

May 5, 1959

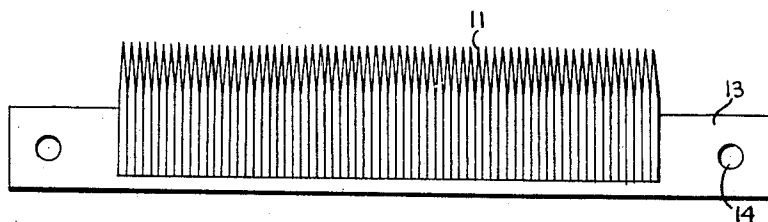
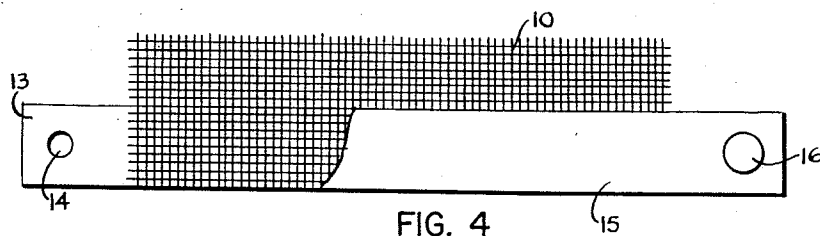
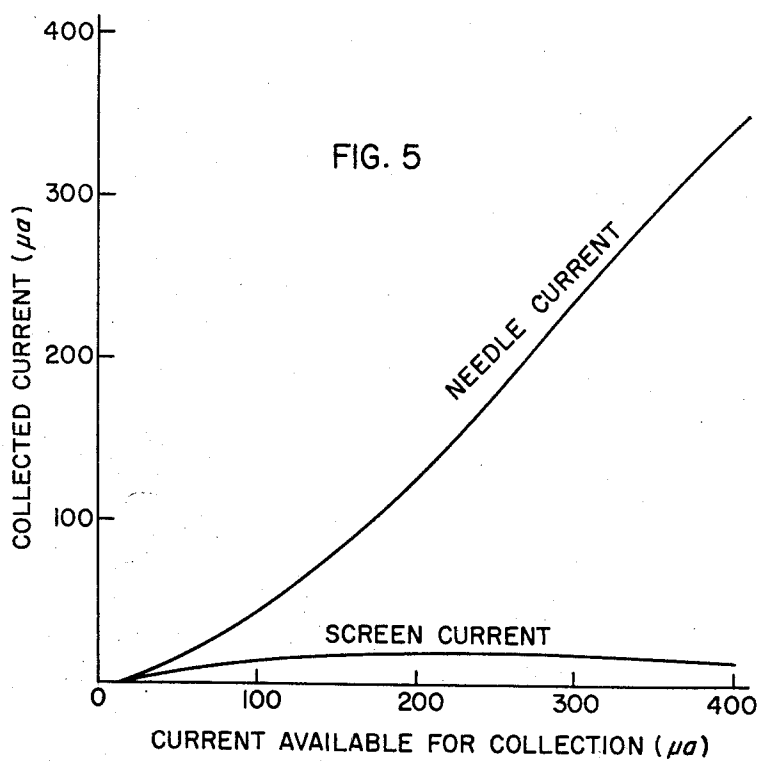
E. E. HAND

