotive force is connected at one side to inductor **94** and at the other side to ground, while electrode support **92** may be grounded, as at **97**. The source of electromotive force **96** connected as shown is merely typical of any means for applying a suitable potential difference between ionizing electrode **93** and inductor electrode **94**. Located along the tube in the direction of gas flow from inductor **94** is an internal collector tube **98**, here shown furnished with a forwardly projecting arm **99** having at its outer end a terminal electrode **100**. An electrical lead **101** leading from terminal **100** may be connected to load, while the other side **102** of the load may be grounded, as indicated.

The generator of Fig. 7 operates essentially in the same manner as the previously described form of Fig. 3, the potential difference between the inductor and ionizing electrode being made sufficient that the electrostatic field established between said electrode creates the required degree of ionization about inner electrode **93** to produce the desired charge of the gas flow between electrode **93** and collector **98**. It will be evident that when inductor electrode **94** is moved along tube **91** to a position entirely surrounding ionizing electrode wire **93**, the electrostatic field therebetween is at a maximum, and consequently the charge given to the gas current and carried up the tube to the collector is then at its maximum value. Inductor 94 is shown in this position in full lines in Fig. 7. On the other hand, by moving inductor 94 along tube 91, the electrostatic field between ionizer and inductor is decreased in intensity, with the result that gaseous ionization is lessened, and, finally, the electric charge carried along the tube by the gas current is decreased. Here again, the method of operation of the generator is first to place inductor electrode 94 in such a position, as the full line position in Fig. 7, that the charge on the collector and terminal electrode will continually build up until the desired collector terminal voltage is reached, at which time inductor electrode 94 is moved relatively to ionizing electrode 93 to adjust the electrostatic field between those electrodes to such a value that the rate of electric charge carried along the tube to the collector and terminal electrode just balances the load current and leakage from the collector and terminal electrode.

Certain of my machines now to be described accomplish the terminal voltage regulation method of the invention by adjustably shielding the ionizing electrode, in such a way that only a desired extent of the ionizing electrode is active in producing charge.

Figs. 8 and 9 show this form of the invention applied to a belt type generator. In said figures numeral 110 designates generally the flexible belt, which passes downwardly around lower drum 111 and then rises to pass over an upper drum 112 at the collection end of the generator. A spherical collector electrode 113 surrounds drum 112. Placed adjacent the inner surface of the rising side of the belt is the usual inductor plate 119, and located oppositely thereto, on the other side of the belt, is a rod 120 which extends transversely of the belt and is provided with ionizing points 121 which extend toward the surface of the belt. Fitted to slide longitudinally on rod 120 is a shield member 122 provided with a metallic shield portion 123 which surrounds and shields points 121. It will be evident that by sliding this shield member back and forth along rod 120 more or less of points 121 are enclosed within shield portion 123, and are thus shielded and prevented from having any ionizing or charging action. Accordingly, when the shield is entirely removed, charging of the belt is at a maximum; when the shield covers all of the points, there is no charging action at all produced by the points; while by regulating the position of the shield between these extremes any degree of charging of the belt within the limits of the machine may be achieved.

Fig. 3 shows the application of the method of shielding the ionizing electrode to the blast type generator. The wire electrode 54 of that figure is mounted at its rear end in a cylindrical mounting member 130, which in turn is mounted in the rear end of a supporting tube 131 which extends through and is supported by the curved rearward end of dielectric tube 48 and extends concentrically within the straight portion of said tube 48 to a point substantially even with the rearward edge of inductor electrode 58. An electrode shielding tube 134 is mounted to slide longitudinally within tube 131, and is provided with a central bore 135 adapted freely to pass ionizing electrode wire 54. This tube or shield 134 is movable longitudinally within tube 131 by means of an operating rod 137 attached to its rearward end and extending through a bore 138 in mounting member 130. Rod 137 is freely movable within bore 138, but is provided with a gas tight fit therein. A handle 140 on the rearward end of operating rod 137 may be grasped and pulled rearwardly to retract shielding tube 134 and expose electrode wire 54 for the total extent of its length opposite inductor 58. In this position of the parts the field intensity adjacent the ionizing electrode is at its maximum value, and gaseous ionization and the rate of electric charge transportation along the tube is therefore at its highest value. On the other hand, when operating rod 137 is moved in a forward direction to cause shielding tube 134 to surround the entire length of the ionizing electrode wire 54 which is opposite inductor 58, the electrostatic field then exists between the surface of tube 134 and inductor 58; and in this instance, as will be well understood by those skilled in the art, the field intensity adjacent tube 134 will be much weaker in intensity than was the field adjacent electrode wire 54 (for the same conditions of potential difference) when shielding tube 134 was withdrawn within tube 131. Shielding tube 134 is made of such diameter that when it is in the last described position, that is, entirely surrounding the extent of the electrode wire within inductor 58, the field intensity at the surface of tube 134 will not be sufficient to produce gaseous ionization, and the generator is in inoperative position. For intermediate positions between the extremes mentioned, such as in the position illustrated in Fig. 3, there is an active portion of the ionizing electrode wire 54 which produces gaseous ionization and results in effecting a charge of the gas current which is moving at all times along the tube, and the extent of such action of course is determined by the active length of the ionizing wire, and consequently upon the position of shielding tube 34. Consequently, the rate of charge transportation up the tube by the gas current is adjustable to any value desired within the range of the machine by moving shielding tube 134 forwardly or rearwardly on the ionizing electrode 54.

