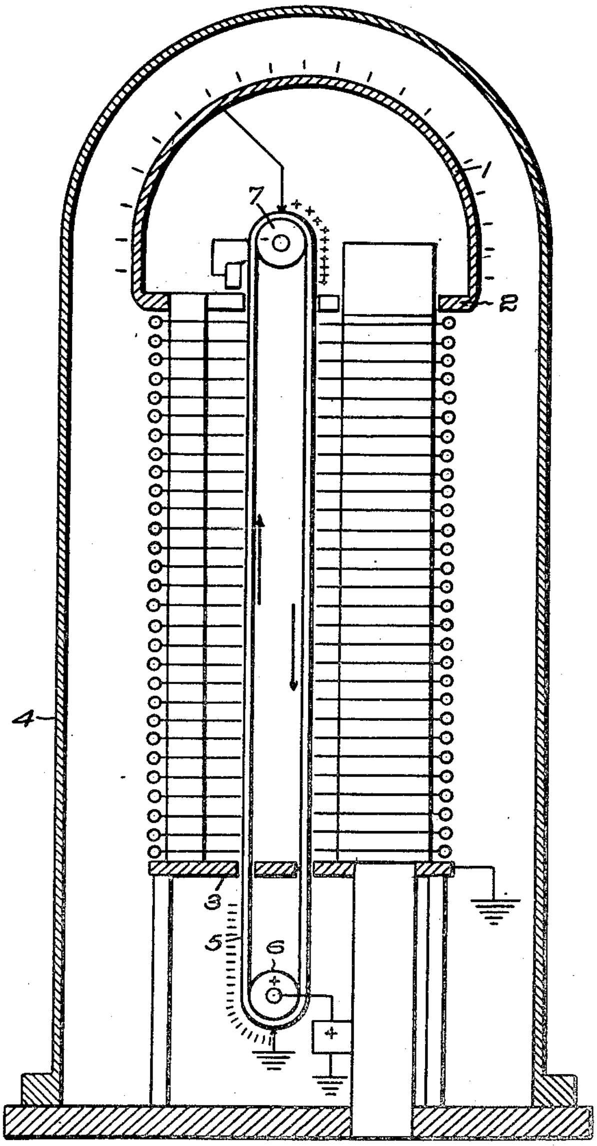
April 4, 1950 J. G. TRUMP ET AL 2,503,224

CHARGE TRANSFERRING MEANS FOR HIGH-VOLTAGE ELECTROSTATIC APPARATUS

Filed July 1, 1947 2 Sheets-Sheet 1

Fig. 1.



Inventors:
John G. Trump,
Robert W. Cloud,
by Emery, Booth, Townsend, Miller and Weidner
Attys.

April 4, 1950 J. G. TRUMP ET AL 2,503,224
CHARGE TRANSFERRING MEANS FOR HIGH-VOLTAGE
ELECTROSTATIC APPARATUS
Filed July 1, 1947 2 Sheets-Sheet 2

Fig. 2.

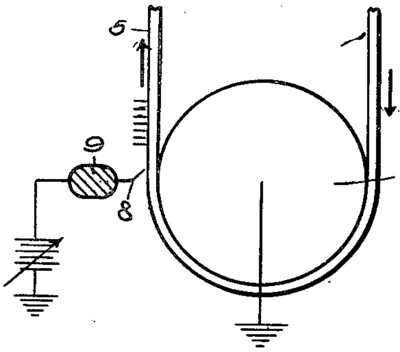


Fig. 3.

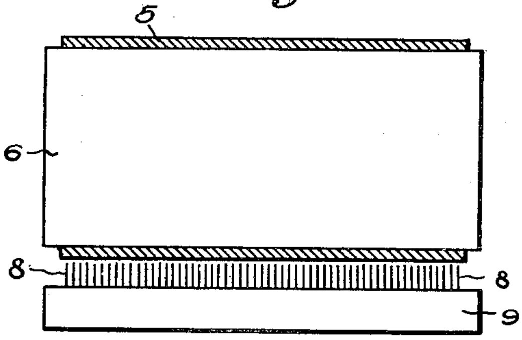


Fig. 4.

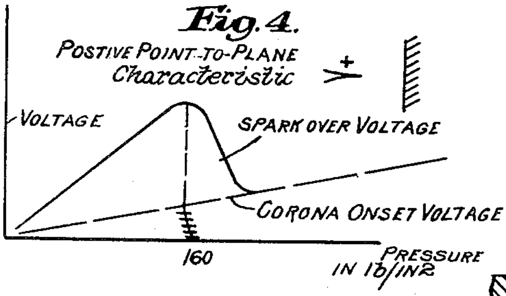


Fig. 5.

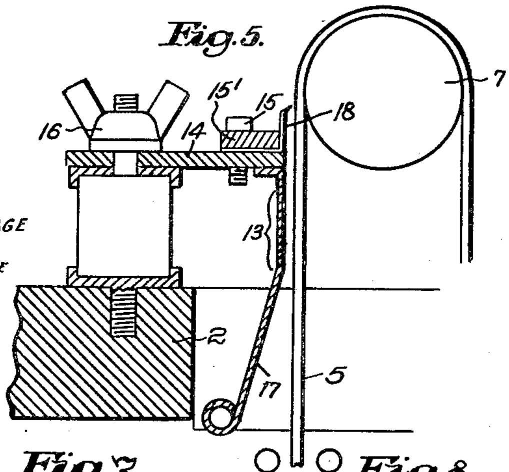


Fig. 6.

