Aug. 12, 1941. J. G. TRUMP 2,252,668

ELECTROSTATIC APPARATUS

Filed Feb. 24, 1939 2 Sheets-Sheet 1

Fig. 1.

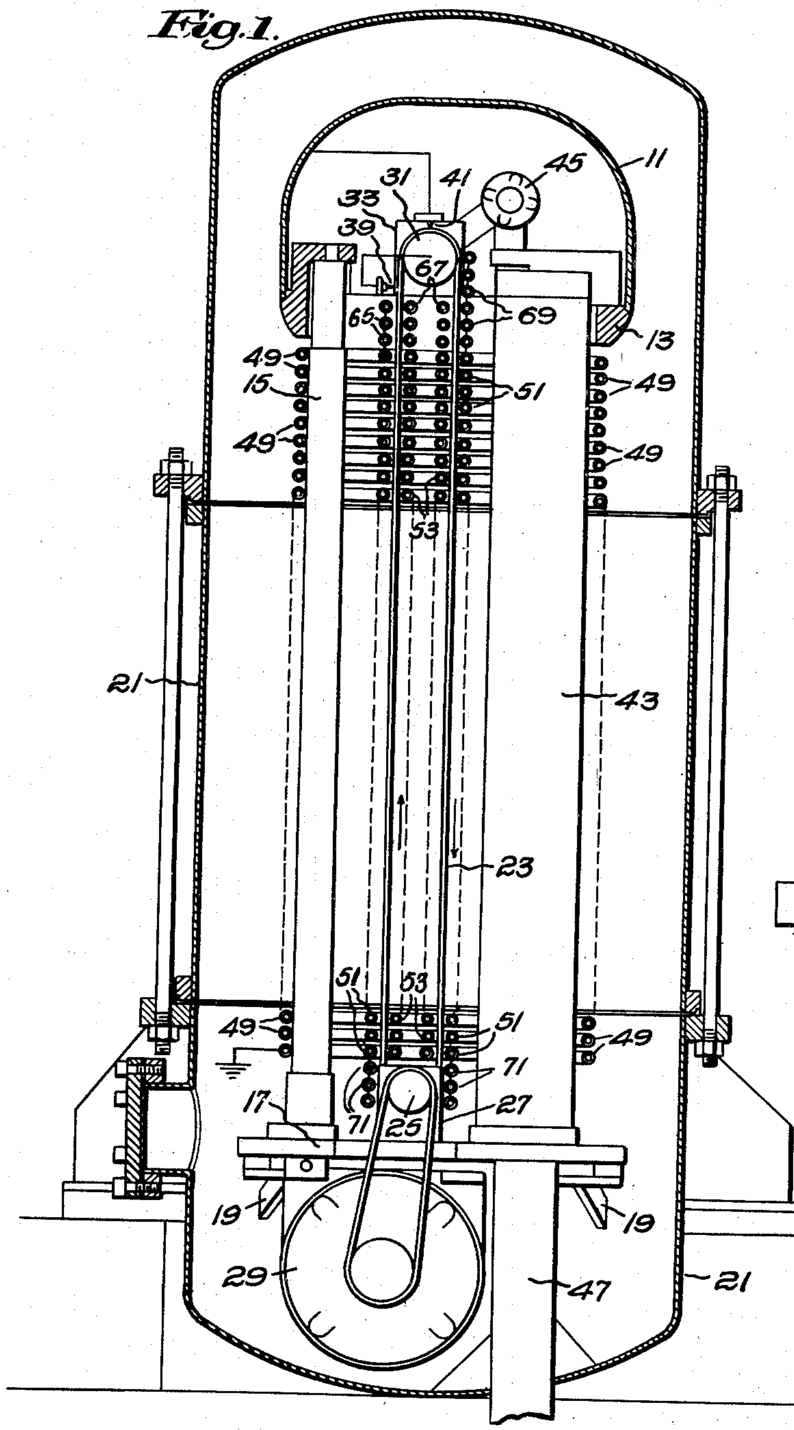

Fig. 2.