It will be evident that the shielding method now described in its application to the belt type (Figs. 8 and 9) and also to the blast type (Fig. 3) generators function in their final effect to regulate the rate of electric charge input to the collector or terminal electrodes; and the method of operation in both instances is again first to adjust the charging action of the carrier, by unshielding the ionizing electrode, until the collector or terminal electrodes charge up to the desired terminal voltage, and then to regulate the charging of the carrier, by shielding the proper extent of the ionizing electrode, until the rate of charge input, or electric current input, to the collector terminals balances the load current plus leakage losses drawn therefrom.

The previously described methods and means all involve regulation of the amount of charge given to, or transported by, the carrier medium. methods now to be described involve regulation of the amount of charge input to the collector terminals by regulation of the amount of charge per second appropriated from the carrier. This variation is here shown for illustrative purposes in connection only with the belt type of generator, although it should be obvious that the scheme is broadly applicable to other types of generators as well.

Fig. 1 shows one means for regulation of the quantity of charge appropriated per second from the belt. The collecting electrode or comb 36, which involves a point or series of points placed adjacent but out of contact with the charged surface of the belt, is shown as mounted to move towards and from the belt in a guide way 150 which extends perpendicularly in the belt in an electrode mounting member 151. Since the charge appropriated by electrode 36 depends upon its proximity to the belt, the capability for movement of comb 36 provides means for regulation of the rate of charge input to the collector terminal.

Fig. 4*a* shows a means for regulation of the quantity of charge appropriated by the belt by lateral shift of the collector comb. In this instance the collector comb 155 is mounted to slide transversely of the belt in a way 156 provided in a mounting member 157. It will be evident that the width of belt from which charge will be collected will depend upon the position of comb 155 with reference to the belt, and that the rate of charge input to the collector accordingly depends upon the position of the shiftable comb.

Fig. 8 illustrates how regulation of charge collected from the belt may be effected by shielding. The collecting comb 160 is in this instance made in the same form as the ionizing electrode 120, 121 shown at the bottom of Fig. 8, and a transversely slidable shield 161 is provided which is adapted to shield more or less of the active points of the comb. It will be evident that the rate at which charge is collected from the belt will depend upon the position of shield 161.

In all of the last three instances, the method of regulation is to allow the collector to charge up until the desired potential is reached, and then to regulate the rate at which charge is appropriated from the belt to balance the load output and losses from the collector.

Another variational method of regulation of potential is by controlling the distance between inductor and ionizer, on the one hand, and the collector electrode or comb, on the other. Fig. 7 shows this scheme applied to the gas blast type of machine. In this instance the collector electrode 98 is movable longitudinally in tube 91. Since the distance which the charged gas must be transported up the tube determines the final potential of the collector, the position of electrode 98 controls the potential of the generator. The method of operation is first to charge up the collector to the desired potential, and then to regulate the position of 98 to hold the potential constant with the rate of charge input equal to load plus losses.

Figs. 4, 5 and 6 show a belt type machine in which the ionizer 75 and inductor 74 are movable in a direction parallel to the belt for the purpose of regulating the potential of the collector. As shown, the ionizer and inductor are mounted on an insulation slide member 170 which slides vertically, parallel to the belt, in ways 171. A screw 173 operating on slide member 170 is shown as a means for accomplishing vertical movement of member 170. The method of control is to allow the collector to charge up to the desired potential, and then to adjust the position of the movable ionizer and inductor unit in such a manner as to hold the potential constant with the rate of charge input to the collector equal to load plus losses. It will be evident that the effect with this control arrangement, as well as with that described in the preceding paragraph, the effect is to control the final potential of the collector for a given rate of transportation of charge to the collector, since the effect is to vary the work done in carrying a given quantity of charge per second to the collector.

Figs. 10 to 15, inclusive, show various systems for automatic regulation and maintenance of potential. Fig. 10 shows one typical and preferred electrostatic pick-up means, which is adapted to be moved under the control of the potential of the high voltage sphere. In this instance the pick-up consists of a hollow sphere 200, preferably of very thin sheet metal, provided with a short cylindrical collar 201 and suspended over the high potential sphere 204 of the electrostatic generator by means of a wire 205 connected to the end of a pivoted lever 206. The short collar 201 is loosely received within a vertical cylinder 207, which serves the double purpose of preventing the globe 200 from swinging and also prevents the formation of corona on wire 205. The globe 200 is so placed as to be subject to the electric attraction of the terminal or collector 204 of the generator, as indicated. Sphere 204 is shown provided with a collector comb 204*a* adapted to receive charge from generator belt 301.

Lever 206 is pivoted at 208, and is provided with a spring 209 which counterbalances the weight of globe 200. The rear end of lever 206 is provided with a short vertical contact rod 210, which, when there is no attractive force on the globe, makes contact with an insulated lower electrical contact 211. When globe 200 is attracted downwardly with sufficient force, this contact rod makes contact with an upper insulated contact 212. The outer end of the lever is provided with a flexible connection 214 attached to a binding post 215. When the rearward end of lever 206 is in the lower position (Fig. 10), an electrical circuit is made from a lead 216 connected to contact 211, through contact 210, lever 206, connection 214, and binding post 215 to a lead 217. When the globe 200 is strongly attracted by the high voltage sphere, and lever 206 is swung to a position with rod 210 against contact 212, an electrical circuit is formed from a lead 218 through said contact 212, contact 210, lever 206, connection 214 and binding post 215 to lead 217. When the attractive force on globe 200 is such as just to balance spring 209, with the lever in an intermediate position with contact rod 210 midway between contacts 211 and 212, circuits 216, 217 and 218, 217 are open. Lead 217 is provided with a ground connection 217*a*, so that the globe 200 is grounded through wire 205, lever 206, flexible connection 214, lead 217, and ground connection 217*a*. Under these conditions, due to the inductive effect of the highly charged terminal 204, a charge of opposite sign to that on the terminal flows into the globe 200, resulting in an attractive force being exerted by terminal 204 on globe 200. This attractive force will be directly proportional to the voltage of the terminal 204.