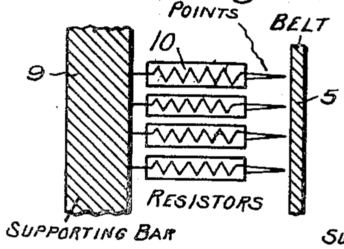


Fig. 7.

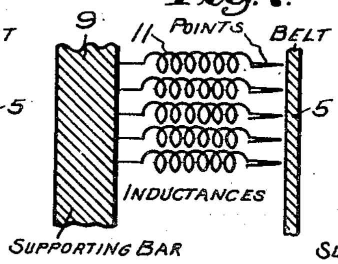


Fig. 8.

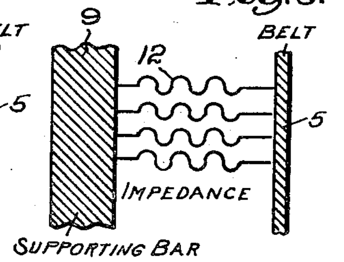
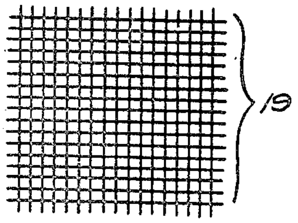


Fig. 9.



Inventors.
John G. Trump.
Robert W. Cloud.
by Emery, Booth, Townsend, Miller and Weidner
Attys.

Patented Apr. 4, 1950 2,503,224

UNITED STATES PATENT OFFICE

2,503,224

CHARGE TRANSFERRING MEANS FOR HIGH-VOLTAGE ELECTROSTATIC APPARATUS

John G. Trump, Winchester, and Robert W. Cloud, Lexington, Mass., assignors to Research Corporation, New York, N. Y., a corporation of New York

Application July 1, 1947, Serial No. 758,352

32 Claims. (Cl. 171—329)

1

This invention relates to apparatus or system for spraying charges upon and removing charges from the movable charge carrier of a high-voltage electrostatic apparatus.

In order that the principle of the invention may be readily understood, we will, without limiting ourselves thereto, set forth one embodiment of means constituting said apparatus or system by which the invention may be practised.

In electrostatic generators of the Van de Graaff type, such as shown in the United States patent to Robert J. Van de Graaff, No. 1,991,236, dated February 12, 1935, electric charge is deposited by a corona mechanism on a rapidly moving insulating belt and carried physically to the high-voltage terminal. There it is removed by a charge collector which also employs the corona mechanism. Similarly, the descending run of the belt may have charge sprayed on it within the terminal which is physically carried down to ground potential, where it is removed in like fashion.

The method which is generally employed for spraying and removing electric charges from such belt conveyors makes use of a row of metallic corona points which are directed at the insulating belt and which row extends across the width of the belt. The spraying of a charge on the belt is accomplished by causing a potential difference to exist between these points and the pulley over which the belt passes. That is, there is caused an electric gradient in the region of the corona points sufficient to produce ionization of the gas, and to cause the movement of ions between the corona or transferring points and the surface of the charge carrier. The high gradient in the region of the points due to their geometry causes ionization of the gas and the movement of ions to and away from the corona points, depending on the polarities involved. If the points are negative, for example, negative ions are directed away from the points toward the pulley of the insulating belt, but are intercepted by the said intervening insulating belt and carried away. The spraying on of an electric charge is always accomplished in the vicinity of the said pulley or other metallic electrode adjacent to the belt.

For the removal of an electric charge, a similar arrangement of metallic corona points extending across the width of the insulating belt is employed. In this situation, however, the removing of a charge is accomplished in a region which is remote from the belt pulley or other metallic electrode, since it is desired that the

2

capacitance between the charged belt surface and the collecting electrode system be small. When this is the case, the charge density on the belt results in a high difference of potential between this charged surface and the row of metallic corona points, which in turn produces a high electric gradient in the region of the said points and ionization of the surrounding gas, as stated. The availability of ions in this local electric field results in the flow of an electric charge toward the belt, which flow just neutralizes the charge on the belt, and a corresponding flow of ions of the opposite sign toward the said corona points. Thus the charge on the insulating belt is neutralized and the points collect a current equal to the rate at which charge is brought.

The said method of charge-spraying and charge-removing has been found to be satisfactory at atmospheric pressures, but becomes less satisfactory when gas pressures of many atmospheres are used to insulate the electrostatic generator. In particular, the performance of these conventional corona points becomes unsatisfactory when the point is of positive polarity and when the gas pressure is higher than the sparking point in the positive point-to-plane characteristic, which for air is about 160 pounds per square inch.

In addition to the difficulty caused by this positive point-to-plane effect, which will be described in detail presently herein, the performance of corona points is less satisfactory at high pressures because the individual corona points may be called upon to spray or collect a larger current due to the higher current capacity of the insulating belt at elevated pressures. Moreover, for electrostatic generators operating at high pressures the electric gradients are generally higher, so that a greater requirement exists in such devices for high insulating strength and complete control of conditions of ionization.

The positive point-to-plane phenomenon will now be described.