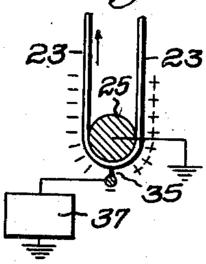

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Fig. 3.

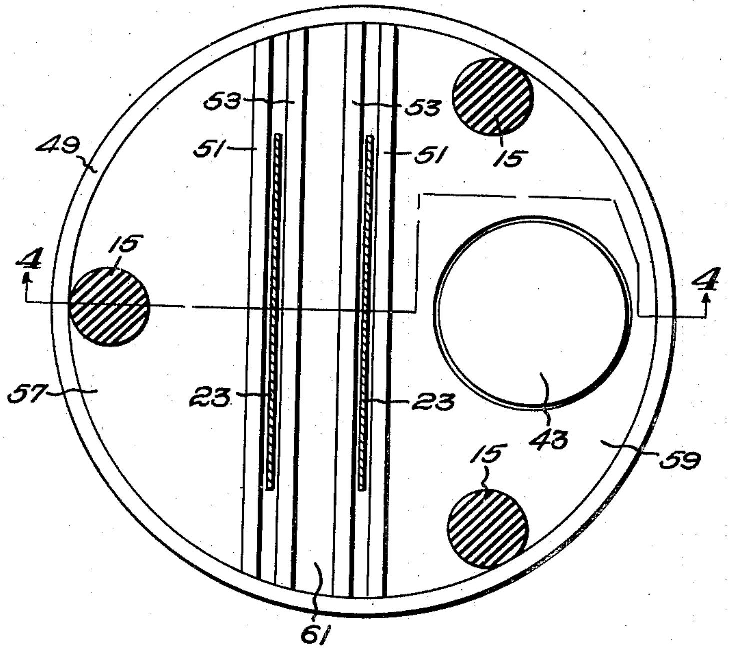
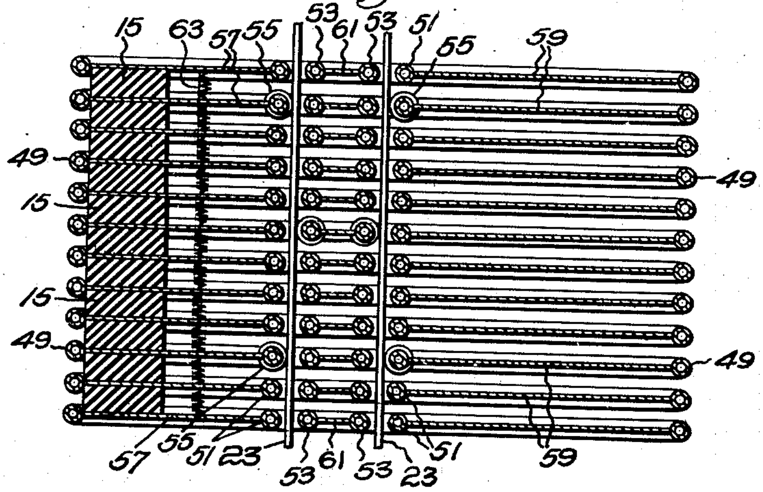


Fig. 4.



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UNITED STATES PATENT OFFICE

2,252,668

ELECTROSTATIC APPARATUS

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Application February 24, 1939, Serial No. 258,268

19 Claims. (Cl. 171—329)

This invention relates to high potential electrostatic apparatus embodying the general principles disclosed in prior Patent No. 1,991,236 to Robert J. Van de Graaff. Such apparatus when utilized as generators is intended for the production of high, steady, direct current potentials and comprises generally an electrode mounted on an insulating support to which charges are constantly transferred by a charge conveying medium, usually in the form of a movable carrier body and more often in the form of an endless belt or the like.