The spring 209 is so chosen and adjusted that the contact 210 will leave contact 211 just before the electric force on globe 200 reaches a value corresponding to the final voltage desired, and such that exactly the voltage desired will cause the lever to take an equilibrium position with contact 210 midway between contacts 211 and 212.

Leads 216, 217 and 218 are indicated in Fig. 11 as going to an automatic control unit C. As shown in detail in Fig. 11, wires 217 and 218 are connected to one winding 222 of an electrical relay 223 of unit C, and wires 216 and 217 are connected to the other winding 224 of said relay, a battery 225 and a switch S being included in lead 217. The relay armature 226, which is arranged to be pulled over in one direction or the other as windings 222 or 224 are energized, operates a double-pole double-throw reversing switch 227.

The two movable arms 228 of switch 227 are connected by leads 229 across the electric supply line 230. Also connected across line 230 are leads 231 which are connected to the field winding 232 of a motor 233. The pair of relay contacts 234 and 235 that are closed when relay winding 222 is energized are connected one by a wire 236 to the stationary contact 237 of a limit switch 238, and one by a wire 239 to the armature 240 of motor 233. The pair of relay contacts 242 and 243 closed when relay winding 224 is energized are connected one by a wire 244 with the stationary contact 245 of a second limit switch 246, and one by wire 239 to motor armature 240. The movable contacts 247 and 248 of limit switches 238 and 246, respectively, are connected to a wire 249 leading to the armature 240 of motor 233.

It will be evident that, limit switches 238 and 246 both being assumed closed, movement of relay armature 226 to one side or the other as it is alternately attracted by energization of relay windings 222 and 224 will operate reversing switch 227 to connect line wires 229 to the motor armature first with one polarity and then the other. Since the polarity of the field current is not correspondingly reversed, motor 233 accordingly runs in one direction or the other depending upon which way the switch is thrown by the relay.

The shaft of motor 233 is shown provided with a drive pinion 260 driving a gear 261 on a rotatable lead screw shaft 262 journaled in frame members 263 and 264.

Shaft 262 is cut with a screw thread 265, and working thereon is a follower carriage 266. As here shown, carriage 266 slides on a guide rod 267 mounted parallel to lead screw 262 between supports 263 and 264. In one form of the invention, carriage 266 is provided with an operating rod 268 which is also parallel to lead screw 262 and reciprocates through support 264 as carriage 266 is worked back and forth by means of screw 262.

The two previously mentioned limit switches 238 and 246, which are so constructed as to stand normally closed, are opened by lugs 270 and 271, respectively, mounted on traveling carriage 266. Motor 233 is so arranged and connected that lead screw 262 is rotated in a direction to move carriage 266 toward the right (as viewed in Fig. 11) when relay winding 222 is energized and switch 227 is moved over to the right, and is rotated in a reverse direction to move the carriage toward the left when relay winding 224 is energized and switch 227 is moved over to the left. Upon reaching positions at the desired end limits of such movements, carriage 266 brings its lugs 270 or 271 into engagement with the movable contacts of limit switches 238 or 246, as the case may be, opening the limit switch and so opening the circuit which is at that time energizing the motor armature. Driving motor 233 accordingly stops and can only be restarted by causing switch 227 to throw over in the reverse direction, which will energize the armature winding with reverse polarity and so operate the motor to move the carriage in the reverse direction. The carriage is accordingly limited in movement in both directions, and can be caused to reciprocate between these limiting positions, or between any positions within this limiting range, by alternate energization of relay windings 222 and 224.

In the operation of the system, relay winding 222 is energized and carriage 266 caused to travel toward the right when the globe 200 of Fig. 10 is strongly enough attracted by the charge on sphere 204 to overcome the force of spring 209, the resulting downward movement of the globe causing contact 210 to lift into engagement with contact 212, thereby closing circuit 217, 218 leading to relay winding 222. And relay winding 224 is energized whenever the charge on sphere 204 is sufficiently weak that globe 200 is permitted to rise sufficiently, under the influence of spring 209, that contact 210 comes against lower contact 211, resulting in closing of circuit 216, 217 leading to relay winding 224. In the neutral position, with the forces between sphere 204 and globe 200 so balanced that contact 210 takes a position midway between contacts 211 and 212, circuits 216, 217 and 217, 218 are both open, and both windings of the relay are deenergized. The relay armature then takes a central normal position, such as indicated in Fig. 11, with switch 227 open both ways. Such a normal central position for the relay armature may be established in any usual manner, for instance, by use of a centering spring, not shown.

