United States Patent [19]

Jahn

[11] **3,900,735**

[45] **Aug. 19, 1975**

[54] **CORONA DISCHARGE APPARATUS**

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[22] Filed: **Mar. 27, 1974**

[21] Appl. No.: **455,485**

Related U.S. Application Data

[63] Continuation of Ser. No. 287,330, Sept. 8, 1972, abandoned.

[30] **Foreign Application Priority Data**

Sept. 10, 1971 Germany 2145268

[52] **U.S. Cl.** ..... **250/324**; 317/262 A

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

[58] **Field of Search** ..... 250/324, 325, 326; 317/262 A

[56] **References Cited**

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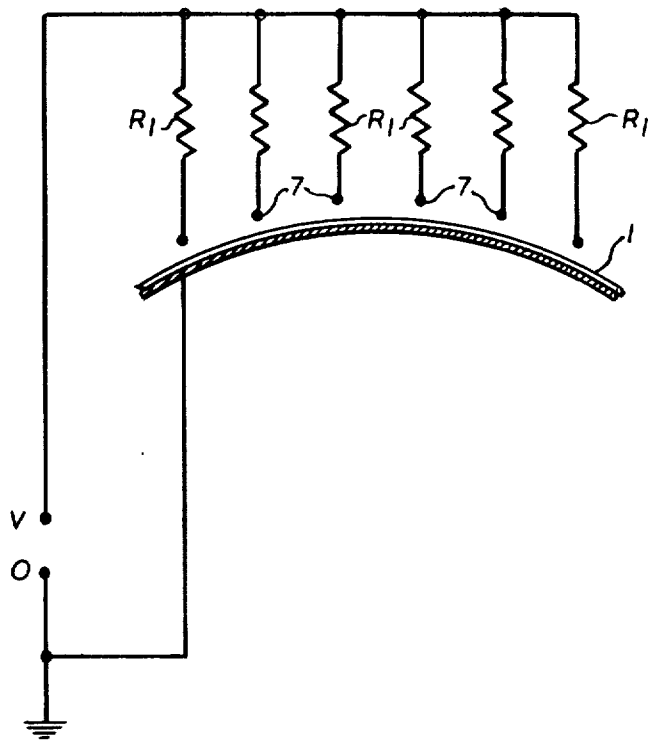
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Assistant Examiner—C. E. Church
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[57] **ABSTRACT**

Corona discharge apparatus having a plurality of discharge elements provided with a plurality of resistors for connecting respective discharge elements, or groups of discharge elements, to a voltage source to result in more uniform corona discharge from the discharge elements.

20 Claims, 7 Drawing Figures



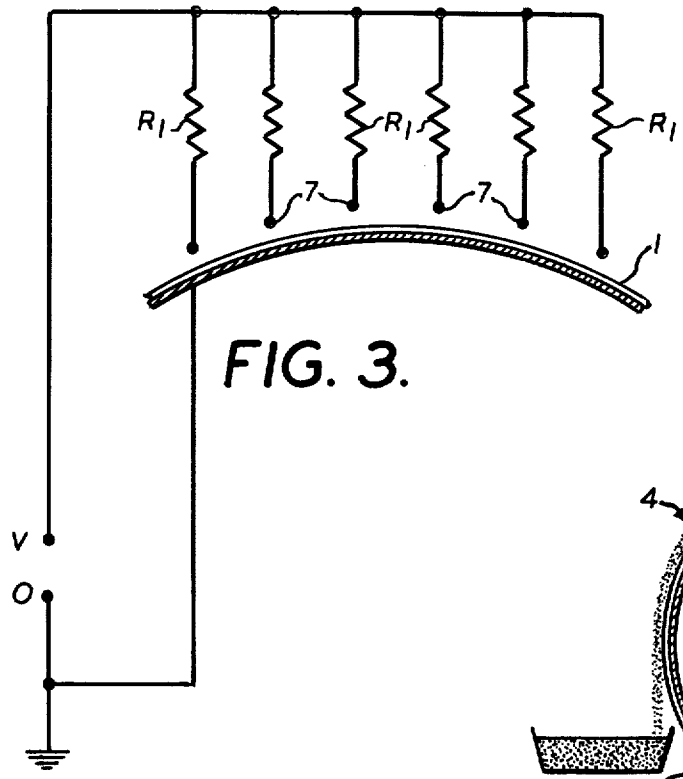


FIG. 3.

FIG. 1.