The use of such high potential direct current electrostatic generators has become of increasing importance as the voltage source in X-ray generators for cancer therapy, for the acceleration of charged particles in nuclear research, and for other purposes.

The need in such applications for voltages of the order of several millions and the desirability of obtaining such high voltages with relatively compact apparatus have led to the utilization of gases under high pressure in place of atmospheric air as the medium surrounding the component parts of such generators. Since the insulating strength of air or other gas between parallel electrodes increases approximately with the pressure, an increased compactness in the apparatus as a whole should be realized. Compressed air is ordinarily utilized for this purpose, although the insulating effect may be further augmented by the use of compressed gaseous compounds having inherently a higher dielectric strength than air at the same pressure, an example of such a compound being CCl_2F_2.

In such cases, the apparatus, including the high potential electrode, its insulating support or supports, and an endless charge conveyor, is mounted in a tank filled with gas under pressure by which the parts are surrounded, use being commonly made of a column-like series of closely spaced but separated conductive rings surrounding the conveyer and the insulating supports to maintain a substantially uniform potential gradient between the electrode and ground by dividing the total voltage of the generator between the successive rings under the principles set forth in the said Patent No. 1,991,236.

It would be expected that the gain in the dielectric strength arising from the increased pressure of the gaseous medium employed for insulating the high voltage terminal and the charge conveyer should result in a corresponding gain in the maximum charge which can be carried by the conveyer. Such expected increase, however, has not been realized, but the result has been that about the same charge only can be carried under the conditions of high pressure gas insulation as under atmospheric air, or in some cases even a lesser charge. Attempts to increase the amount of charge carried have resulted in erratic sparking of the generator, large current fluctuations, a lowering of the maximum voltage which should be produced, and in general unsatisfactory operation.

Consequently the advantage of compressed gas insulation cannot be effectively availed of. Due to the condition of low charge-carrying capacity of the charge carrier required for reasonable stability in operation, such electrostatic generators, even though surrounded by compressed gas of high dielectric strength, remain unnecessarily large due to space requirements for large charge carriers operating at relatively low charge densities.

A careful investigation of the action of electrostatic generators working under the conditions described has revealed the fact that the instability of operation and the low charge carrying capacity of the carrier is due to ionization and sparking existing in the neighborhood of the carrier, this in turn being due to the failure of any provision for suitably controlling the electric field arising from the carrier charge.

It has been found, for example, that to develop the maximum charge carrying capacity in the case of an endless charge-carrying belt, which is the more commonly employed form of charge carrier, the electric field, due to lines of force arising from the belt charge, should terminate at relatively short distances from the belt in order that the potentials due to the belt charge remain small, and that such lines of force should extend outwardly with equal density from both sides of each run of the belt.

These conditions are not realized by the means commonly adopted for establishing a controlled potential gradient along the column between the electrode and the ground, as, for example, where a column of ring-like members surrounds the insulating supports and the belt, with the total voltage divided between the rings. This not only leaves a considerable distance between the belt surface and any one ring in a transverse plane and a resulting high potential difference between them due to the belt charge, but a distance and a potential difference which undergo a substantial variation across the width of the belt.

For example, if the belt is charged along its length so that its surface gradient is 40,000 volts per centimeter, the field extends outwardly and transversely toward the rings, and if the separation between a point on the belt and the nearest point on the adjacent ring is even as small as 10 centimeters, the potential difference between such point and the ring in the same transverse plane would be about 400,000 volts, and correspondingly greater for greater distances of separation. Since such distances of separation vary widely between different points on the belt in the same transverse plane, due to ring curvature, two points on the same transverse plane of the belt would have a substantial potential difference. These high potential differences, due to the large and unequal spacing of the belt from the ring, tend to cause ionization and sparking which reduce and redistribute the charge on the belt and cause instability and impaired operation.

If the equi-potential rings or other equivalent means for establishing a controlled potential gradient along the insulating supports are not made use of, the lines of force from the charged areas on the belt surface would have to extend still further to terminate on the grounded walls of the tank, or on other objects, with the effect of creating still greater potential differences.