It will thus be evident that motor driven carriage 266 will be moved toward the right when pick-up globe 200 is attracted by sphere 204 and is moved downwardly until contact is established between contacts 210 and 212, and will be moved toward the left when the globe is lifted, with weaker field between 200 and 204, and contact is established between contacts 210 and 211. In an intermediate position, with contact 210 between but out of contact with contacts 211 and 212, the carriage will be stationary.

The described reverse movements of carriage 266 with rise and fall of field strength between spheres 200 and 204 may be utilized in several manners to control the rate of charging of sphere 204. One such manner is indicated in Fig. 12.

In Fig. 12 there is shown at 300 and 301 the lower wheel and belt of the electrostatic generator indicated partially in Fig. 10. The usual grounded inductor electrode is indicated at 302, mounted adjacent the rising side of the belt, and the pointed ionizing electrode 303 is mounted opposite thereto on the other side of the belt. In the instance here shown, the ionizing electrode is mounted in guide means 305 for reciprocation towards and from the belt (similarly to the machine of Fig. 1), and connected to said electrode is a wire 306 having a source of electricity 307, the other side of source 307 being grounded. Operatively connected to ionizing electrode 305 is the previously mentioned operating rod 268, which is moved by the carriage 266 and motor 233 of control unit C (Fig. 11). This operating rod 268 is preferably of insulation material.

To set the system of Figs. 10, 11 and 12 in operation, the electrostatic generator is started up and belt wheel 300 driven at constant speed. Since at the start the terminal voltage of collector 204 is zero, pick-up globe 200 is in its uppermost position and contacts 210 and 211 are together, with circuit 216, 217 closed and relay winding 224 energized. Control motor 233 is accordingly driven to move carriage 266 and the operating rod 268 and ionizing electrode 303 toward the left, as viewed in Figs. 11 and 12. The tip of the ionizing electrode thus approaches the surface of the belt, coming to a position which is determined by the position of limit switch 246. It should here be noted that both limit switches

238 and 246 may be adjustable in position, so that the limiting positions of the carriage and the ionizing electrode may be set as desired. The ionizing electrode 303 thus being brought to its position of closest proximity with the belt, a maximum electric field exists between ionizer 303 and inductor 302, and the rate at which electric charge is given to the rising belt and transported toward the high potential collector electrode 204 is accordingly at a maximum.

The corresponding current inflow to the collector electrode 204 is previously determined to be considerably in excess of the current drained from the collector by the load connected thereto. Under these conditions the collector electrode charges up and its voltage increases.

When the collector sphere 204 has attained the desired voltage for which the control device is set, the pick-up sphere 200 is pulled downwardly, breaking contact 210 from contact 211 and closing contact 210 with contact 212, thereby causing deenergization of relay winding 224 and energization of relay winding 222. The relay armature is accordingly pulled over to the other side and acts through switch 227 to cause motor 233 to be driven in a reverse direction. Ionizer electrode 303 is accordingly withdrawn in such direction as to decrease the current flowing onto the belt and collected by electrode 204. This proceeds until a point of balance is reached where the current carried by the belt and collected by electrode 204 is just sufficient to balance the outflow from 204 to the load. At this point pick-up sphere 200 may take a position with contact 210 between and out of contact with contact members 211 and 212, both windings of relay 223 accordingly being deenergized. Relay armature 226 may accordingly take a neutral central position with switch 227 open and the field of motor 223 deenergized. With any fluctuation in the strength of the field between spheres 200 and 204, sphere 200 will move either up or down and produce automatically the movement of ionizing electrode 303 required to reestablish the normal field between said spheres.

Accordingly, any change in the potential of high voltage electrode 204 will produce such an actuation of the automatic mechanism as may be necessary to restore the current balance and predetermined voltage of the high potential sphere.

I have here illustrated the automatic mechanism as applied to a physically movable member which controls the current input to the high voltage collector sphere by way of a specific showing of a form in which the ionizer electrode is movable toward and from the belt. It will be understood, however, that the automatic device may be applied as well to any of my other forms of voltage control means which involve a physically movable control member, or to any other control means of that general type not herein specifically illustrated.

In Fig. 13 I show how the automatic regulator system of Figs. 10 and 11 may be applied to control of the voltage which is impressed between the ionizer and inductor electrodes of the generator. In this instance the motor manipulated control rod 268 of Fig. 11 is operatively connected to a rack gear 320 which meshes with a pinion gear 321 on the rotatable control shaft 322 of an induction regulator 323 of conventional type. The primary 324 of regulator 323 is connected across supply line 325, and the secondary 326 of the regulator is connected in series with one side of the supply line. The induction regulator here indicated is of well known type and will require no detailed explanation beyond merely to note that it constitutes a means for regulating the voltage of a supply line and is controllable by a rotatable shaft such as indicated at 322.

Line 325, the voltage of which is thus controllable by means of regulator 323, is connected to the primary winding of a transformer 330. The secondary winding of transformer 330 is included in the plate circuit 331 of kenotron 332. As indicated in Fig. 13, the circuit 331 is connected between the kenotron 332 and the inductor electrode 334 of electrostatic generator 335, the generator being again illustrated as of the conventional traveling belt type, having upper and lower rollers 336 and 337, respectively, charge carrying belt 338, and high voltage collector sphere 339. The electrostatic pick-up sphere and automatic unit are omitted from Fig. 13. The ionizer electrode 341 is mounted as usual on the side of the belt opposite the inductor 334, and is connected by means of wire 342 to the filament of kenotron 332.

