United States Patent

Sato et al.

[15] **3,689,767**

[45] **Sept. 5, 1972**

[54] **METHOD AND APPARATUS FOR UNIFORMLY CHARGING THE SURFACE OF AN INSULATING MEMBER**

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[30] **Foreign Application Priority Data**

Dec. 4, 1969 Japan 44/97341

[52] **U.S. Cl.** .....**250/49.5 ZC,** 250/49.5 GC

[51] **Int. Cl.** **G03g 15/00**

[58] **Field of Search** .250/49.5 ZC, 49.5 GC, 49.5 TC

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[57] **ABSTRACT**

Method and apparatus for uniformly and efficiently charging the surface of an insulating member. A plurality of charging needles in substantially perpendicular positions with respect to the surface to be charged are provided. The charging needles are further positioned on a plane parallel to the surface corresponding to the lattice points of a two-dimensional lattice. A low bias potential is applied to at least one of the charging needles corresponding to a lattice point of the basic lattice. A relatively high bias potential is applied to the tips of the remaining charging needles, the tips being maintained at a substantially fixed distance from the surface to be charged. The surface to be charged and the charging needles are displaced relative to each other along a direction which is not parallel or perpendicular to the basic translation vectors of the two-dimensional lattice formed by the closest and next-closest high bias potential charging needles.

4 Claims, 15 Drawing Figures

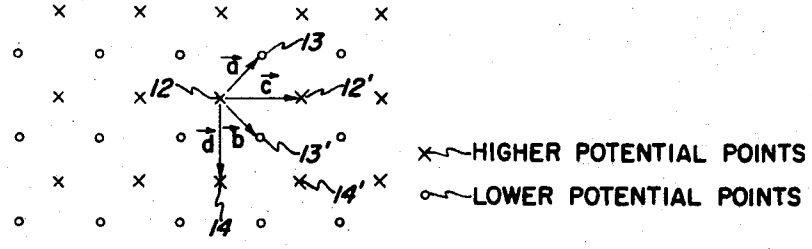


FIG. 1

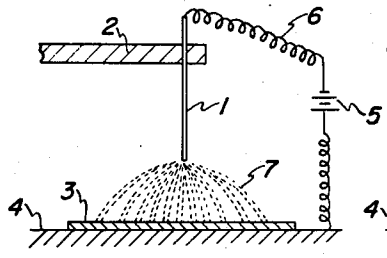


FIG. 3

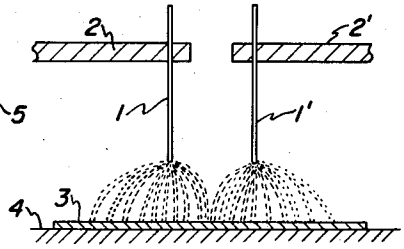


FIG. 2

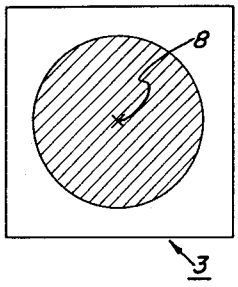


FIG. 4

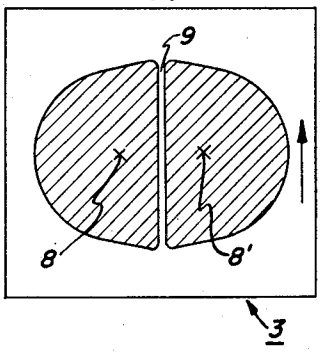
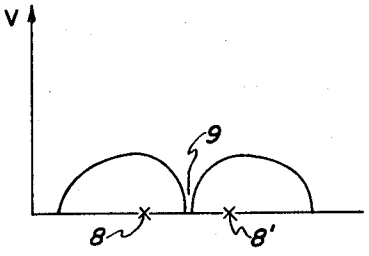