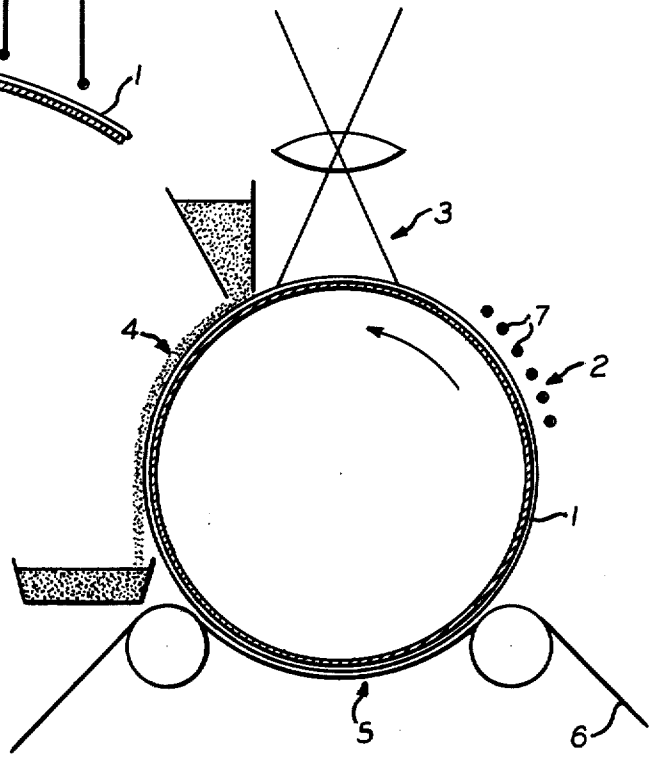


FIG. 2.

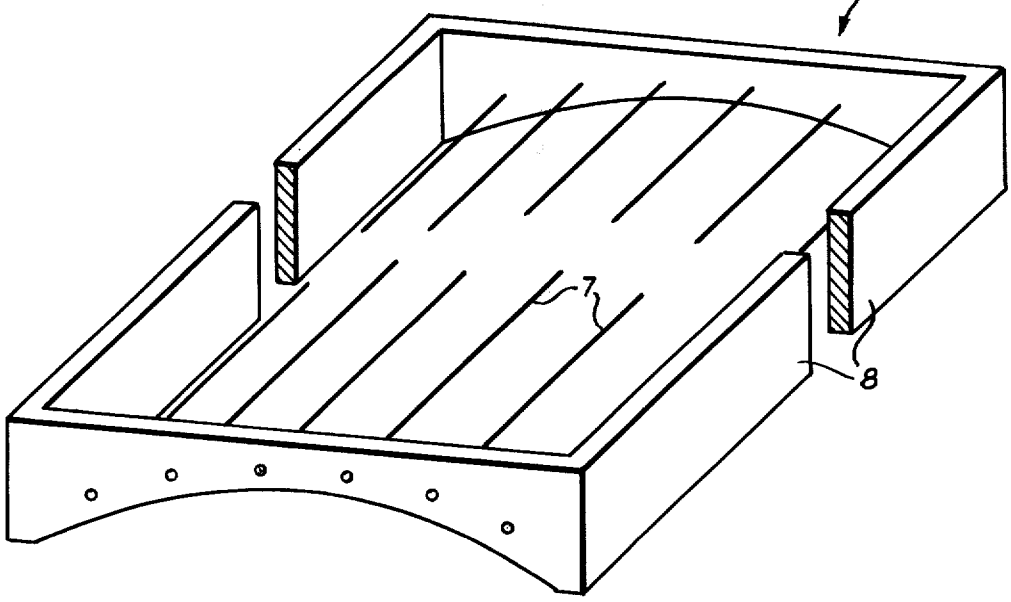


FIG. 4.