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CHARGE TRANSFERRING MEANS FOR ELECTROSTATIC GENERATORS

Filed Feb. 8, 1955

2 Sheets-Sheet 1



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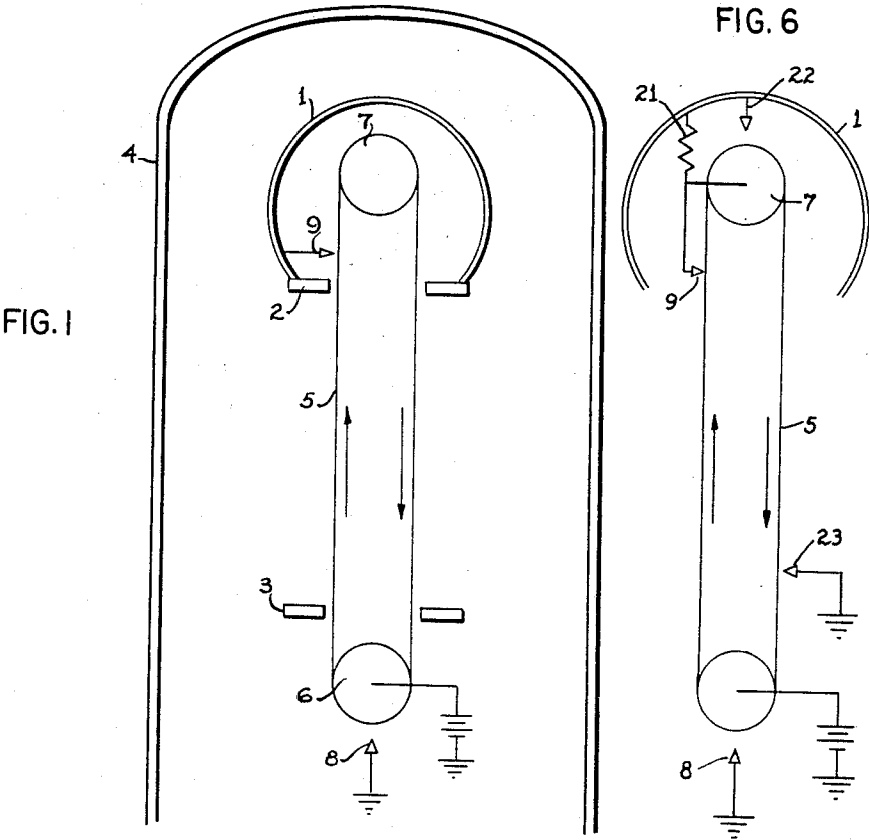
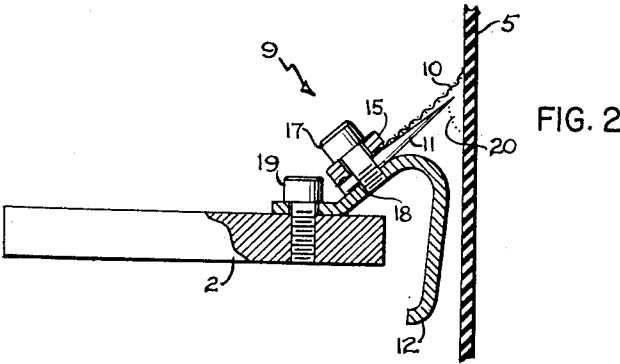
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CHARGE TRANSFERRING MEANS FOR ELECTROSTATIC GENERATORS

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10 Claims. (Cl. 317-2)

This invention relates to apparatus for collecting electric charge from the movable charge carrier of a high-voltage electrostatic generator, and in particular to apparatus for collecting electric charge, by a corona mechanism, from the traveling endless belt of an electrostatic belt-type generator. In accordance with my invention, such apparatus includes two components, one of which initiates the necessary corona discharge and the other of which collects the major portion of the electric charge collected from the belt.

When the movable charge carrier carries a net negative charge, the charge-collecting process is believed to involve predominantly a transfer of negative charge from the carrier to the charge-collector via the corona discharge. When the movable charge carrier carries a net positive charge, the charge-collecting process is believed to involve predominantly a transfer of negative charge from the charge-collector to the carrier via the corona discharge resulting in a neutralization of the net positive charge on the carrier and in the production of a net positive charge at the charge-collector. In the following specification and claims, the term "charge-collection" and related terms include both the actual transfer of the net charge from the carrier to the charge-collector and the apparent transfer resulting from neutralization of the net charge on the carrier with resultant production of net charge at the charge-collector.

In electrostatic generators of the type 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 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 upon 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

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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 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 tends to neutralize the charge on the belt, and a corresponding flow of ions of the opposite sign towards the said corona points. Thus the charge on the insulating belt may be neutralized and the points may collect a current equal to the rate at which charge is brought.