One object of the present invention is to increase the charge-carrying capacity of the conveying medium by controlling the electric field due to the carrier charge.

Another object is to effect that control so as to isolate such electric field and confine it to regions closely adjacent the charge-carrying member and to reduce the transverse potential due to the charge.

Another object is to so effect such control as to increase the longitudinal voltage strength of the carrier by distributing the field due to the carrier charge along the length of the carrier through controlled potentials effectively applied to a succession of short sectional lengths of the carrier.

Another object in the case of a multiple charge carrier or the like is to provide means for shielding the separate runs of the carrier one from another so that they become electrically independent.

These and other objects of the invention will be best understood by reference to the following description when taken in connection with the accompanying illustration of one specific embodiment of the invention, while its scope will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is an elevation, in partial section, showing one type of high voltage electrostatic generator employing a charge-carrying belt and embodying one form of the invention;

Fig. 2 is a detail indicating in conventional form the method of establishing electric charges on the lower end of the upwardly traveling belt;

Fig. 3 is a section in plan, on a somewhat larger scale, showing the insulating supporting columns, the belt conveyer, one of the equi-potential rings, and transverse conducting members for controlling the field due to the belt charge, there being certain additional elements herein shown which, for most effective control, may be embodied in the generator illustrated in Fig. 1; and

Fig. 4 shows in vertical section, on the same scale as Fig. 3, a portion of the belt with the associated transverse conducting members and other parts, as indicated in Fig. 3.

Referring to the drawings, and more particularly to Fig. 1 and to the embodiment of the invention which is there shown for illustrative purposes, the electrostatic generator comprises the main high potential electrode 11 consisting of a hollow shell of conductive 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 13 of conductive metal, the outer exposed surface of which is rounded, the ring in turn being mounted on the top of three spaced elongated pillars or columns 15 of insulating material of high dielectric strength, one such column only being visible in Fig. 1.

The bases of these columns rest on the base plate 17 of conductive metal which is supported by brackets 19 attached to the inner walls of the tank 21. The tank 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, and is filled with gas, which, for example, may be assumed to be air, maintained under a suitable pressure, pressures employed for this purpose being ordinarily between 100 and 200 pounds per square inch above atmospheric.

The charge carrier as herein shown is in the form of an endless belt 23 of such a 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 25 journaled in brackets 27 on the base plate, so that the pulley has a grounded connection. The pulley is driven by the motor 29 to which current is supplied by conductors entering the walls of the tank through a suitable bushing.

The belt runs vertically upward and then downward in a parallel run, passing into and out of the hollow electrode 11 and over a metallic pulley 31 within the electrode shell, the pulley being journaled in but insulated from brackets 33 supported by the ring 13. At its lower end, 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. Simultaneously charges of opposite sign are transferred from the electrode to the belt at its upper end and carried away by the descending run to the lower end, where they are removed.

The generator might be made self-exciting, but the usual effective method of applying charges to the belt is indicated in Fig. 1, where there is provided a brush electrode or comb-like series of points 35 extending across the width of the belt and closely adjacent thereto, these being connected to an electro-magnetic source of charge supply 37, conventionally indicated but which comprises a source of rectified alternating current utilizing a transformer and a vacuum tube rectifier, all as commonly employed for this purpose.

At the top of the belt, charges are removed from the upward run of the belt and transferred to the electrode by the provision of a similar brush electrode 39 just below the pulley 31 and electrically connected thereto. A second similar brush electrode 41 operatively related to the belt at the top of the pulley and connected to the electrode serves to remove charges of opposite sign from the electrode and transfer them to the downward run of the belt.

The direct current high potential maintained on the electrode 11 may be utilized for any desired purpose. In the illustrative embodiment it is availed of as a source of high potential for an X-ray tube 43, mounted vertically on the base plate 17 and having its upper opposite end extending into the hollow electrode with which it has connection. A generator 45 driven from the pulley 31 supplies current to the filament of the tube, and the grounded metallic continuation 47 of the X-ray tube extends through the bottom walls of the tank 21 and terminates in an X-ray target with beam defining means, which, like the tube, may of be any usual or suitable construction and which therefore is omitted from the drawings.