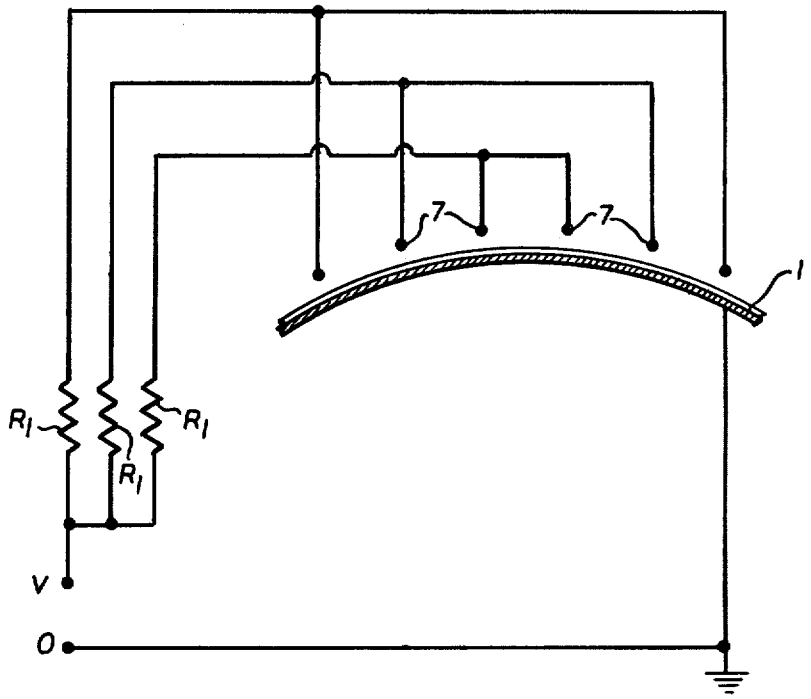


FIG. 5.

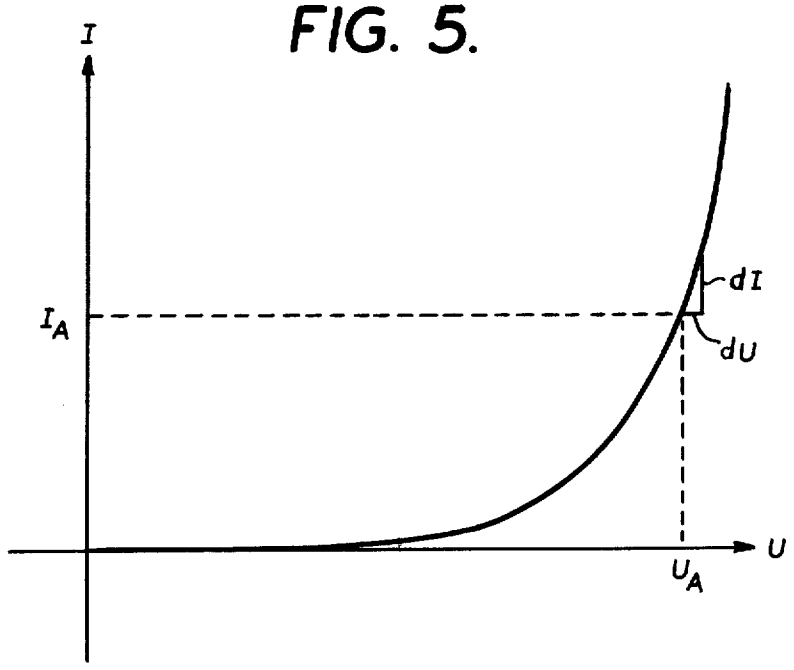


FIG. 4A.