In general, if a metal point be directed at a plane and be maintained at a constant voltage with respect to the plane, a current will flow between the point and the plane because of the ionization of the gas in the vicinity of the point. This current will become measurable at a definite voltage difference called the "corona onset voltage," which depends on various factors. In particular, the corona onset voltage decreases with decreased point-to-plane spacing. 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 hereinbefore stated, the spraying of charge onto the belt is accomplished by applying a potential difference between the spray-on corona points and the pulley over which the belt passes. A relatively large potential difference is readily available for this purpose, so that considerable latitude is permissible in the construction of the spray-on corona points and in the spacing between the spray-on points and the belt. In two-million-volt pressurized generators, of the type shown in the patent to John G. Trump, No. 2,252,668 dated August 12, 1941, it is common to use a set of needles, extending in a straight line across the width of the belt, as the spray-on corona points. These needles are spaced $\frac{1}{16}$ -inch from the belt and $\frac{1}{16}$ -inch from each other, and a potential difference, derived from a voltage source, is applied between the needles and the pulley over which the belt passes. Such a charge-spray-on unit, comprising a set of needles and an external voltage source, may be provided either at the grounded pulley or at the pulley within the high-voltage terminal, or at both pulleys. Usually a charge-spray-on unit is provided at the grounded pulley only.

In order that electric charge may be transferred between ground and the high-voltage terminal, a charge-collector unit must be provided for each charge-spray-on unit. Thus, if a charge-spray-on unit is provided at the grounded pulley, a charge-collector unit must be provided within the high-voltage unit. The charge-collector unit differs from the charge-spray-on unit in that no external voltage source utilized in the collection of charge from the belt. The voltage difference between the belt and the collector corona points is created solely by the charge on the belt. This voltage difference is thus limited by the charge density on the belt, and so the collector points must be placed sufficiently close to the belt in order to initiate corona therebetween. The proximity required

is such as to render impractical the use of needles of the type used in the spray-on unit.

Owing to the thickness of the needles, the needle points must be spaced apart at least $\frac{1}{16}$ -inch, or thereabouts. Corona is initiated at each point, and each such corona discharge fans out in a cone from the point towards the belt. In the spray-on unit, the needles are spaced from the belt sufficiently so that the cross-section of each cone at the belt surface is large enough to overlap the cross-section of adjacent cones, with the result that charge is sprayed uniformly across the width of the belt. However, when the needles are very close to the belt, as they must be in the collector unit, the cross-sections at the belt surface of adjacent corona-discharge cones are spaced apart, and those portions of the charge on the belt which lie in the intervening gaps may not be collected by the collector needles.

Moreover, the proximity required between the collector needles and the belt tends to cause gouging of the belt by the needles. At the spray-on unit, the belt hugs the pulley as it passes by the needles, so that the belt does not strike the needles. But at the collector unit, the belt is remote from the pulley and tends to vibrate against the needles. Furthermore, the spray-on needles may always be spaced from the belt sufficiently to avoid any danger of gouging, since any increase in needle-to-belt spacing may be compensated for by increasing the voltage supplied, by the external voltage source, between the pulley and the needles. This flexibility in needle-to-belt spacing is not available at the collector unit, as hereinbefore noted.

For the foregoing reasons, it has been customary to use a wire screen as the collector points. A 50-mesh screen, for example, provides a row of points which are very close together, and the screen is sufficiently pliant to avoid gouging the belt. However, wire screens of this nature burn out in a relatively short time, and must be replaced frequently. Since the wire screen is located in the high-voltage terminal of the generator, the replacement thereof is an elaborate and time-consuming process.

My invention overcomes all the foregoing difficulties by providing a collector unit in which a set of corona points placed sufficiently close to the belt to initiate a corona discharge is used in combination with a corona probe positioned within the ionized region of the corona discharge but spaced sufficiently from the belt to avoid contact therewith. The corona probe is positioned in advance of the set of corona points with respect to the approaching belt, so that in general the major portion of the current removed from the belt will be carried by the corona probe. The set of corona points, which initiates the corona discharge, should be flexible, since it will probably come in contact with the belt at least occasionally, and in most cases it will actually ride against the belt surface with slight pressure. The points should be sharp and closely spaced, since they must initiate the corona discharge. Hence a wire screen is generally used as this set of corona points. The corona probe, which carries the major portion of the current collected, should be fixed in position, so that it always lies in the same part of the ionized region of the corona-discharge. However, since the corona probe does not need to be capable of initiating the corona discharge, the sharpness and spacing of the points of the corona probe are not especially critical.

Hence, the corona probe may comprise a row of needles or even a knife-edge. Moreover, even if the sharpness of the needle-points or knife-edge is adversely affected by heavy currents collected by the corona probe, no harm is done, since the corona probe does not initiate the corona discharge. The wire screen, which does initiate the corona discharge, is protected against damage, since it collects only relatively light currents.