Either positive or negative charges may be applied to the end of the belt, but since the requirements and the arrangement of the X-ray tube are best served by a high negative potential on the electrode 11, the ascending run of the belt is herein indicated (Fig. 2) as having negative charges and the descending run as having positive charges applied thereto.

Means is herein provided to maintain a uniform potential gradient between the electrode and the ground, such means consisting of a series of closely spaced but separated rings 49, each of conductive metal and preferably tubular in form to present rounded external surfaces, these rings being connected with each other by suitable resistances so as to divide the potential on the terminal uniformly between them. These rings (Fig. 3) enclose the three insulating pillars 15 and provide a column-like series of successive rings extending from the upper end of the insulating supports, just below the electrode 11, to the bottom of such supports, a number of the uppermost rings and a number of the lowermost rings only being shown. These rings preferably contact with and are supported in their assigned spaced relation in any suitable manner by the insulating pillars 15. The lowermost ring is connected to ground and establishes the ground plane.

As a means of controlling the field due to the belt charge, there is provided a vertical series of conductors extending transversely across the entire width of each run of the belt (Figs. 3 and 4) and separated each from the belt preferably by a relatively small distance.

These comprise a vertical series of such conductors 51 which are closely spaced from the outside face of the ascending run of the belt, and a similar series closely spaced with relation to the outside face of the descending run of the belt. Each series extends vertically over the same range or distance as the rings 49. These conductors are shown as tubular in form, although such form is not essential so long as the surfaces presented to the belt are rounded or present no sharp corners or projections. The tubes are preferably small in diameter and closely spaced to avoid variations in distance between the belt and different parts of the conductor.

While it is not essential that these conductors conform in number or in spacing to the number or spacing of the rings 49, there is preferably provided a conductor in each series located in the plane of each ring, and as shown in Fig. 3 each conductor is prolonged in length beyond each outside edge of the belt and receives mechanical support from and electrical connection to the ring 49 located in the same plane.

Such field control means further comprises a second vertical series of conductors 53, similarly spaced and similarly constructed, such series being vertically co-extensive with the series of conductors 51 and positioned respectively in the same transverse planes but located between the ascending and descending runs of the belt and spaced therefrom at the same distance of separation as the spacing between the tubes 51 and the outer faces of the belt. In the generator illustrated in the drawings, these conductors comprise two vertical series of tubular conductors, one closely spaced from the inner face of the ascending run of the belt and the other from the inner face of the descending run of the belt, these conductors also extending across the full width of the belt and each prolonged to have electrical and mechanical connection to the ring 49 lying in the same transverse plane.

A single vertical series only of transverse conducting tubes 53 between the two belts might be used, but the employment of two such series or of a single series, where each conductor would span a large part of the space between the belts (which, as will be seen, is the effect of the arrangement illustrated in Figs. 3 and 4), permits a small separation from the inner faces of the belt irrespective of the actual spacing between the belt runs which may be imposed by the diameter of the driving pulley employed.

The described arrangement causes the belt on each side to face the transversely arranged and parallel conducting tubes which are spaced longitudinally or vertically between the high voltage terminal and the ground plane, the tubes being separated from the belt by a slight distance only, which distance is the same across the entire width of the belt. The lines of force arising from the belt charge therefore terminate at relatively short distances from the belt, thereby causing only relatively slight differences of potential in the transverse plane, and, moreover, such distances and potential differences are substantially uniform across the width of the belt. Furthermore, such lines of force extend outwardly with equal density from both sides of each run of the belt.