In general, if a metal point be directed at a plane and be maintained at a constant positive voltage, a current will flow between the point and the plane because of the ionization of the gas in the vicinity of the said point. This current will become measurable at a definite voltage difference called the "corona onset voltage," which depends upon the pressure of the gas and the point-to-plane spacing as well as the sharpness of the metal point. As the voltage is increased beyond this onset value, the current increases rapidly until ultimately a voltage value is reached at which a spark will pass. In the normal spraying and charge-removing process, the corona points are operated in this intermediate region, in which a steady unidirectional flow of current can be obtained from the said point.

As the pressure of the gas increases, a higher voltage is required to initiate corona, and sparkover likewise takes place at a still higher value. For a positive corona point this progressive increase in both corona onset voltage and sparkover voltage continues with pressure until the sparking point in the positive point-to-plane characteristic is reached (for about 160 pounds per square inch), whereafter the sparkover voltage diminishes markedly and only exceedingly small corona currents can be obtained from the point before sparkover, as will be subsequently referred to in connection with the drawings. For electrostatic generators operating at pressures above such sparking point, it is evident that the process of spraying and removing a charge is severely handicapped whenever the points are of positive polarity. This limitation is not observed when the points are of negative polarity.

We have found that these difficulties can be overcome, and steady, sparkless, transfer of electric charges can be effected between metallic, conducting or semi-conducting corona points and an insulating belt or other insulating, movable charge-carrier regardless of the pressure of the gas or of the polarity of the corona points.

Our herein disclosed system or method for accomplishing this makes use of an exceedingly large number of metallic conducting or semi-conducting corona points compared to the number conventionally used, the points themselves being spaced very close to the electrically charged surface of the belt and indeed virtually in contact therewith. The said corona points, of conducting or semi-conducting material, are closely adjacent in a line transverse to the direction of motion of the belt or other charge-carrier, and are virtually in contact with the surface of the charge-carrier. For the charge-spraying operation this is the principal requirement, although we have also found it useful to arrange the said individual metal corona points in such a way that they are spaced from each other and have considerable impedance to their common electrical connection.

In the case of corona points used for charge-removing, we have found it desirable additionally to control the electric field due to the belt charge, by means of a conducting or semi-conducting member constituting a field-controlling member. The surface of this field-controlling member is arranged so as gradually to approach the belt surface. This arrangement keeps the charge on the belt until it comes opposite the points mounted on the trailing edge of the shielding surface provided by the field-controlling member. The minimum spacing of the shield and also of the corona points from the belt is about equal to the spacing between the points themselves, or less. The effect of this arrangement is to keep the potential difference between the charged belt and the collecting member small until the charge comes under the influence of the charge-removing points.

Under proper shielding conditions each corona point collects a fraction of a microampere of current from its portion of the belt width. The multiple point system may, in accordance with our invention, be constructed in both charge-spraying and charge-removing cases, of parallel 5-mil wires (.005 of an inch), which are, for example, spaced from each other with about fifty wires per linear inch of the belt. Impedance may be introduced by kinking or curling or otherwise bending or deforming from a straight axial line these individual wires before they are attached to the solid metal bar which holds them. The impedance may also, in accordance with our invention, be introduced by connecting these individual wires through a high-resistance element to the common metallic bar. Alternatively a fairly satisfactory construction, which is within the scope of our invention, has been to use a 50-mesh wire screen, the corona point-providing edge of which is held in almost touching contact with the charged belt surface. The wave of the individual wires constituting the said corona points is sufficient to introduce considerable impedance to the high-frequency transients characteristic of ionization phenomena. These constructions will be more specifically referred to in connection with the drawings.

It is evident that other constructions may be used within the scope of our invention to accomplish these results.

The essential features of the invention in the order of importance are (*a*) the use of multiple corona points of conducting or semi-conducting material, far in excess of the number ordinarily used and virtually in contact with the electrically charged surface, (*b*) the introduction of impedance in series with the individual spaced corona points, and (*c*) in the case of charge-removing corona points, the localization of the electric field due to the charge on the belt as it approaches the charge-removing corona points.

The following inventive results are attained by the herein disclosed system or method and apparatus: (*a*) a positive charge can be sprayed on and a negative charge can be taken off an insulating belt or other insulating charge-carrier, even at elevated gas pressures well above the herein before referred to sparking point in the point-to-plane characteristic; (*b*) the flow of current to and from the corona points remains the steady flow characteristic of corona rather than the discontinuous flow characteristic of repeated sparkover, and since the density of ionization in the core of the spark may be several orders of magnitude greater than the density of ionization in corona flow, this novel system or method and apparatus which maintains corona flow, has advantages in less destructive effect both on the gas molecules, on the belt material and on the corona points themselves, it also having advantages in greater steadiness than could be obtained with intermittent sparkover; (*c*) the effect of multiple corona points in close spacing to the belt or charge-carrier is to reduce the energy applied to the ionization of the gas and to distribute this reduced energy among the greater number of corona points, this resulting in reduced decomposition of the gas and surrounding materials; (*d*) the ionization is also confined to a more localized region of the belt or charge-carrier than would be the case with larger spacings, this having the advantage of keeping such region of ionization further removed from the portion of the belt or charge-carrier which is subjected to high electric gradients because of the generator terminal voltage.