FIG. 5



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BY

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FIG. 6

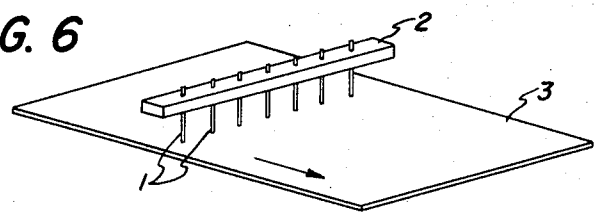


FIG. 7

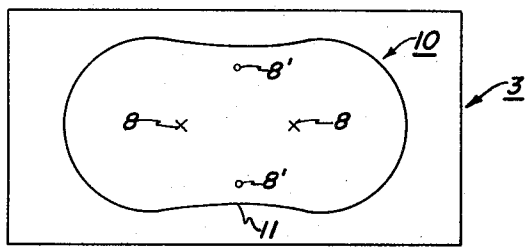


FIG. 8

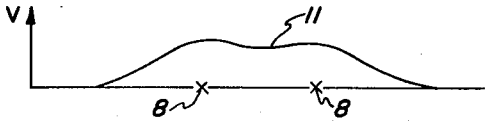
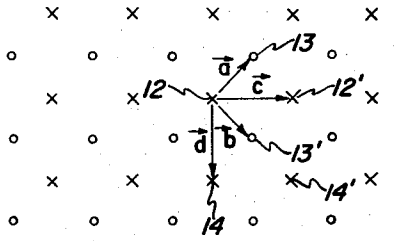