To maintain the spacing between the transverse conductors and the belt uniform and constant, when the belt or portions thereof may be subject to deviation from a true rectilinear path, as by the presence of a certain amount of slackness, means may be provided such as insulating spacing sleeves or sheaths 55 mounted on the tubular conductors and in close clearance only from the face of the belt and extending for more than the width of the belt. These serve to prevent the bowing out of the belt, its displacement from the electrically neutral position, and the resulting unbalancing of field distribution due to the belt charge. Although these spacing means 55 are shown in Fig. 4 as mounted only at intervals on the tubular conductors, insulating sheaths of dielectric strength, high in comparison with that of the gaseous medium, may be applied to each successive tubular conductor of the entire series on each opposite side of the two belt runs with consequent increase in the charge which can be conveyed.

It may be pointed out that the provision of the conductors between the belts causes each run of the belt to be electrically shielded from its next adjacent run, so that a plurality of runs or a plurality of belts may be employed yet each run of belt will be electrically independent of each other run and insensitive to its charge. Such a condition is not realized in the case of two adjacent runs of a charged belt having no intervening grid at controlled potentials. In such a case the lines of force from one belt extend to the corresponding opposite charges on the other belt, and hence the charges on the two runs of belt are mutually dependent. Moreover, the separation between runs of the same belt is ordinarily equivalent to the pulley diameter, which is sufficiently great to result in a high potential difference across any transverse plane between runs of belts carrying electric charge. With this situation, the conditions for high charge density herein provided are difficult to realize.

It will also be observed that the provision of the transverse conductors exercises an effective control over the field arising from the belt charge, regardless of the location of the belts with respect to the rings 49, since it makes the conditions arising from the charges on the belt independent of the distance of the belts from the rings. This permits, as in the case of the illustrated generator, the utilization of a part of the space enclosed by the rings for other apparatus, such as the X-ray tube 43, shielding such space from the influence of the electric field due to the belt charge.

The use of the controlling conductors longitudinally spaced close to the belt has the effect of dividing or separating the belt longitudinally into a series of short sections, with controlled potentials applied between each section. This has been shown to result in an increase in the longitudinal voltage strength of the belt and a substantial increase in the total voltage which can be impressed and maintained upon the electrode.

The provision of the vertical series of spaced conductors 51 and 53 assists in maintaining a controlled potential gradient lengthwise and adjacent the belt from the electrode to ground by the establishment of equi-potential surfaces, much as the rings serve to maintain such gradient lengthwise and adjacent the insulating column. The maintenance of such equi-potential surfaces at and adjacent the belt is assisted when the conductors 51 and 53 lie in the respective planes of the rings by the connection of each conductor to its corresponding ring. The establishment of such definite equi-potential surfaces, however, may be further assisted, as is indicated in Figs. 3 and 4, by the employment of flat, equi-potential surfaces in the form of thin, flat, conductive plates. A series of such plates is indicated in Figs. 3 and 4 as connected to each conducting tube 51 lying at each outside face of the belt, extending outwardly transverse thereto and connected to the inner periphery of the corresponding ring 49 or that which lies in the same plane.

A series of plates 57 is shown as extending between each ring and its corresponding conducting tube on the ascending side of the belt, and a similar series 59 is shown as extending from each ring to the corresponding conducting tube 53 on the descending side of the belt. These plates are preferably of a width transversely equal to or greater than that of the belt and may cover the whole or a part only of the entire area lying in any one plane between the conducting tube and the ring and left uncovered by the insulating pillars, X-ray tube or other interfering objects. In the construction shown in Figs. 3 and 4, the plates 57 and 59 cover the entire area lying in any one transverse plane between the conducting tubes 51 and the rings, except for that occupied by the X-ray tube, transecting the insulating pillars 15 which, in this case, are built up of a series of co-axial, cylindrical sections separated one from another by the thin conductive plates.

A similar series of flat metallic conductive plates 61 is provided to extend between opposite tubular conductors 53 of each pair and extends to and is connected at each opposite end to the inner periphery of the corresponding ring 49.