In the drawings:

Fig. 1 is a view, mainly in vertical transverse section, showing one type of high-voltage electrostatic generator employing a charge-carrying belt and representing one form of the invention;

Fig. 2 is a detail indicating the system or method herein disclosed of establishing electric charges on the lower end of the upwardly traveling belt;

Fig. 3 is a detail in transverse section through both runs of the belt and indicating somewhat diagrammatically a row of charge-transferring means, either the charge-spraying means or the charge-removing means;

Fig. 4 is a diagram indicating the positive point-to-plane characteristic;

Fig. 5 is a detail in vertical section of the field-controlling member closely adjacent the belt surface and having a row of charge-removing points at the trailing upper edge thereof;

Figs. 6, 7 and 8 are diagrammatic views of three different forms or types of impedance employed with the charge-transferring points; and

Fig. 9 is a diagrammatic detail indicating a fine-mesh wire screen, the edge whereof is held in almost touching contact with the charge belt surface and constitutes charge-transferring points.

Referring to the drawings, and first to Fig. 1 thereof, therein is shown such parts of an electrostatic generator as are necessary to an understanding of this invention. The said generator is of the type shown in the patent to John G. Trump, No. 2,252,668, August 12, 1941. The invention herein claimed may be applied to the said type of electrostatic apparatus, but our invention is not necessarily limited to use with such type of apparatus.

In said Fig. 1, the electrostatic generator comprises the main high-potential electrode 1 consisting of a hollow shell of conducting material, such as brass, this being of a generally rounded and approximately hemispherical shape and free from external projections. The electrode rests on a ring 2 of conductive metal, the outer exposed surface of which is rounded, the said ring, in turn, being mounted on the top of any suitable number, such as three, of spaced elongated pillars or columns, which may be similar to those in the said patent to Trump, said pillars or columns being of insulating material of high dielectric strength.

The bases of these columns rest on the base plate 3 of conductive material which is supported by suitable brackets attached to the inner walls of a tank 4 which provides a chamber completely enclosing all the parts of the generating apparatus, but leaving a substantial clearance between its walls and the electrode and insulating columns. The said tank is desirably filled with a gas of many atmospheres pressure which, for air, may be about 400 pounds per square inch. Pressures may be employed, in the practice of our invention, which are above the said sparking point in the positive point-to-plane characteristic.

The charge-carrier may be of any suitable type, but is herein shown as in the form of an endless belt 5 of such construction that the charges on its surface are longitudinally insulated from each other, the belt herein being of insulating material, such as a multiple-ply rubber fabric. At its lower end the belt passes over a metallic driving pulley 6 journaled in suitable brackets on the base plate, so that the pulley has a grounded connection, as indicated. The said pulley is driven by a suitable motor not herein illustrated, to which current is supplied by conductors entering the walls of the tank through a suitable bushing.

The belt 5 runs vertically upward and then downward in a parallel line, passing into and out of the hollow electrode 1 and over a metallic pulley 7 within the electrode shell, the said pulley 7 being journaled in or insulated from suitable brackets supported by the ring 2 in a manner not necessary to illustrate or to refer to further.

At the lower end of the belt 5 charges of one sign are established on the moving belt, and at its upper end the charges carried thereby are removed and transferred to the electrode 1. Simultaneously charges of opposite sign are transferred through the electrode 1 to the belt 5 at its upper end and are carried away by the descending run to the lower end of the belt, where they are removed.

The system or method employed by us of applying charges to the belt and for removing charges therefrom is indicated more particularly in Figs. 2, 3 and 5 of the drawings. In accordance with our invention we employ charge-transferring means, which term is herein employed broadly to designate either the charge-spraying means or the charge-removing means, or both of such means. Heretofore a series of corona points was employed both for charge spraying and for charge removing, but the said points were relatively far apart, being as much as about one-quarter to one-half of an inch apart and terminating about one-sixteenth to one-eighth of an inch from the surface of the belt. In accordance with the present invention, the metallic, conducting or semi-conducting, corona points, which extend entirely across the width of the belt 5 in a direction transverse to the direction of motion of the said belt, are of an exceedingly large number compared with the number heretofore used, as, for example, fifty per linear inch transversely of the belt 5. They are such in number per linear inch as is sufficient, in a gas at many atmospheres, to deliver an approximately uniform density of electric charge across the width of the charge conveyor in a steady sparkless manner notwithstanding the high gas pressure and regardless of polarity. Moreover, the said points are spaced very close to the electrically charged surface of the belt 5, being virtually in contact therewith. In the operation of the apparatus they may become very slightly spaced from the belt. The actual number of corona points per linear inch across the belt, both for charge-spraying and for charge-removal, must as a minimum be such that the distribution of charge across the width of the belt will be substantially uniform with the said points in close proximity. With such close spacing, many points per linear inch of belt width are required to effect this result. It is our belief, based upon our tests, that the corona points should probably be separated by an amount which is as near to the point-of-belt-separation as possible, which is elsewhere herein defined as not more than about 0.02 of an inch from the electrically charged surface of the moving charge carrier.

The purpose of employing the greatly increased number of conducting or semi-conducting corona points both for charge-spraying and for charge-removal and the positioning of the points virtually in contact with the surface of the belt is, as hereinbefore set forth, to overcome the difficulties which have heretofore arisen if the pressure of the gas within the tank 4 is increased. As the pressure of the gas increases, a higher voltage is required to initiate corona, and sparkover takes place at a still higher value. The corona under said voltage depends upon the pressure of the gas and the point-to-plane spacing as well as the sharpness of the metal conducting or semi-conducting, corona points. As the voltage is increased beyond this onset value the current increases rapidly until ultimately the voltage value is reached at which a spark will pass. The difficulties heretofore experienced when employing high gas pressures are overcome by our invention, and steady, sparkless transfer of electric charges can be effected between the metallic conducting or semi-conducting, corona points and the belt 5 regardless of the pressure of the gas or of the polarity of the corona points. An example of a well known semi-conducting material suitable for the purposes referred to is synthetic rubber containing an appropriate amount of fine carbon particles.