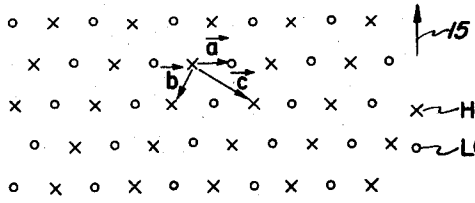
FIG. 9



HIGHER POTENTIAL POINTS

LOWER POTENTIAL POINTS

FIG. 10



HIGHER POTENTIAL POINTS

LOWER POTENTIAL POINTS

FIG. 11

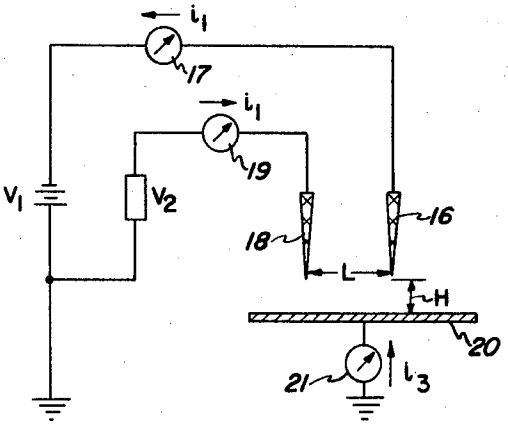


FIG. 12

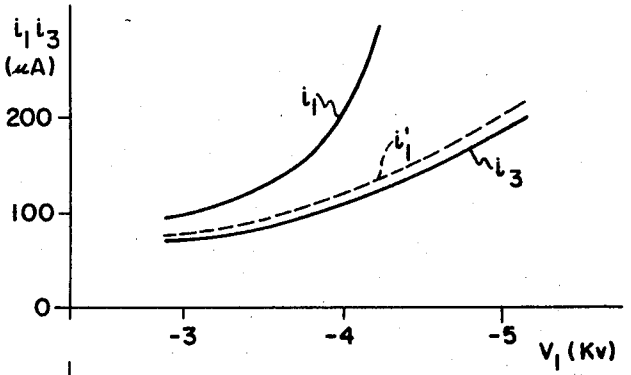


FIG. 13

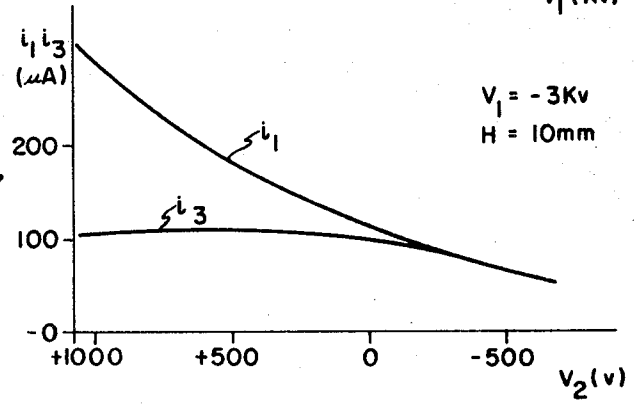


FIG. 14

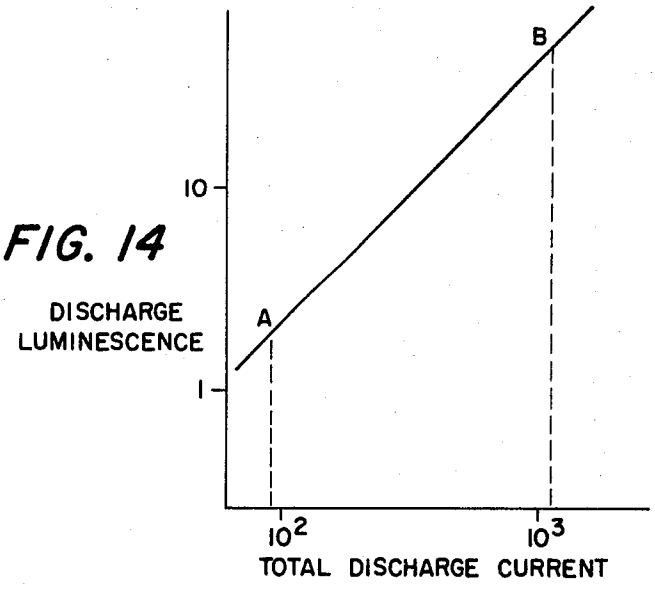
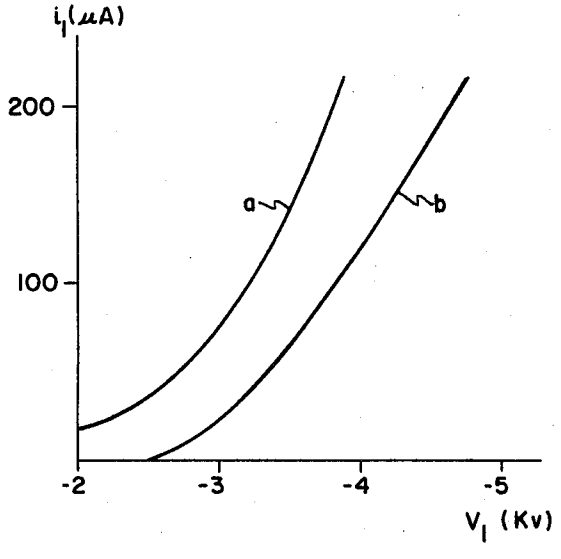

B
10
A
DISCHARGE
LUMINESCENCE
1
10^2
10^3
TOTAL DISCHARGE CURRENT

FIG. 15


$i_1(\mu A)$
200
100
a
b
-2
-3
-4
-5
V_1 (Kv)

METHOD AND APPARATUS FOR UNIFORMLY CHARGING THE SURFACE OF AN INSULATING MEMBER

BACKGROUND OF THE INVENTION

Prior art corona charging devices can be classified into those utilizing charging wires, called corona wires, and those utilizing charging needles. Charging wires, although manufactured more easily, have the drawbacks of requiring higher potential for charging with an accompanying increase in corona luminescence, the luminescence being uneven particularly in the case of negative corona leading to non-uniform charging, and requiring shield plates between wires thereby leading to considerable lowering of charging efficiency. This type of device, in addition, is larger in size when the number of wires are increased. On the other hand, although charging needles require rather complicated engineering if plural needles are to be arranged in a row, they have the advantages of lower charging potential required and less corona luminescence. In this type of device, however, the arrangement of charging needles with spacings therebetween results in charge being deposited on the material to be charged except in areas corresponding to the spacings and thus inevitably provides a charging pattern instead of uniform potential over the whole surface of the material. In the case of reproducing images including continuous tone or solid areas electrophotographically, the charging pattern deteriorates the image quality and therefore should be eliminated.

In the situation wherein the electrophotographic layer has an elevated photographic speed, light decay caused by corona luminescence becomes a problem. For example, during the electrostatic charging of the electrophotographic layer with corona discharge, the luminescence of the charging needles increases the conductivity of the electrophotographic layer resulting in a lower charging speed and a lowered saturation charge. This phenomenon becomes even more marked when the electrophotographic layer is provided with a very high sensitivity wherein charging may not be possible in extreme cases.

In order to prevent such drawbacks, grounded shield plates on both sides of the charging needles arranged in a row have been provided in the prior art. However this technique does not provide a marked improvement in the result. When this technique is utilized for obtaining uniform electrostatic charging, a major part of the discharge current is dissipated to the shield plates, the current utilized for charging thereby becoming quite small. Consequently, the efficiency of charging is lowered and the advantages of using charging needles is substantially lost.

Another technique utilized in the prior art consists of positioning the row of charging needles diagonally with respect to the direction of movement of the material to be charged. Although this technique is effective, the electrode unit including the charging needles is inevitably larger.