It will readily be understood that the voltage between ionizer 341 and inductor 334, and therefore the current flow carried by the belt toward the collector electrode (not shown), will depend upon the voltage impressed upon the primary winding of transformer 330, and therefore upon the setting of induction regulator 323 which controls said voltage. The induction regulator 323 is in turn controlled by the operating rod 268 which is manipulated by the automatically operated control motor 233.

In operation, the electrostatic generator is started up and lower belt wheel 336 driven at constant speed. Since the voltage of the high potential collector sphere is initially zero, the pick-up sphere 200 is initially at its uppermost position, and contacts 210 and 211 closed. Switch S being closed, motor 233 is accordingly energized, in the manner previously described, to drive carriage 266 toward the left, causing rack 320 to turn gear 321 and shaft 322 to manipulate induction regulator 323 in such a manner as to raise the voltage applied across the input of transformer 330. The limit of this increase of voltage is of course again set by limit switch 246, which finally opens the motor circuit and stops the induction regulator in a position with a certain predetermined high voltage applied across transformer 330. Under these conditions a high current flows onto the belt from ionizer 341. This current is previously determined, in the design of the electrostatic generator, to be considerably in excess of the current drained from the collector by the high voltage load which is to be applied thereto. Accordingly, the high potential collector electrode charges up and its voltage increases.

When the collector has attained the desired voltage for which the automatic device is set, control sphere 200 moves downwardly and causes contact to be made between contact 210 and upper contact 212, thereby causing control motor 233 to move operating rod 268 and rack 320 in a reverse direction, and so manipulating the induction regulator as to decrease the voltage impressed across transformer 330. The electric current flowing from ionizer 341 onto the belt is therefore decreased, until a point is reached where the current flowing from ionizer 341 onto the belt and picked up by the high potential electrode is just sufficient to balance that flowing to the load from the high potential electrode. When the current flow into the collector electrode falls slightly below this value, the potential of the collector will fall slightly, sufficiently far to reestablish contact between contacts 210 and 211, in which event the system will operate to increase the potential of the ionizer and thus increase the current flow up the belt to raise the potential of collector 204. Sphere 200 will finally come to an equilibrium position with contact 210 midway between contacts 211 and 212. At this time both relay windings are deenergized, and the motor 233 controlling the induction regulator is stationary.

Any change in load current will then cause a change in the electrostatic field between spheres 200 and 204, causing sphere 200 to move up or down and thereby to cause automatic operation of control motor 233 to adjust the induction regulator in the proper direction and by the proper amount to restore the current balance at the original potential level.

It will be understood, of course, that while the potential regulator constitutes a very suitable and convenient instrumentality for variation of the voltage applied to the kenotron-transformer system, any other suitable voltage control device may be substituted, if desired. It will be understood also that gear 261 of control unit C could be mounted directly on the shaft 322 of the induction regulator 323 (Fig. 11*a*) or motor 233 could be coupled to shaft 322 through the medium of any suitable speed reducer. In such a case suitable provision may be made for the limit switches, designated in Fig. 11*a* at 238*a* and 246*a*, by mounting on the shaft an arm 400 with projecting lugs 401 to operate the limit switch.

Fig. 14 shows another manner by which the automatic control system of Figs. 10 and 11 may be applied to control of the voltage impressed between the ionizer and inductor electrodes of the electrostatic generator. In this instance the traveling carriage 266 which is manipulated by lead screw 262 is provided with a movable electrical contact 350 which rides on a potentiometer winding 351 mounted between supports 263 and 264 (see Fig. 11). A suitable source 352 of high potential electricity is connected across the ends of potentiometer winding 351, as indicated in Fig. 14, and a suitable electrical connection is made to moving contact 350. Such a connection is indicated at 353 in Fig. 14, and may be embodied in any form found convenient. For instance, assuming carriage 266 to be of conductive material, the electrical connection may be considered as made through lead screw 262 to support 264. Support 264 is electrically grounded, thus grounding movable contact 350, as indicated in the diagram of Fig. 14. To one side of winding 351 is connected a lead 360 which goes to the ionizer electrode 361 of the generator, designated diagrammatically at 362 in Fig. 14. The electrostatic pick-up and automatic unit are omitted from Fig. 14. The inductor electrode 363 is shown in Fig. 14 to be electrically grounded. It will be evident that with carriage 266 moved over to the left as viewed in Fig. 11, the voltage applied between ionizer 361 and inductor 363 will be at a maximum, and with the carriage moved over to the right, the voltage will be at a minimum.

The system of Fig. 14 operates in a manner generally similar to that of Fig. 13, the only difference being that a potentiometer voltage control is substituted for the induction regulator and kenotron-transformer system of Fig. 13. It will accordingly not be necessary to give a detailed description of operation in connection with Fig. 14.

Fig. 15 shows an additional method of voltage control. In this instance the electric current input to the high voltage collector electrode is controlled by varying the speed of the charge carrier belt. In Fig. 15 there is shown at 380 the lower portion of an electrostatic generator, including lower belt wheel 381, belt 382 and belt wheel driving motor 383. Motor 383 is a variable speed motor, and may be a shunt motor having a variable resistance in its shunt field circuit. The line 385 is indicated as connected across the armature of the motor, and as having branch leads 386 and 387 which are to be understood as connected across the potentiometer winding 351 of the same control unit C, shown in Fig. 11. Only the potentiometer winding 351 of unit C appears in Fig. 15. The movable contact 350 is connected by wire 388 to one side of motor field winding 389, and one end of the potentiometer is connected by lead 390 to the other side of field winding 389.