These plates extend transversely from the inner periphery of each ring toward but terminate short of the belt runs, whereat they present the rounded contour of the tubular conductors spaced from but parallel to the belt.

A uniform potential gradient throughout the series of equi-potential surfaces is provided by the slight flow of current from each transverse conducting assembly to the adjoining underlying one, as by the resistance indicated in conventional form at 63, between plates 57.

Although no potential gradient exists within the high voltage electrode or at levels substantially above the plane of the uppermost ring 49, it is desirable to control the field due to the belt charge and to localize it at positions above that of the uppermost ring. Accordingly, as shown in Fig. 1, above the uppermost conducting tube 51 on the ascending side of the belt there is provided a series (herein three) of spaced tubular conductors 65 terminating just short of the brush electrode 39. These conducting members are similar to the tubular conductors 51, being of a length sufficient to extend fully across and beyond the width of the belt. They may be supported each by the next adjacent underlying member and the lowermost one by the uppermost tubular conductor 51, or may be supported by the ring 13.

Two similar series of conducting tubes 67, and similarly supported, are provided to extend the two series of tubes 53 up into and within the electrode and just below the pulley 31. On the descending side of the belt another series of similar tubular conductors 69 is provided and similarly supported. This series, however, extends up into the electrode to approximately the plane of the pulley axis.

For similar reasons, although there is no gradient due to the potential of the terminal below the lowermost and grounded ring 49, to better control the belt charge in that region, the series of tubes 51 on each outside face of the belt is prolonged downwardly by providing several conductors 71 similar to the conductors 65 and 69, these being suspended from the lowermost tube 51 of each series or supported by some other suitable means.

While there is herein shown and described one specific means and one specific method of carrying into effect the principles which have been set forth, it is understood that the invention is not to be limited to the details of construction shown and described or to the form or relative arrangement of parts, but that obvious modifications will occur to those skilled in the art.

What I claim is:

1. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable charge-carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with gas at a high

pressure, and means to limit the extent and increase the uniformity of the distribution of the electric field due to the conveyer charge.

2. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable charge-carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means for isolating the electric field due to the conveyer charge and confining it to a region closely adjacent the conveyer.

3. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable charge-carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means to effect a substantially uniform distribution of the electric field due to the conveyer charge throughout the length of the conveyer.

4. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable charge-carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means for distributing the potential difference between the terminal and the ground in predetermined increments along the length of the conveyer.

5. A high voltage electrostatic apparatus, comprising a high voltage terminal, a movable charge conveying medium for conveying charges between the terminal and ground, insulating supporting means for insulating the terminal from ground, means for establishing a substantially uniform potential gradient along the insulating supporting means between terminal and ground, and means associated with the conveying medium to limit the extent and increase the uniformity of the distribution of the field due to the conveyed charge.

6. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, means for surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air and means for confining the electric field due to the charge on a run of the conveyer to a region adjacent the conveyer, comprising a series of transverse conductive members spaced lengthwise said conveyer run closely adjacent thereto and on each opposite side thereof.

7. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, means for surrounding said terminal, supporting means and conveyer with a medium of high dielectric strength than that of atmospheric air, and means for confining the electric field due to the charge on a run of the conveyer to a region adjacent the conveyer and maintaining the potential due to the conveyer charge substantially uniform across the width of the conveyer in any transverse plane.

8. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless charge conveyer having adjoining runs for conveying charges between said terminal and ground, means for surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means between said adjoining runs for electrically shielding one run from the electric field due to the charge of the adjoining run.

9. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, means for surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means lengthwise the conveyer for establishing a series of conductive surfaces closely adjacent the conveyer at successive transverse sections thereof and maintaining a predetermined distribution of the terminal potential along said series of surfaces.

10. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless charge conveyer having adjoining runs for conveying charges between said terminal and ground, and means for determining the field distribution due to the charge on the conveyer, comprising a series of transverse conductive members spaced one from another and closely adjacent but spaced from the conveyer, said members extending across the charged surface of the conveyer.

11. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, and means for determining the field distribution due to the charge on the conveyer, comprising a series of flat, metallic plates lying in spaced planes transverse to the path of the conveyer and provided adjacent the conveyer with conductive members presenting rounded surfaces closely adjacent but spaced from the conveyer and extending across the charged surface thereof.

12. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, means for determining the field distribution due to the charge on the conveyer, comprising transverse conductive members spaced one from another and closely adjacent but spaced from the conveyer, said members extending across the charged surface of the conveyer, and means for guiding a run of the conveyer to maintain its intended spacing from said members.

13. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable conveyer for conveying charges between said terminal and ground, means for determining the field distribution due to conveyer charges comprising a longitudinal series of groups of connected conductive members, the members of each group being spaced from the members of the next adjoining group, each group comprising transverse conductors closely adjacent to but spaced from each opposite side of the conveyer, and resistance means between successive groups for maintaining a controlled potential difference between successive groups.

14. A high voltage electrostatic apparatus, comprising a high voltage terminal, an endless belt-like conveyer arranged in two adjoining runs for conveying charges between said terminal and ground, a plurality of insulating pillars supporting said terminal, means for establishing equi-potential planes between said terminal and ground and along said insulating pillars, comprising a series of spaced conductive members associated with said pillars, arranged in successive planes and embracing the space occupied by said conveyer, and means for determining the field distribution due to the conveyer charge comprising a series of spaced conductive members, each adjacent to and extending transversely across the charged surface of the conveyer and lying in successive transverse planes, there being a series of conductive members longitudinally on each side of each run of the conveyer, said members having each electrical connection to one of the embracing members in the same transverse plane.

15. A high voltage electrostatic apparatus, comprising a high voltage terminal, a plurality of insulating pillars supporting said terminal, a series of spaced conductive rings embracing said pillars and arranged in successive transverse planes, an endless belt-like conveyer for conveying charges between said terminal and ground, arranged in adjoining runs in the space embraced by said rings and pillars, a series of spaced conductive members each adjacent to and extending across the charged surface of the conveyer and lying in the same successive transverse planes as said conductive rings, there being a series of said members longitudinally on each side of each run of the conveyer, said members each having connection to one of said rings, flat conductive plates extending between said members and said conductive rings, and means for dividing the terminal potential between said spaced conductive rings.

16. A high voltage electrostatic apparatus, comprising a high voltage terminal, insulating supporting means, a movable endless belt-like charge conveyer for conveying charges between said terminal and ground, means for surrounding said terminal, supporting means and conveyer with gas at a high pressure, and means for determining the distribution of the electric field due to the charge on a run of the conveyer and confining it to a region adjacent the conveyer, comprising a series of transverse conductive members spaced lengthwise said conveyer run closely adjacent thereto and on each opposite side thereof, said conductive members being each covered with an insulating sheath of high dielectric strength.

17. A high voltage electrostatic apparatus comprising a high voltage terminal, insulating supporting means, a movable charge carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and a series of substantially equi-potential surfaces closely adjacent the conveyer at successive transverse sections, thereby to increase the charge-carrying capacity of the conveyer.

18. A high voltage electrostatic apparatus comprising a high voltage terminal, insulating supporting means, a movable charge carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, means to increase the longitudinal voltage strength of the conveyer comprising a series of transverse conductive members spaced lengthwise and on each side of each run of said conveyer, and means for distributing the potential difference between terminal and ground uniformly along said said series of members.

19. A high voltage electrostatic apparatus comprising a high voltage terminal, insulating supporting means, a movable charge carrier for conveying charges between said terminal and ground, means surrounding said terminal, supporting means and conveyer with a medium of higher dielectric strength than that of atmospheric air, and means to confine the lines of force arising from the conveyer charge to a region extending outwardly a relatively short distance only from the conveyer and so determining the distribution of such lines of force that they extend with substantially equal density from both sides of each run of said conveyer.

JOHN G. TRUMP.