SUMMARY OF THE PRESENT INVENTION

The present invention provides method and apparatus for uniformly and efficiently charging the surface of an insulating member utilizing a plurality of charging needles. In particular, a plurality of charging needles in substantially perpendicular positions with respect to the surface to be charged are provided. The charging needles are further positioned on a plane parallel to the surface corresponding to the lattice points of a two-dimensional lattice. A low bias potential is applied to at least one of the charging needles corresponding to one of the lattice points of the basic lattice. A relatively high bias potential is applied to the tips of the remaining charging needles, the tips being maintained at a substantially fixed distance from the surface to be charged. The surface to be charged and the charging needles are displaced relative to each other along a direction which is not parallel or perpendicular to the basic translation vectors of the two-dimensional lattice formed by the closest and next-closest high bias potential charging needles.

It is an object of the present invention to provide novel method and apparatus for uniformly charging the surface of an insulating member.

It is a further object of the present invention to provide novel method and apparatus for uniformly charging the surface of an electrophotographic member utilizing a plurality of charging needles.

It is still a further object of the present invention to provide novel method and apparatus for uniformly and efficiently charging the surface of an electrophotographic member utilizing a plurality of charging needles and wherein corona luminescence is significantly reduced.

It is an object of the present invention to provide novel method and apparatus for uniformly and efficiently charging the surface of an electrophotographic member utilizing a plurality of charging needles and wherein the magnitude of the potential necessary to initiate corona discharge between the charging needles and the surface of the electrophotographic member is significantly reduced.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention, as well as other objects and further features thereof, reference is made to the following description which is to be read in conjunction with the accompanying drawing wherein:

FIGS. **1** and **3** are elevation views showing electrostatic charging with one and two needle electrodes, respectively;

FIGS. **2** and **4** are plan views showing the charged areas obtained utilizing the charging apparatus of FIGS. **1** and **3** respectively;

FIG. **5** is a graph showing the distribution of charge potential generated by the electrostatic charging apparatus shown in FIG. **3**;

FIG. **6** is a perspective view of apparatus for transporting the material to be charged in a direction perpendicular with respect to a row of plural charging needle electrodes;

FIG. **7** is a plan view showing the basic arrangement of high potential charging needle electrodes and low potential charging needle electrodes and the charged area obtained therefrom;

FIG. **8** is a graph showing the distribution of charge potential in the charge area of FIG. **7**;

FIGS. **9** and **10** are plan views showing the arrangement of charging needle electrodes as utilized in the charging apparatus of the present invention;

FIG. 11 is a schematic diagram of the charging apparatus of the present invention;

FIGS. 12 and 13 are graphs showing the electrical characteristics of the apparatus shown in FIG. 11;

FIG. 14 is a graph showing the relationship between the discharge current of the corona discharge apparatus and the intensity of light emitted from the charging needles; and

FIG. 15 is a graph comparing the discharge efficiency with and without the presence of low potential charging needle electrodes.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates the electrostatic charging of the surface of an insulating member utilizing one charging needle. A charging needle 1, having a fine, or sharpened, tip is held by an insulating bar 2. Insulating material to be charged 3, such as an electrophotographic layer, is placed on a conductor 4, functioning as an electrode. A direct current high potential source 5 is applied between charging needle 1 and electrode 4 via wire 6. The lines of electric force between the tip of electrode 1 and electrode 4 is represented by reference numeral 7. Electrostatic charging on the material to be charged 3 is commenced when the corona discharge is started, and a substantially circularly distributed electrostatic charge pattern is deposited on material 3 when the application of potential from potential source 5 is terminated after an appropriate period. The charge thus obtained can be rendered visible by applying a developer powder having a polarity opposite to the polarity of the charge deposited on material 3, as shown in FIG. 2. The center 8 of the charger pattern is approximately located directly below the charging needle 1 of FIG. 1. The dimension of the charge pattern is dependent on the potential applied to needle 1, the charging period, the distance between the tip of needle 1 and the surface of material 3, the diameter of the charging needle tip, etc. If the charging needle 1 is not perpendicular to the surface to be charged, the center 8 of the charge pattern is no longer located directly below the tip of charging needle 1 but is displaced according to the inclination thereof.