My invention may best be understood from the following detailed description with reference to the accompanying drawings, in which:

Fig. 1 is a diagram representing schematically the essential components of an electrostatic generator;

Fig. 2 is a detail in vertical section of a charge-collector unit constructed in accordance with my invention, and including the combination of a set of needles with a wire screen;

Fig. 3 is a plan view of the set of needles of the charge-collector unit of Fig. 2;

Fig. 4 is a plan view of the assembly of the set of needles, the wire screen, and the supporting bar in the charge-collector unit of Fig. 2, the supporting bar being partly broken away to show the wire screen more clearly;

Fig. 5 is a graph illustrating the current collected by the needles and the current collected by the wire screen as a function of the total current available for collection; and

Fig. 6 is a diagram, similar to that of Fig. 1, representing schematically the essential components of an electrostatic generator in which the down-run of the belt is used to convey electric charge to ground.

Referring more particularly to the drawings, and first to Fig. 1 thereof, therein are shown diagrammatically 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, dated August 12, 1941. The invention herein claimed may be applied to the said type of electrostatic apparatus, but my invention is not necessarily limited to use with such type of apparatus.

In Fig. 1 the electrostatic generator, merely diagrammatically shown, comprises the main high-potential electrode 1 consisting of a hollow shell of conducting material, such as stainless steel, this being of a generally rounded and approximately hemispherical shape and free from external projections. The electrode rests on a ring or terminal plane 2 of conductive material, the outer exposed surface of which is rounded, the said terminal plane, in turn, being mounted on the top of any suitable number, such as three, of spaced elongated pillars or columns, not shown, 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.

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 5 herein being of insulating material, such as a multiple-ply rubber fabric. At its lower end the belt 5 passes over a metallic driving pulley 6 journaled in suitable brackets on the base plate 3. The said pulley 6 is driven by a suitable motor, not herein illustrated, to which current is supplied by conductors entering the walls of the tank 4 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 suitable brackets supported by the terminal plane 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 5, and at its upper end the charges carried thereby are removed and transferred to the electrode 1. The charging of the down-running side of the belt 5 with charges of the opposite

sign, for the purposes of further increasing the total charge delivered to the electrode 1 is optional and is not necessary to the function of my invention.

The charge spraying corona points are indicated diagrammatically at 8 and the charge removing apparatus is indicated diagrammatically at 9. The charge spraying corona points 8 may be of the conventional type, and no further reference to them is necessary to an understanding of my invention.

The charge-collecting apparatus 9 of my invention is shown in detail in Figs. 2, 3 and 4. A wire screen 10 and a row of needles 11 are bolted to an electrostatic shield 12 and the electrostatic shield 12 is bolted to the terminal plane 2, so that the entire charge-collecting assembly 9, including the screen 10, the needles 11, and the shield 12, are electrically connected directly to the high-voltage terminal 1. The row of needles 11 is shown in detail in Fig. 3, and may comprise a row of stainless steel needles each of which is about $\frac{1}{16}$ -inch in diameter at the base. The needles may be soldered to one another near their respective bases so as to form a rigid comb-like structure extending the width of the belt 5, the needle points being spaced about $\frac{1}{16}$ -inch from each other. An apertured metal tab 13 may be soldered to each extremity of the row of needles 11, by means of which tab 13 the row of needles 11 is supported.

The wire screen 10, which may comprise a 50-mesh stainless steel screen, is placed upon the row of needles 11 as shown in Fig. 4. The wire screen 10 should extend at least the width of the belt 5, and preferably extends beyond the extremities of the row of needles 11 and up to the apertures 14 in the tabs 13. The wire screen 10 is held in place by being clamped between the tabs 13 and a supporting bar 15, which is placed over the wire screen 10 so that the apertures 16, in the supporting bar 15 are in alignment with the apertures 14 in the tabs 13, as shown in Fig. 4.

Bolts 17 are inserted through the apertures 16 in the supporting bar 15, through the apertures 14 in the tabs 13, and are screwed into corresponding tapped apertures 18 in the electrostatic shield 12, so that the entire unit 9 is thus clamped together. The entire unit 9 is in turn supported on the terminal plane 2 by bolts 19.