Referring to Fig. 2, one of the said charge-spraying corona points is indicated at 8 and the transverse row thereof is diagrammatically indicated in Fig. 3. The said conducting or semi-conducting corona points 8 are very closely spaced and extend across the entire width of the belt 5 and virtually into contact therewith. It is impossible to represent, in a drawing upon the scale of Fig. 3, the number of the said points, but, as hereinbefore stated, they consist of an exceedingly large number compared with the number heretofore used, and may, for example, be as numerous as fifty per linear inch of the belt, and they are, as stated, of conducting or semi-conducting material. They are carried by or extend from a common electrical connection indicated at 9 in Fig. 2, and also in Figs. 6, 7 and 8. Desirably all of the said charge-spraying points as well as the charge-removing points have a connection of considerable impedance to their common electrical connection, shown at 9, for the charge-spraying points. Such impedance may take the form of a resistance for each of the points, as indicated at 10 in Fig. 6, or an inductance as indicated at 11 in Fig. 7, or the wires constituting the corona points may be kinked or waved as indicated at 12 in Fig. 8 to provide impedance. That is, the inductive impedance may be achieved by kinking or twisting or coiling the wires which terminate in the corona points.

In Fig. 6 the resistors are in series with each point; in Fig. 7 the inductance is in series with each point; and in Fig. 8 the individual wires are kinked, twisted or coiled to provide the inductive impedance. The frequency components of a spark discharge can be reduced or prevented by the introduction of impedance in series with each individual point, which impedance is in fact very high. As a result, even the small inductance caused by bending the individual wires into complete or partial loops will be effective in retarding the development of high current transients. Such departure from a straight wire can be accomplished even though the wires are closely spaced with respect to each other, as herein disclosed, by producing them in a plane which is transverse to the plane of the conducting points.

For the removal of electric charges, a like arrangement of very closely spaced, metallic, conducting or semi-conducting, corona points extending across the entire width of the belt 5 is employed and, as in the case of the charge-spraying points, the charge-removing points are virtually in contact with the surface of the belt 5.

As heretofore stated, the removing of a charge is accomplished in a region which is remote from the belt pulley or other metallic electrode.

In the case of the corona points used for charge-removing, we have discovered that it is very desirable to control the electric field, due to the belt charge, by means of a conducting or semi-conducting member constituting a field-controlling member. One form of such a member is indicated at 13 in Fig. 5. This member is suitably supported by a metal bracket 14, to which it may be secured by a suitable number of bolts 15 extending through the bracket 14 and through a metal bar or plate 15'. The bracket 14 is supported in any suitable manner from the ring 2, as by means of a suitable number of wing nuts 16. It will be noted that the form of the field-controlling member 13 is such that its upper portion is parallel with and exceedingly close to the surface of the belt 5, but that its lower portion, indicated at 17, is at an incline to the surface of the belt, so that the surface 17 of the field-controlling member 13 gradually approaches the surface of the belt 5. This construction, by providing a high capacitance and uniform field to the electrically charged belt, tends to keep the charge on the belt 5 until it comes opposite the charge-removing points 18, which are of the same character as those shown in Fig. 3, and which charge-removing points 18 are mounted on what may be termed the trailing edge of the shielding surface that is provided by the said field-controlling member 13. The inclined or gradually approaching portion 17 of the field-controlling member 13 is, of course, anterior to the area of location of the charge-removing points 18. The minimum spacing of the shield or field-controlling member 13 and of the charge-removing points 18 from the belt 5 may be such as just to avoid touching the belt and may be about equal to the spacing between the points themselves. The effect of the described arrangement is to keep the potential difference between the charge-belt and the collecting member as small and as uniformly distributed as possible, until the charge comes under the influence of the charge-removing points 18.

Instead of employing corona points as described, which are very slightly spaced from each other (as, for example, .02 of an inch) and individually extending from the common metallic bar, such as indicated at 9 in Figs. 2, 6, 7 and 8, either the said charge-spraying or the charge-removing points, or both, may be formed as a fine-mesh wire screen, such, for example, as a fifty-mesh wire screen, indicated at 19 in Fig. 9. Such screen, when used as charge-removing points, is received between the top surface of the field-controlling member 13 and the overlying bar 15', Fig. 5. In the event of the use of a fine-mesh wire screen, the wave of the individual wires thereof that constitute the corona points is sufficient to introduce considerable impedance.

While other constructions than those heretofore specifically referred to may be used to accomplish the purposes and results of the invention, an underlying feature of the invention is the employment of multiple corona points of conducting or semi-conducting material far in excess of the number ordinarily used and virtually in contact with the electrically charged surface of the belt 5. As stated, it is exceedingly desirable to introduce impedance between the said corona points and their common metallic support. In the case of the charge-removing points, the disclosed construction (particularly illustrated in Fig. 5) effects the localization of the electric field, due to the charge on the belt 5 as the charge approaches the charge-removing corona points 18.

We have hereinbefore referred to the positive point-to-plane phenomena. This is diagrammatically indicated in Fig. 4, wherein the point-to-plane characteristic is indicated, as well as the voltage and the gas pressure.