FIG. 3 illustrates electrostatic charging with two charging needles. The lines of electric force arising from two charging needles 1 and 1' repel each other leading to the distorted charge pattern as shown in FIG. 4. In this illustration, the two charging needles are provided with an electric potential of the same polarity. Thus if charging needles q and 1' are positioned with a relatively small spacing therebetween, the lines of electric force arising therefrom repel each other to form a boundary zone between the charging patterns generated by each charging needle. As a result of such repulsion, a substantially charge free boundary zone 9 appears on a plane perpendicular to the charging needles and along the line bisecting said needles, as shown in FIG. 4 in which electrostatically charged areas are represented by two almost semicircular zones, and wherein the points 8 and 8' are located below the tips of charging needles 1 and 1' respectively. When the distance between charging needles 1 and 1' is sufficiently large or when the charging potential is sufficiently small, non distorted circular charge patterns are obtained. The potential gradient in the distorted portions is steeper than that in FIG. 1. Thus, when the material to be charged 3 is displaced along the direction of the arrow in FIG. 4, a band-shaped, non-charged area corresponding to boundary zone 9 is produced.

FIG. 5 shows the distribution of charge potential on the material to be charged 3 when this is seen from the direction of the arrow in FIG. 4.

FIG. 6 shows a method of operation in which a plurality of charging needles arranged in a row along a straight line with constant spacings therebetween are kept at a fixed height from the material to be charged 3 while the material is displaced in a direction perpendicular to the row of charging needles. In this case, material 3 is charged, for the reasons set forth hereinabove, in the shape of a plurality of strips corresponding to the number of charging needles and having a plurality of non-charged band-shaped zones therebetween.

FIGS. 7 and 8 are a plan view and a graph of the distribution of charge potential, respectively, illustrating the principles of the present invention, as compared to the results shown in FIGS. 4 and 5. The points 8, 8, represented by a cross, and the points 8', 8', represented by a dot, correspond to the locations on the material to be charged directly below the charging needles of high bias potential and low bias potential, respectively. The locations of the charging needles correspond to the lattice points of a two-dimensional diagonal lattice. The charging needles 8' are either grounded or connected to a source of low bias potential. The reference number 10 indicates the boundary of the charged area obtained when the position of the material to be charged is kept fixed with respect to the charging needles. Due to the presence of lower potential charging needles 8', the boundary of the charged area obtained by higher potential charging needles 8 shows recessed portion 11 having a relatively low potential. In addition, the potential gradient becomes less steep when compared with that in FIG. 5. In the device of FIG. 7, the distance between the higher potential charging needles 8, 8 and the surface to be charged is identical with that between the lower potential charging needles 8', 8' and the surface, although these distances need not necessarily be the same.

FIG. 9 shows an example of an arrangement of charging needles corresponding to the two-dimensional basic lattice as shown in FIG. 7. The direction of relative motion between the surface to be charged 3 and the charging needles is selected so as not to be perpendicular and not parallel to the basic translation vectors of a two-dimensional lattice formed among the charging needles located corresponding to the lattice points of a two-dimensional lattice by the closest and next-closest higher potential charging needles. For example, in FIG. 9, the basic translation vectors of a two-dimensional lattice formed by two higher potential charging needles 12 and 12' and two lower potential charging needles 13 and 13' are represented by $\vec{a}$ and $\vec{b}$. On the other hand, the two-dimensional lattice formed by charging needle 12, the closest higher potential charging needle 14 thereof and next-closest higher potential charging needle 14', is represented by 12–14–14'–12'–12, and the basic translation vectors thereof are represented by $\vec{c}$ and $\vec{d}$. The relative motion is in any direction except the direction of vectors $\vec{a}$, $\vec{b}$, $\vec{c}$, and $\vec{d}$.

FIG. 10 shows an example of a two-dimensional hexagonal lattice based on basic translation vectors $\vec{a}$ and $\vec{b}$. In this case the two-dimensional lattice consisting of higher potential charging needles is formed by basic translation vectors $\vec{b}$ and $\vec{c}$, and the desirable direction of relative motion is indicated by arrow **15**.

In the arrangement of charging needles shown in FIGS. **9** and **10**, two charging needles among those located corresponding to the lattice points of a two-dimensional lattice are supplied with a higher electric potential while the remaining two charging needles are supplied with lower electric potential. Alternatively, a higher potential may be applied to one charging needle and a lower potential to the remaining needles, or vice versa.