The wire screen 10 should be so positioned as to ride against the belt 5 with slight pressure, as shown in Fig. 2. The needles 11 should be so positioned that their points are spaced from the belt 5, a distance of $\frac{1}{16}$ -inch being a suitable distance when negative charge is to be collected from the belt 5 at about 350 p.s.i. pressure. The appropriate spacing between the belt 5 and the needle points 11 may vary with each particular generator and with pressure and composition of the gas, and such spacing may be greater than $\frac{1}{16}$ -inch in some cases, particularly when positive charge is to be collected from the belt 5.

Referring again to Fig. 2, the function of the wire screen 10 is to initiate ionization in the gas intervening between the collector unit 9 and the belt 5. Since the edge of the wire screen 10 rides against the belt 5 in vertical contact therewith, the potential difference produced between the wire screen 10 and the belt 5 by the charge on the belt 5 is adequate to initiate this ionization or corona discharge. It should be noted that despite the fact that the edge of the wire screen 10 appears to be in contact with the belt 5, there will actually always be a thin layer of gas therebetween.

Once the corona discharge has been initiated between the wire screen 10 and the belt 5, the region of ionization extends out from the wire screen 10 towards the approaching belt 5 through a relatively large volume the boundary of which is indicated approximately by the broken line 20 in Fig. 2. The needles 11 are so positioned that the needle points extend into this region of ionization, and hence the needles are able to collect electric charge from the belt 5. Furthermore, once the

passage of electric charge through the ionized region between the belt 5 and the needles 11 has been initiated in the foregoing manner, the needles 11 may help to sustain the discharge, even though they would not have been able to initiate the discharge in the first instance.

Fig. 5 is a graph showing the current collected by the needles and by the wire screen in a 2-million-volt negative-potential pressurized generator, the atmosphere surrounding the generator being 80 percent nitrogen and 20 percent carbon dioxide at 350 p.s.i. gage. The currents collected are shown as a function of the current available for collection, the latter quantity corresponding roughly to the net charge on the belt. The graph of Fig. 5 shows that as the current delivered by the belt is increased, the needles carry a greater proportion of the current collected; and at the higher currents the needles carry most of the current, while the current collected by the wire screen never exceeds about 25 microamperes.

Owing to the fact that a wire screen, such as that shown at 10 in Fig. 2, is quite flexible, it is difficult to maintain the edge, which rides upon the surface of the belt, in a straight line. As a result, the current collected by the screen may be non-uniform along its edge, and sometimes portions of the edge of the screen do not collect any current from the belt. This phenomenon markedly reduced the total current collected from the belt, where such a screen provides the only charge-collecting corona points. However, in accordance with my invention and as shown in Fig. 2, the ionized region produced by the wire screen 10 will generally extend across the entire length of the row of needles 11 even if some portions of the edge of the screen 10 are collecting no current. Since the needles 11 carry the major portion of the current collected from the belt 5, the total current collected is not appreciably affected by any non-uniformity in the current collected at the screen 10.

The invention also tends to stabilize the current collected, since any fluctuation in the current collected by the needles 11 is compensated for, at least in part, by an opposing fluctuation in the current collected by the screen 10. Thus, if the current collected by the needles should drop momentarily, there will be a corresponding increase in the charge density remaining on the belt when it passes the edge of the screen, so that the current collected by the screen will rise momentarily. Similarly, a transient rise in the current collected by the needles results in a transient drop in the current collected by the screen.

As hereinbefore stated, in addition to spraying electric charge onto the belt at ground and collecting the charge within the high-voltage electrode, electric charge of the opposite sign may be sprayed onto the belt within the high-voltage electrode and collected at ground. Such an arrangement is shown in Fig. 6, wherein the voltage source required to spray charge onto the belt 5 within the high-voltage electrode 1 is derived by causing the current collected by the collector points 9 to pass through a resistor 21 which electrically connects the collector points 9 to the high-voltage electrode 1. Charge-spray-on points 22 are electrically connected directly to the high-voltage electrode 1, and the upper pulley 7, which is opposite said spray-on points 22, is electrically connected directly to the collector points 9, so that the potential difference across the resistor 21, resulting from the current therethrough, also appears between the spray-on points 22 and the upper pulley 7. The polarities are such that the charge sprayed by the spray-on points 22 is of a polarity opposite to that of the charge collected by the collector points 9.

The electric charge carried by the down-running side of the belt 5 is removed at ground by collector points 23 in the same manner as the electric charge carried by the up-running side of the belt is removed by the collector points 9 within the high-voltage electrode 1. Accordingly, the grounded collector points 23 shown in Fig.