By our invention positive as well as negative charges can be sprayed on and negative as well as positive charges can be taken off a charge-carrier even at elevated gas pressures well above the said sparking point in the positive point-to-plane characteristic. The flow of current to and from the corona points, in the practice of our invention, remains the steady flow characteristic of corona rather than the discontinuous flow characteristic of repeated sparkover. The effect of multiple corona points in very close spacing, as herein disclosed, is to reduce the energy applied to the ionization of the gas and to distribute this reduced energy among the greater number of corona points. The ionization is confined to a more localized region of the belt than would be the case with the hereinbefore employed much larger spacings between the corona points.

We have herein disclosed a system or method of spraying and of removing charge from a charge-carrier, such as a moving belt of insulating material, which system or method is particularly suitable for electrostatic generators operating in high gas pressures and/or gas at many atmospheres pressure, in which the steady, sparkless flow of current between the belt and the charge-spraying or charge-removing means is accomplished by the use of a relatively large number of sharp corona points per inch of belt width, such corona points being of conducting or semi-conducting material and being close to and virtually touching the electrically charged surface of the belt, the said points being spaced from one another and having a connection of considerable impedance to their common electrical connection. As fully hereinbefore explained the electric field is localized in the case of the charge-removing points due to the charge on the arriving portion of the belt 5, as indicated in Fig. 5.

It is to be understood that in accordance with our invention, in the process or method of spraying charge on the endless belt 5 or other charge-carrier, the potential difference is applied from a small transformer rectifier (not shown), which is either in series with the conducting or semi-conducting corona points and looking toward a grounded pulley, or is applied to an insulated pulley with the said corona points connected to ground.

It is also to be understood that each of the corona points herein disclosed desirably consist of a wire not exceeding approximately .010 of an inch in diameter, and that they may be as small in diameter as .005 of an inch, and that in number they are approximately fifty per transverse linear inch of the endless belt or charge-carrier, and that they are spaced not more than about 0.02 of an inch from the electrically charged surface of the moving charge carrier.

Having thus described one embodiment of the invention and the best way known to us for practising the same, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

What we claim is:

1. High voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge between said charge-carrier and charge-transferring means, such latter means comprising a multiplicity of sharp, fine-wire conducting or semi-conducting points per linear inch of charge-carrier width, largely exceeding the number of those conventionally used that were spaced about one-quarter to one-half an inch apart, and each having a diameter on the order of approximately .010 to .005 of an inch, such multiplicity of sharp fine-wire points being so great in number as respectively just to lack lateral contact with each other throughout a line transverse to the traveling surface of the charge carrier, such multiplicity of sharp fine-wire points that just lack lateral contact with each other throughout such transverse line constituting, therefore, such a number of sharp fine-wire points per linear inch as is consequently sufficient in a gas of high pressure to deliver an approximately uniform density of electric charge across the width of the charge carrier in a steady, sparkless manner, notwithstanding such high gas pressure and regardless of polarity.

2. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier and cooperating charge-spraying means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge-spraying means to said charge carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier.

3. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier and cooperating charge-spraying means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge-spraying means to said charge-carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier, said corona points each consisting of a wire not exceeding approximately .010 of an inch in diameter.

4. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier and cooperating charge-spraying means for convey-

ing charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge-spraying means to said charge-carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier, and means for stabilizing the current to the said charge-spraying corona points.

5. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-spraying means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge-spraying means to said charge-carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier, and means for stabilizing the current to the said charge-spraying corona points, said current stabilizing means consisting of impedances in series with the individual charge-spraying corona points.

6. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-spraying means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge-spraying means to said charge-carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier, and means for stabilizing the current to the said charge-spraying corona points, said current stabilizing means consisting of resistances in series with the individual charge-spraying corona points.

7. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-spraying means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from the charge spraying means to said charge-carrier, such charge-spraying means comprising corona points numbering approximately fifty per transverse linear inch of the said charge-carrier, and virtually touching the electrically charged surface of said moving charge-carrier, and means for stabilizing the current to the said charge-spraying corona points, said current stabilizing means consisting of inductors in series with the individual charge-spraying corona points.

8. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, such charge-removing means comprising a multiplicity of sharp corona points per inch of charge-carrier width, largely exceeding the number of those conventionally similarly used, and positioned close together and virtually touching the electrically charged surface of said moving charge-carrier, said charge-removing corona points numbering approximately fifty per transverse linear inch of the said charge-carrier and spaced not more than about 0.02 of an inch from the electrically charged surface of said moving charge-carrier.

9. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, such charge-removing means comprising a multiplicity of sharp corona points per inch of charge-carrier width, largely exceeding the number of those conventionally similarly used, and positioned close together and virtually touching the electrically charged surface of said moving charge-carrier, said charge-removing corona points each consisting of a wire approximately .005 of an inch in diameter.

10. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points having a diameter on the order of .010 to .005 of an inch, and being so numerous per linear inch that they are spaced apart a distance on the order of their own diameters, and being, therefore, such in number per linear inch across the width of the charge carrier as is sufficient in a gas at many atmospheres to deliver approximately uniform density of electric charge across the width of the charge carrier in a steady, sparkless manner regardless of gas pressure or polarity; and electric-field controlling means positioned anterior to said charge-removing corona points and closely spaced from the arriving portion of said charge-carrier, thereby to reduce the potential of the said charge-carrier relative to the charge-removing means.

11. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge-carrier, and means for effecting a steady spark-

less flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points; and a field-controlling member positioned close to the surface of the charge-carrier anterior to said charge-removing corona points, said field-controlling member having its surface that faces the said charge-carrier arranged to approach gradually the surface of the charge-carrier, thereby keeping the charge on the charge-carrier until the said charge comes opposite the said charge-removing corona points.

12. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge carrier, and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points and a field-controlling member positioned close to the surface of the charge-carrier and having the said charge-removing corona points mounted on the trailing edge thereof.

13. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge carrier, and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points and a field-controlling member positioned close to the surface of the charge-carrier and having the said charge-removing corona points mounted on the trailing edge thereof, said charge-removing corona points largely exceeding in number those conventionally similarly used, and positioned close together and virtually touching the electrically charged surface of the said moving charge-carrier.

14. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge carrier, and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points and a field-controlling member positioned close to the surface of the charge-carrier and having the said charge-removing corona points mounted on the trailing edge thereof, said charge-removing corona points being formed as a very fine mesh wire screen.

15. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high-gas pressure means surrounding said terminal, said supporting means and said charge carrier, and means for effecting a steady sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points and a field-controlling member positioned close to the surface of the charge-carrier and having the said charge-removing corona points mounted on the trailing edge thereof, said charge-removing corona points being composed of parallel wires substantially .005 of an inch in diameter, spaced from each other a distance to provide substantially fifty wires per transverse linear inch of the charge-carrier.

16. High voltage, electrostatic apparatus in accordance with claim 1, but wherein there is a bent connection providing substantial impedance between the said points and their common electrical connection.

17. High voltage, electrostatic apparatus in accordance with claim 1, but wherein the individual points are connected through an inserted high resistance element to the common metallic bar connection therefor.

18. High voltage, electrostatic apparatus in accordance with claim 1, but wherein the individual points are connected through bends providing inductances to their common electrical connection.

19. High voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between said charge-carrier and charge-transferring means, such latter means comprising a woven wire mesh screen extending at its inner edge along a line transversely of the surface of the charge-carrier into very close proximity to the surface of the said charge-carrier, so as to be spaced therefrom a distance on the order of about .02 of an inch, the wave of the individual wires incident to their woven formation in said screen constituting marked impedance.

20. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between the charge-transferring means and said charge-carrier, such charge transferring means comprising corona points extending in a line transverse to the traveling surface of the charge-carrier and numbering in said line approximately fifty per transverse linear inch of said charge-carrier.

21. High-voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between said charge carrier and charge-

transferring means, such means comprising a multiplicity of fine wire corona points extending close to said charge-carrier along a line transverse to said charge-carrier, and having individually a formation providing a connection of substantial impedance between them and their common electrical connection.

22. High-voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between said charge-carrier and charge-transferring means, such means comprising corona points extending close to said charge-carrier along a line transverse to said charge-carrier which are individually connected through an inserted high resistance element to the common metallic bar connection therefor, said corona points along said line transverse to the charge-carrier respectively just lacking lateral contact with each other.

23. High-voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between said charge-carrier and charge-transferring means, such means comprising a multiplicity of fine wire corona points extending close to said charge-carrier along a line transverse to said charge-carrier which are individually connected through formation providing inductances to their common electrical connection, said corona points along said line transverse to the charge-carrier respectively just lacking lateral contact with each other.

24. High-voltage electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge between said charge-carrier and charge-transferring means, such means comprising a multiplicity of fine wire corona points extending close to said charge-carrier along a line transverse to said charge-carrier, said corona points each consisting of a wire not exceeding approximately .010 of an inch in diameter and being spaced apart from each other by distances approximating their own diameters.

25. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure comprising a high-voltage terminal; insulating supporting means; a moving charge-carrier and cooperating charge-transferring means for conveying charges between said terminal and ground; high gas pressure means surrounding said terminal, said supporting means and said charge carrier; and means for effecting a steady, sparkless flow of charge between the charge-transferring means and said charge-carrier, said charge-transferring means comprising a set of fine-wire charge-spraying corona points and a set of fine-wire charge-removing corona points, each set being respectively positioned along a line transverse to the traveling surface of the charge-carrier, the corona points of each set having a diameter on the order of approximately .010 to .005 of an inch, and being so numerous per linear inch that they are spaced apart a distance on the order of their diameters, and being consequently sufficient in gas at many atmospheres pressure to deliver an approximately uniform density of electric charge across the width of the charge carrier in a steady, sparkless manner notwithstanding such gas at many atmospheres pressure and regardless of polarity.

26. High-voltage electrostatic apparatus operating in gas at many atmospheres pressure, comprising a high-voltage terminal; insulating supporting means, a moving charge-carrier and cooperating charge-removing means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge-carrier; and means for effecting a steady, sparkless flow of charge from said charge-carrier to said charge-removing means, said charge-removing means comprising sharp corona points; and electric field controlling means positioned wholly anterior to the said charge-removing corona points, and itself providing high capacitance and uniform field to the said charge carrier, said electric field controlling means being a wide elongated plate having a part at least of the bare inner face thereof which presents an area of relatively large extent both transversely and lengthwise of said charge carrier very close to and in unobstructed vacant-space relationship to the closely adjacent surface of the said charge carrier at an area that is wholly anterior to the said charge removing corona points.