The present invention will be further explained by reference to a representative for example thereof. With an arrangement of charging needles as shown in FIG. **10**, under the conditions of basic translation vectors $|\vec{a}| = |\vec{b}| = 10$ mm, the distance between the tips of the charging needles and the surface to be charged is set to 10 mm, the potential applied to the lower potential charging needles is −3kV, the potential applied to the lower potential charging needles is 0 (grounded) and the relative translating speed is 5 cm/sec (along the arrow **15**) sufficient electrostatic charging was obtained without the non-charged band shaped zones and with very little discharge luminescence. In the above example the discharge current decreases remarkably resulting in insufficient electrostatic charging if the distance between the tips of the charging needles and the surface to be charged is increased to 20 mm while the other conditions are maintained unchanged. In this condition, sufficient electrostatic charging can be obtained by modifying the potential applied to the higher potential needle to −5 kV, but this modification gives rise to an extreme increase of current flowing between the higher potential charging needles and the lower potential charging needles, leading to a marked increase in total discharge current and discharge luminescence. In this condition, the application of a negative potential of about several hundreds to 1,000 volts to the lower potential charging needles decreases significantly the current between the higher potential discharge needles and lower potential discharge needles, thereby decreasing the total discharge current and discharge luminescence.

As can be seen from this example, the increase in distance between the tips of the charging needles and the surface to be charged with respect to the distance between the higher potential charging needles and the lower potential ones is unfavorable due to the requirement for higher potential. Thus, in the preferred embodiment, the distance between the surface to be charged and the tips of the higher potential charging needles is preferred to be similar to or less than the distance between the higher potential charging needles and the lower potential charging needles.

FIG. **11** illustrates an example of an electric circuit adapted for use in the present invention. A negative potential V_1 is applied to higher potential charging needle **16** through an ammeter **17**, and a bias potential V_2 is applied to lower potential charging needle **18** through an ammeter **19**. Reference letter H represents the distance between the tip of charging needle **16** and the surface to be charged **20**. Reference letter L represents the distance between needles **16** and **18**. The material to be charged **20** (in this figure assumed to be made of a conductive material is grounded through ammeter **21**.

In the present invention, the conditions $|V_2| < |V_1|$ and L≥H is preferred although L<H is also possible if it is permissible to employ larger values of V_1. In the case of FIG. **11**, $i_1 = i_2 + i_3$, in which i_1, $i_3$and i_2, respectively stand for total discharge current, current effective for charging toward the surface to be charged and current loss dissipated from charging needle **18** to charging needle **16**. It is desirable to realize the conditions of $i_2 = 0$ and $i_1 = i_3$ so as to utilize the whole current effectively for electrostatic charging and thus to obtain a higher charging efficiency.

FIG. **12** shows the relationships of V_1 versus i_1 or i_3 in the case where $H = L = 10$ mm. When $V_2 = 0$, i_1 increases rapidly with the increase of $|V_1|$ as shown by the solid line, while i_3 does not increase so rapidly thereby resulting in the increase of $i_2 = i_1 - i_3$, corresponding to the lowering of charging efficiency and an increase in discharge luminescence. When $V2 = -200$ V, i_1 (i_1') changes as indicated by the dotted line, leading to a remarkable decrease of $i_2 = i_1 - i_3$. It can be seen that i_3 remains almost constant when $V_2 = 0$ and $V_2 = -200$ V. Thus it is possible to minimize the value of i_2 by choosing appropriately the value of V_2.

FIG. **13** shows the relationships of V_2 versus i_1 or i_3 in the case of $H = L = 10$ mm and $V_1 = -3kV$. As can be seen from this figure, the preferable range under these conditions can be represented by $0 > V_2 > -600V$ whereby $i_2 = i_1 - i_3$ is kept small. A value of V_2 larger than zero will lead to larger i_1 and therefore larger i_2, whereas a value of V_2 smaller than −600 V will result in small i_1 and thus lower charging speed though i_2 is nearly zero.

The desirable range of V_2 is determined as the function of H, L and V_1. Thus it is preferred to increase $|V_2|$ along with the increase of $|V_1|$ if H and L remain constant. In order to satisfy these conditions automatically, the potential drop induced by the current i_2 across a resistance may be utilized as the bias potential V_2. For example, if the charging needle **18** is grounded through a high resistor of 100 megohms, with the condition $H = L = 10$ mm, the potential appearing across this resistor will be used as an effective bias potential even when the value of V_1 is changed since i_2 increases as $|V_1|$ increases.