6 may be constructed in accordance with my invention and as shown in Figs. 2, 3, and 4.

Similarly, the spray-on points 8 shown in Figs. 1 and 6, and the spray-on points 22 shown in Fig. 6, may be constructed in accordance with my invention. Such a construction might be desirable if, for example, the external power supply used to create the corona discharge from the spray-on points 8 to the belt 5 had only a limited voltage output. However, at the present time the major application of my invention is in the collection of charge from the belt, where the voltage difference across the corona gap is necessarily limited.

Having thus described the principles of the invention, together with an illustrative embodiment, thereof, 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.

I claim:

1. Apparatus for transferring electric charge between a traveling charge carrier and an electrode, between which a voltage difference exists, comprising in combination a set of corona points electrically connected to said electrode and supported sufficiently close to said traveling charge carrier so as to initiate a corona discharge between said set of corona points and said traveling charge carrier, and a corona probe electrically connected to said set of corona points and supported within the ionized region of said corona discharge but sufficiently remote from said traveling charge carrier so as to avoid any contact therewith, said corona probe being so positioned that said charge carrier in its traveling movement passes by said corona probe before passing by said set of corona points.

2. Apparatus in accordance with claim 1, wherein said corona probe comprises a second set of corona points.

3. Apparatus in accordance with claim 1, wherein said corona probe comprises a knife-edge.

4. Apparatus in accordance with claim 1, wherein said voltage difference is produced by an external power supply and wherein the apparatus produces a net electric charge on the charge carrier.

5. Apparatus in accordance with claim 1, wherein said voltage difference is produced by a net electric charge on the charge carrier and wherein the apparatus collects electric charge from the charge carrier.

6. Apparatus for collecting electric charge from the traveling belt of an electrostatic generator, comprising in combination a set of corona points supported sufficiently close to said belt so as to initiate a corona discharge between said set of corona points and said belt, and a corona probe electrically connected to said set of corona points and supported within the ionized region of said corona discharge but sufficiently remote from said belt so as to avoid contact therewith, said corona probe being positioned in advance of said set of corona points with respect to the approaching belt.

7. Apparatus for collecting electric charge from the traveling insulating belt of an electrostatic generator, com-

prising in combination a flexible set of closely spaced corona points supported sufficiently close to said belt so as to initiate a corona discharge between said set of corona points and said belt, and a corona probe electrically connected to said set of corona points and supported within the ionized region of said corona discharge but sufficiently remote from said belt so as to avoid contact therewith, said corona probe comprising a fixed set of corona points and being positioned in advance of said set of corona points with respect to the approaching belt.

8. Apparatus for collecting electric charge from the traveling insulating belt of an electrostatic generator, comprising in combination a flexible set of corona points supported almost in contact with the charge-carrying surface of the belt, whereby an ionized region is produced in the neighborhood of said corona points and extending towards the approaching belt; and a fixed set of corona points electrically connected to said flexible set of corona points and positioned so as to probe said ionized region but sufficiently remote from said belt so as to avoid contact therewith, whereby said fixed set of corona points collects electric charge from said belt prior to the arrival of said belt at said flexible set of corona points.

9. Apparatus for collecting electric charge from the traveling insulating belt of an electrostatic generator, comprising in combination a flexible screen of conductive material one edge of which rides with slight pressure against the charge-carrying surface of the belt, whereby an ionized region is produced in the neighborhood of said corona points and extending towards the approaching belt; and a fixed set of corona points electrically connected to said flexible set of corona points and positioned so as to probe said ionized region but sufficiently remote from said belt so as to avoid contact therewith, whereby said fixed set of corona points collects electric charge from said belt prior to the arrival of said belt at said flexible set of corona points.

10. Apparatus for collecting electric charge from the traveling insulating belt of an electrostatic generator, comprising in combination a flexible screen of conductive material one edge of which rides with slight pressure against the charge-carrying surface of the belt, whereby an ionized region is produced in the neighborhood of said edge and extending towards the approaching belt; and a fixed set of conductive needles the points whereof are within said ionized region but spaced from said belt so as to avoid contact therewith, the points of said set of needles being positioned in advance of said edge of said screen with respect to the approaching belt, said needles being electrically connected to said screen.

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