It will be understood that movement of control motor 233 of the control unit C, which is under the control of pick-up sphere 200 and the automatic relay, will cause variation of the variable resistance 351 in the motor field winding, and will consequently cause variation in the speed of motor 383 and of generator belt 382. The motor is at first operated by the system at high speed, to charge the high voltage electrode of the generator up to the desired high voltage, after which the pick-up sphere is pulled downwardly, as in the other forms, and causes the automatic system to drive the control motor 233 to so move the movable contact of potentiometer 350 as to cause decrease in the speed of generator driving motor 383, the system finally coming to an equilibrium condition with belt 382 running at a speed to maintain the current inflow to the high voltage electrode at just such a value as to balance the outflow therefrom, at the desired potential level of said electrode.

I claim:

1. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises causing the charge carrier to transport electric charge to the high voltage terminal at a rate in excess of charge outflow from said terminal until the terminal reaches the desired voltage, then regulating the quantity of charge carried per second by the carrier to the high voltage terminal to balance the quantity of charge per second leaving said terminal.

2. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises causing the charge carrier to transport electric charge to the high voltage terminal at a rate such as to bring the terminal to the desired voltage, and then regulating the rate of charge input to the high voltage terminal to balance the rate of charge outflow from the terminal and also to maintain the terminal voltage at the desired level.

3. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises charging the carrier by subjecting it to the influence of an electrostatic field, regulating the strength of said field in such manner that the carrier initially transports electric charge to the high voltage terminal at a rate in excess of charge outflow from said terminal, and then, when the desired terminal voltage is reached, adjusting the strength of the electrostatic charging field until the charge carried per second by the carrier to the high voltage terminal just balances the quantity of charge per second leaving said terminal.

4. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises charging the carrier by subjecting it to the influence of an electrostatic field energized by a source of electricity having a variable potential, regulating the potential of said source of electricity in such manner that the carrier initially transports electric charge to the high voltage terminal at a rate in excess of charge outflow therefrom, and then, when the desired terminal voltage is reached, adjusting the potential of the source of electricity until the charge carried per second by the carrier to the high voltage terminal just balances the quantity of charge per second leaving said terminal.

5. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises causing the charge carrier to transport electric charge to the high voltage terminal at a rate in excess of charge outflow from said terminal until the terminal reaches the desired voltage, and then regulating the rate of collection of charge from the carrier by the high voltage terminal to balance the rate of charge outflow from said terminal.

6. The method of operating at substantially constant terminal voltage an electrostatic generator having an electric charge carrier and a terminal electrode which collects electric charge from the carrier, that comprises charging up the high voltage terminal of the generator until said terminal is at the desired voltage, and then regulating the distance the electric charges are carried by the carrier toward the terminal electrode to hold the terminal voltage constant with the rate of charge input to the terminal equal to the rate of charge outflow therefrom.

7. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier and a high voltage terminal adapted to receive charge from the carrier: means for controllably regulating the quantity of charge per second collected by the high voltage terminal from the carrier to effect a balance between the rate of charge input to the high voltage terminal and the rate of charge outflow therefrom and to hold the terminal voltage at constant value.

8. In an electrostatic generator having a traveling carrier for electric charges, ionizing and inductor charging electrodes adapted to have a difference of potential impressed between them and arranged to cause charging of the carrier, and a high voltage terminal adapted to receive charge from the carrier: electrode guiding and moving means such that at least one of the charging electrodes is shiftable in position to cause variation in charging effect on the carrier.

9. Charging means for the traveling carrier of an electrostatic generator, comprising an inductor electrode and an ionizing electrode arranged to cause charging of the carrier, said ionizing electrode being controllably movable with reference to the carrier to vary the degree of charging effect on the carrier.

10. Charging means for the traveling carrier of an electrostatic generator, comprising an inductor electrode and an ionizing electrode arranged to cause charging of the carrier, and adjustable shielding means for the ionizing electrode adapted to be controllably moved to regulate the effective extent of the ionizing electrode and thereby regulate the degree of charging effect produced on the carrier.

11. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: a charge collecting electrode positioned adjacent the carrier near the high voltage terminal and electrically connected to the terminal, said charge collecting electrode being movable with reference to the carrier to regulate the rate of charge collection by the high voltage terminal.

12. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: a charge collecting electrode positioned adjacent the carrier near the high voltage terminal and electrically connected to the terminal, and a movable shield for said charge collecting electrode, said shield adapted to be moved to adjust the effective charge collecting surface extent of the collector electrode.

13. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: means for regulating the quantity of charge per second transported by the carrier to the high voltage terminal, and automatic means responsive to changes of potential of the high voltage terminal for controlling the last mentioned means to hold the terminal voltage constant with varying rate of charge outflow from the high voltage terminal.

14. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: means for regulating the quantity of charge per second transported by the carrier to the high voltage terminal, and automatic means responsive to the electrostatic field of the high voltage terminal for controlling the last mentioned means to hold the terminal voltage constant with varying rate of charge outflow from the high voltage terminal.

15. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: automatic means for controlling the terminal voltage of the generator, said automatic means comprising a movable electrode placed in the electrostatic field of the high voltage terminal and adapted to be moved with changes in the strength of said electrostatic field, and means

under the control of said movable electrode adapted to regulate the quantity of charge per second transported by the carrier to the high voltage terminal.

16. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: automatic means for holding the terminal voltage of the generator at a constant value, said automatic means comprising a pick-up electrode placed in the electrostatic field of the high voltage terminal and adapted to be attracted thereby, means supporting said electrode for movement between limits toward and from the high voltage terminal, yielding means yieldingly resisting the attraction of the pick-up electrode by the high voltage terminal, means for regulating the quantity of charge per second transported by the carrier to the high voltage terminal, and means under the control of movement of said pick-up electrode and arranged to cause the last mentioned means to increase the rate of charge transportation by the carrier when the pick-up electrode is in its position most remote from the high voltage terminal of the generator and to decrease the rate of charge transportation of the carrier when the pick-up electrode is moved against said yielding means to its position nearest said high voltage terminal of the generator.

17. In an electrostatic generator having a traveling carrier for electric charges, means for variably charging the carrier comprising inductor, and ionizing electrodes mounted in association with the carrier and a source of electricity of variable potential impressed thereacross, and a high voltage terminal adapted to receive charge from the carrier: automatic means for holding the terminal voltage of the generator at a constant value, said automatic means comprising a pick-up electrode placed in the electrostatic field of the high voltage terminal and adapted to be attracted thereby, means supporting said electrode for movement between limits toward and from the high voltage terminal, yielding means resisting the attraction of the pick-up electrode by the high voltage terminal, and means under the control of movement of said pick-up electrode and arranged to increase the potential of said source of electricity when the pick-up electrode is in its position most remote from the high voltage terminal of the generator, and to decrease the rate of charge transportation by the carrier when the pick-up electrode is moved against said yielding means to its position nearest said high voltage terminal.

18. In an electrostatic generator having a traveling carrier for electric charges, means for variably charging the carrier comprising inductor and ionizing electrodes mounted in association with the carrier and adapted to have a source of an electrical potential impressed between them, one of said electrodes being movable to vary the strength of the electrostatic field between the electrodes and thereby to regulate the rate of charging of the carrier, and a high voltage terminal adapted to receive charge from the carrier: automatic means for holding the terminal voltage of the generator at a constant value, said automatic means comprising a pick-up electrode placed in the electrostatic field of the high voltage terminal and adapted to be attracted thereby, means supporting said electrode for movement between limits toward and from the high voltage terminal, yielding means yieldingly resisting the attraction of the pick-up electrode by the high voltage terminal, and means under the control of movement of said pick-up electrode and arranged to move said movable electrode in a direction to increase the rate of charging of the carrier when the pick-up electrode is in its position most remote from the high voltage terminal of the generator and to move said movable electrode in a reverse direction to decrease the rate of charging of the carrier when the pick-up electrode is moved against said yielding means to its position nearest said high voltage terminal.

19. In an electrostatic generator, the combination of a traveling carrier, a variable speed prime mover for driving said carrier, means for charging the carrier, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal for increasing the speed of the carrier driving prime mover when said electrostatic field is below a predetermined strength and for decreasing the speed of the prime mover when said electrostatic field is above said predetermined strength.

20. Charging means for the traveling carrier of an electrostatic generator, comprising an inductor electrode and an ionizing electrode arranged to cause charging of the carrier, said ionizing and inductor electrodes being controllably relatively movable with reference to one another to vary the degree of charging effect on the carrier.

21. Charging means for the traveling belt carrier of an electrostatic generator, comprising an inductor electrode and an ionizing electrode arranged to cause charging of the carrier, said ionizing electrode being controllably movable in a direction transverse to the belt, so as to vary the active width of the belt charged by the ionizing electrode.

22. In an electrostatic generator, a traveling carrier for electric charges, a high voltage terminal adapted to receive charge from the carrier, means for charging the carrier, means for collecting charge from the carrier and conveying it to the high voltage terminal, and means for controllably regulating the distance between the charging means for the carrier and the means for collecting charge from the carrier.

23. In an electrostatic generator, a traveling carrier for electric charges, a high voltage terminal adapted to receive charge from the carrier, means for charging the carrier, means for controlling the rate of charge of the carrier, means for collecting charge from the carrier and conveying it to the high voltage terminal, and means for controllably regulating the distance between the charging means for the carrier and the means for collecting charge from the carrier.

24. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: means for regulating the rate of charge input to the high voltage terminal, and automatic means responsive to the potential of the high voltage terminal for automatically controlling operation of the last mentioned means.

25. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: means for regulating the quantity of charge per second transported by the carrier to the high voltage terminal, and automatic means responsive to the

potential of the high voltage terminal for automatically controlling operation of the last mentioned means.

26. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: means for regulating the rate of charge input to the high voltage terminal, and automatic means responsive to the electrostatic field of the high voltage terminal for automatically controlling operation of the last mentioned means.

27. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: automatic means for controlling the terminal voltage of the generator, said automatic means comprising a movable electrode placed in the electrostatic field of the high voltage terminal and adapted to be moved with changes in the strength of said electrostatic field, and means under the control of said movable electrode adapted to regulate the rate at which the high voltage terminal is charged.