27. In a high-voltage electrostatic apparatus or system operating in gas at many atmospheres pressure, a tank providing a chamber enclosing the electrostatic generating apparatus, a high-voltage terminal in said tank, insulating supporting means for said terminal, a movable charge carrier and cooperating charge transferring means within said tank, means to establish an elevated gas pressure of many atmospheres in said enclosing chamber, means for effecting a steady sparkless transfer of electric charge between the charge transferring means and the charge carrier in the presence of such elevated gas pressure while reducing the energy applied to the ionization of the gas, including a multiplicity of fine-wire transfer points positioned along a line transverse to and in virtual contact with the traveling surface of the charge carrier and respectively separated from each other along said transverse line by substantially their own diameters, which are on the order of approximately .010 to .005 of an inch, said transfer points being, therefore, sufficient per linear inch in a gas at many atmospheres to deliver an approximately uniform density of electric charge across the width of said charge carrier in a steady sparkless manner regardless of gas pressure or polarity, and means to establish a potential difference between such charge carrier and such multiplicity per linear inch of said transfer points, thereby to cause an electric gradient in the region of such transfer points

sufficient to produce ionization of the gas, and also to cause the movement of ions between such charge transfer points and the surface of such charge-carrier in a steady sparkless manner irrespective of the polarity of such transfer points or the elevated gas pressure in said tank.

28. In a high-voltage electrostatic apparatus or system operating in gas at many atmospheres pressure, a tank providing a chamber enclosing the electrostatic generating apparatus, a high-voltage terminal in said tank, insulating supporting means for said terminal, a movable charge carrier and cooperating charge transferring means within said tank, means to establish an elevated gas pressure of many atmospheres in said enclosing chamber, means for effecting a steady sparkless transfer of electric charge between the charge transferring means and the charge-carrier in the presence of such elevated gas pressure while reducing the energy applied to the ionization of the gas, including a multiplicity of fine-wire transfer points positioned along a line transverse to and in virtual contact with the traveling surface of the charge-carrier and respectively separated from each other along said transverse line by substantially their own diameters, which are on the order of approximately .010 to .005 of an inch, said transfer points being therefore sufficient per linear inch, in a gas at many atmospheres to deliver an approximately uniform density of electric charge across the width of said charge-carrier in a steady sparkless manner regardless of gas pressure or polarity, and means to establish a potential difference between such charge-carrier and said transfer points, thereby to cause an electric gradient in the region of such transfer points sufficient to produce ionization of the gas, and also to cause the movement of ions between such charge transfer points and the surface of such charge-carrier in a steady sparkless manner irrespective of the polarity of such transfer points or the elevated gas pressure in said tank.

29. High-voltage, electrostatic apparatus operating in gas at a pressure of many atmospheres, comprising a high-voltage terminal, insulating supporting means, a moving charge-carrier of insulating material and cooperating charge-transferring means for conveying charges between said terminal and ground, high gas pressure means surrounding said terminal, said supporting means and said charge-carrier, and means for effecting a steady sparkless flow of charge between said charge-carrier and said charge-transferring means, such latter means comprising a multiplicity of sharp, fine wire, conducting or semi-conducting points per linear inch of charge-carrier width, largely exceeding the number of those conventionally similarly used and which were spaced about one-quarter to one-half inch apart, such multiplicity of sharp, fine wire points being respectively spaced apart a distance approximately equalling their own diameters, which are on the order of approximately .010 to .005 of an inch, throughout a line transverse to the traveling surface of the charge-carrier, such multiplicity of sharp fine-wire points constituting therefore such a number of sharp fine-wire points per linear inch as is consequently sufficient in a gas at high pressure to deliver an approximately uniform density of electric charge across the width of the charge-carrier in a steady, sparkless manner notwithstanding such high gas pressure and regardless of polarity.

30. A multiple-point high-voltage electrostatic system for effecting steady sparkless flow of current between a movable charge-carrier and charge spraying or charge-removing points in the presence of high gas pressure of many atmospheres comprising a tank, means to establish therein an elevated gas pressure of many atmospheres, a high-voltage terminal, a movable charge-carrier in said tank to convey charge to and from said terminal, and cooperating charge transferring means within said tank, said transferring means including a line of transfer points extending transversely of the surface of said charge carrier, and in close proximity thereto, said transfer points consisting of fine wire and spaced respectively from each other throughout said transverse line by a distance on the order of their own diameter, which are on the order of approximately .010 to .005 of an inch, the said transfer points accordingly, as defined, being such in number per linear inch that the distribution of charge across the width of the charge-carrier is of substantially uniform density, such defined number per linear inch of the transfer points being therefore such that the energy applied to the ionization of the gas is reduced by distributing such energy among such defined number of transfer points per linear inch, and being such that the movement of ions between the said transfer points and the surface of the charge-carrier is effected in a steady sparkless manner irrespective of the polarity of such transfer points.

31. A system in accordance with claim 30, wherein the transfer points are respectively connected by impedance formations to their common electrical connection.

32. A system in accordance with claim 30, wherein the transfer points include charge-removing points, and wherein there are means closely adjacent to said charge-removing points and to said charge-carrier to control the electric field by providing a high capacitance and uniform field.

JOHN G. TRUMP.
ROBERT W. CLOUD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
643,367	Waite	Feb. 13, 1900
2,005,451	Browne	June 18, 1935
2,252,668	Trump	Aug. 12, 1941