It is important to note that the discharge luminescence is made smaller when i_1 is small. It may be shown that the discharge luminescence associated with charging wires, for example using five molybdenum wires having a diameter of 65 microns arranged parallel with a spacing of 30 mm therebetween and shield plates between and above the charging wires, the distance between the wires and the surface to be charged being selected to be 20 mm, will be much greater when compared with the case of using charging needles as set forth hereinabove.

The relationship between total discharge current and discharge luminescence, when expressed both in logarithmic scale, as in FIG. **14**, becomes linear, and this relation holds both for charging wires and for charging needles. The charging operation is carried out around points A and B in the case of charging needles

and of charging wires, respectively, to obtain comparable electrostatic charging.

A comparison of the cases wherein electrostatic charging is carried out solely with high potential charging needles and with the cooperation of lower potential charging needles is illustrated in FIG. 15. FIG. 15 is a graph showing the relationship of V_1 versus i_1 in the presence (curve *a*) and absence (curve *b*) of lower potential charging needles. It can be seen that the potential V_1 applied for maintaining discharge can be made smaller, even as small as -2 *kV*, if lower potential charging needles are used in association with the higher potential ones. The charging operation can be satisfactorily carried out even at -1 *kV* if finer needles are employed.

The advantages of the present invention can be summarized as follows:

1. It is possible to use photoconductive materials of higher speed without using means to shield the materials from the light generated by the discharge needles since the corona luminescence is significantly decreased,

2. The potential applied to generate the corona discharge can be lowered substantially leading to decreased danger,

3. Substantially uniform charging can be realized,

4. A high charging speed may be obtained which is an important factor in automated apparatus,

5. The charging apparatus (electrode part) can be made much smaller, which is an important factor for compactizing the charging apparatus of the present invention, and

6. It is possible to obtain extremely high charging efficiencies since the whole discharge current is effectively used for charging with almost no loss if the bias potential is appropriately chosen.

Although the member to be charged has been generally characterized as an electrophotographic layer overlying a conductor, the present invention may be utilized with equal facility with an electrically insulating material formed on a conductive support. For example, a layer of plastic formed on a conductive support may be uniformly and efficiently charged with the apparatus of the present invention.

While the invention has been described with reference to its preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teaching of the invention without departing from its essential teachings.

What is claimed is:

1. Apparatus for uniformly charging the surface of an insulating member comprising:

a plurality of charging needles positioned substantially perpendicular to the surface of said insulating member and in the positions in a plane parallel to said surface corresponding to the lattice points of a two-dimensional lattice,

means for applying a first bias potential to at least one charging needle corresponding to a lattice point of said lattice,

means for applying a second bias potential to the remaining charging needles corresponding to the remaining lattice points of said lattice, the tips of said remaining charging needles to which said second bias potential is applied being maintained at a substantially fixed distance from said surface, the absolute magnitude of said second bias potential being greater than the absolute magnitude of said first bias potential, and

means for causing relative motion between said surface and said charging needles along a direction which is not perpendicular or parallel to the basic translation vectors from an arbitrary lattice point at said first bias potential to the closest and the next-closest lattice points at said second bias potential.

2. The apparatus as defined in claim 1 wherein the distance between said surface and the tips of said remaining charging needles is not greater than the distance between a charging needle having said first bias potential applied thereto and a charge needle having said second potential applied thereto.

3. A method for uniformly charging the surface of an insulating member comprising:

positioning a plurality of charging needles substantially perpendicular to the surface of said insulating member and in the positions in a plane parallel to said surface corresponding to the lattice points of a two-dimensional lattice,

applying a bias potential to at least one charging needle corresponding to a lattice point of said lattice,

applying a second bias potential to the remaining charging needles corresponding to the remaining lattice points of said lattice, the tips of said remaining charging needles to which second bias potential is applied being maintained at a substantially fixed distance from said surface, the absolute magnitude of said second-bias potential being greater than the absolute magnitude of said first bias potential, and

producing relative motion between said surface and said charging needles along a direction which is not perpendicular or parallel to the basic translation vectors from an arbitrary lattice point at said first bias potential to the closest and the next-closest lattice points at said second bias potential.

4. The method as defined in claim 3 wherein the distance between said surface and the tips of said remaining charging needles is not greater than the distance between a charging needle having said first bias potential applied thereto and a charging needle having said second bias potential applied thereto.

* * * * *