28. In an electrostatic generator having a traveling carrier for electric charges, means for charging the carrier, and a high voltage terminal adapted to receive charge from the carrier: automatic means for holding the terminal voltage of the generator at a constant value, said automatic means comprising a pick-up electrode placed in the electrostatic field of the high voltage terminal and adapted to be moved in reverse directions by virtue of increase and decrease in strength of said electrostatic field, means for regulating the rate of charge input to the high voltage terminal, and means under the control of movement of said pick-up electrode for causing the last mentioned means to increase the rate of charge input to the high voltage terminal by virtue of movement of said pick-up electrode with decrease of the electrostatic field of the high voltage terminal below a given value, and to decrease the rate of charge input to the high voltage electrode by virtue of movement of said pick-up electrode with increase of the electrostatic field of the high voltage terminal above a given value.

29. In an electrostatic generator, the combination of a traveling carrier, means for variably charging the carrier embodying a source of electric energy and a voltage control means, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal for increasing the voltage of the carrier charging means when said electrostatic field is below a predetermined strength and for decreasing the voltage of the carrier charging means when said electrostatic field is above a predetermined strength.

30. In an electrostatic generator, the combination of a traveling carrier, means for variably charging the carrier embodying a source of electric energy and a voltage control means, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal for increasing the voltage of the carrier charging means when said electrostatic field is below a predetermined strength and for maintaining the voltage of the carrier charging means at a value such as to hold the voltage of the high voltage terminal substantially constant when said electrostatic field has increased to a predetermined strength.

31. In an electrostatic generator having a traveling carrier for electric charges, means for variably charging the carrier comprising inductor and ionizing electrodes mounted in association with the carrier and adapted to have a source of an electrical potential impressed between them, one of said electrodes being movable to vary the strength of the electrostatic field between the electrodes and thereby to regulate the rate of charging of the carrier, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal arranged to move said movable electrode in a direction to increase the rate of charging of the carrier when the field of the high voltage terminal is below a given value, and to move said movable electrode in a direction to decrease the rate of charging of the carrier when the field of the high voltage terminal exceeds a given value.

32. In an electrostatic generator, the combination of a traveling carrier for electric charges, means for variably charging the carrier including a variable potential electrical energizing circuit and a source of electrical energy connected thereto, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal arranged to increase the potential of said charging means when the field of the high voltage terminal is below a given value, and to decrease the potential of said charging means when the field of the high voltage terminal exceeds a given value.

33. In an electrostatic generator, the combination of a traveling carrier for electric charges, means for variably charging the carrier including a variable potential electrical energizing circuit and a source of electrical energy connected thereto, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal arranged to increase the potential of said charging means when the field of the high voltage terminal is below a given value, and to decrease the potential of said charging means when the field of the high voltage terminal exceeds a given value, said automatic means including an induction regulator operated in accordance with variations in the field of the electrostatic field of the high voltage terminal and arranged to control the potential of the energizing circuit of the carrier charging means.

34. In an electrostatic generator, the combination of a traveling carrier for electric charges, means for variably charging the carrier including a kenotron energizing circuit, a high voltage terminal adapted to receive charge from the carrier, and automatic means responsive to the electrostatic field of the high voltage terminal arranged to increase the potential of said charging means when the field of the high voltage terminal is below a given value, and to decrease the potential of said charging means when the field of the high voltage terminal exceeds a given value, said automatic means including an induction regulator operated in accordance with variations in the field of the high voltage terminal and controllably coupled to said kenotron circuit.

35. An electrostatic generator embodying a traveling carrier for electric charges, means for charging the carrier, a high voltage terminal adapted to receive charge from the carrier, and

automatic means operable in response to variations in strength of the electrostatic field of the high voltage terminal for controlling the charge of the high voltage terminal.

36. An electrostatic generator embodying a traveling carrier for electric charges, means for charging the carrier, a high voltage terminal adapted to receive charge from the carrier, and automatic means operable in response to variations in strength of the electrostatic field of the high voltage terminal for controlling the rate of charge of the high voltage terminal.

37. An electrostatic generator embodying a traveling carrier for electric charges, means for charging the carrier, a high voltage terminal adapted to receive charge from the carrier, and automatic means operable in response to variations in voltage of the high voltage terminal for controlling the charge of the high voltage terminal.

38. An electrostatic generator embodying a traveling carrier for electric charges, means for charging the carrier, a high voltage terminal adapted to receive charge from the carrier, and automatic means operable in response to variations in voltage of the high voltage terminal for controlling the rate of charge of the high voltage terminal.

39. In an electrostatic generator having a traveling carrier for electric charges, a high voltage terminal adapted to receive charge from said carrier, and regulating means for varying the rate of charge input to the high voltage terminal: automatic means for operating said regulating means, comprising a pick-up electrode placed in the field of the high voltage terminal and adapted to be moved by said field between given limiting positions, said pick-up electrode normally taking and being yieldingly restrained in a position at one of its limiting positions, and being moved from said position toward the other limiting position by virtue of increase in strength of said electrostatic field, a pair of electrical circuits selectively closed by virtue of occupation by pick-up electrode of one of said limiting positions or the other, said circuits standing open when the pick-up electrode is in intermediate position between said limiting positions, a reversible electric motor, energizing circuiting for said electric motor relay-controlled by said pair of circuits in a manner to cause the motor to operate in reverse directions by alternate closure of said pair of circuits, and to remain stationary when both control circuits are open and control means for said regulating means operated by said motor in a manner to increase the rate of charge when the motor operates in one direction due to occupation of its normal limiting position by the pick-up electrode, and to decrease the rate of charge when the motor operates in the other direction due to occupation of the other limiting position by the pick-up electrode.

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