$R_1 \cong 2R_2$

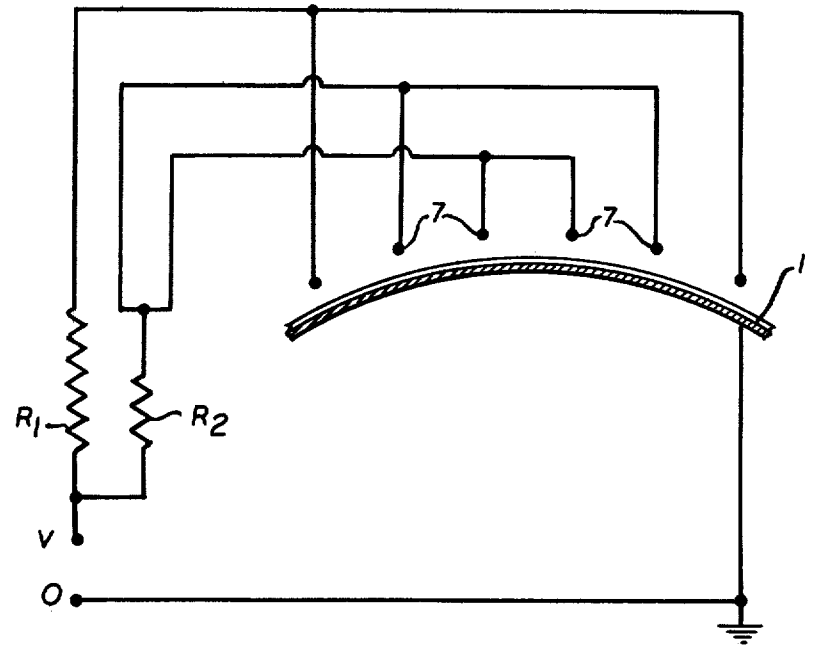
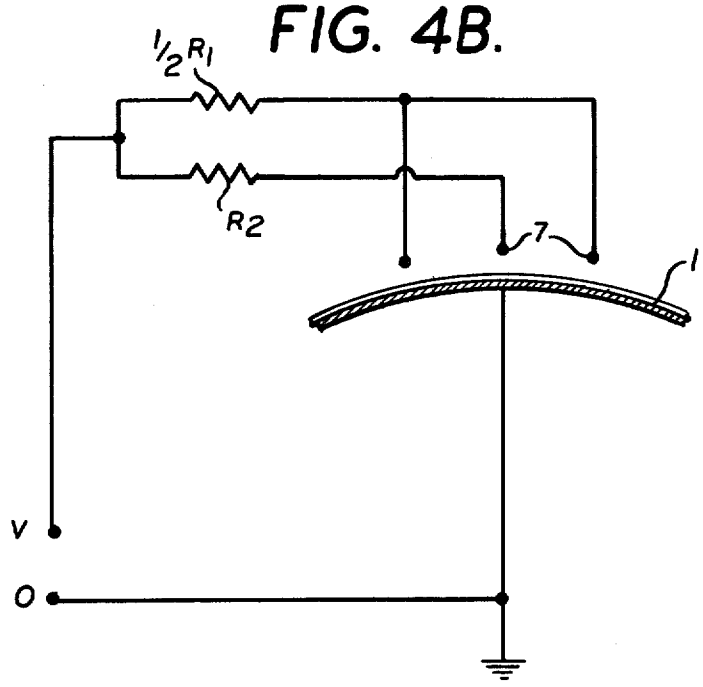


FIG. 4B.



CORONA DISCHARGE APPARATUS

This is a continuation, of application Ser. No. 287,330, filed Sept. 8, 1972 now abandoned.

The present invention relates to a corona-discharge apparatus and especially to such apparatus including a plurality of discharge elements.

In xerographic copying machines, there is provided an intermediate-image carrier, in the form of a photoconductive cylinder, which is electrically charged by means of a corona-discharge apparatus.

In the case of high-capacity copying machines, such corona-discharge apparatus usually comprises a plurality of discharge wires which are disposed parallel to each other and to the surface of the photoconductive cylinder. Such apparatus suffers from the disadvantage that the inner discharge wires produce fewer ions than the outer wires. Efforts have been made to remedy this by bringing the inner wires closer to the photoconductive surface than the outer wires, or to apply a somewhat higher voltage to the inner wires than to the outer ones. Both of these possible solutions, however, suffer from the disadvantage that the variations in the selected compensation parameters are critical, so that over-compensation can easily occur.

An object of the present invention is to provide a corona-discharge apparatus having a plurality of discharge wires in which a substantially uniform current density is achieved in all the discharge wires.

Accoding to the invention there is provided a corona-discharge apparatus having a plurality of discharge elements in which a plurality of resistors is provided for connecting respective discharge elements or groups of discharge elements to a voltage source. In such apparatus in which the discharge elements are arranged symmetrically, the elements can be connected in symmetrical groups and each group connected by way of a separate resistor to the voltage source. In the case in which the apparatus consists of a plurality of discharge wires arranged equidistantly and parallel to one another, the first wire may be connected to the last, the second to the next-to-last, and so forth, and in each case to apply voltage to these pairs of wires by way of resistors respective to the pairs.

The resistors may be chosen so that the voltage across the resistances are of the same order of magnitude as the voltages on the discharge wires to which they are connected, with the additional advantage of a considerably reduced effect on the discharge of changes in moisture content in the air and air pressure, as compared with a system not using such resistors.

The apparatus of the invention offers the particular advantage that the alteration of the electrical field of the wire by the neighboring wires has only a small effect on the strength of the emission current. A higher voltage is automatically established at the inner wires of the discharge apparatus than at the outer wires, this higher voltage on the inner wires resulting from the change in the electric field in the vicinity of those wires compared with that near the outer wires and from the same impressed emission current on both wires.

The invention will now be described in greater detail by reference to an embodiment illustrated in the drawing, in which:

FIG. 1 is a diagrammatic sectional view of a xerographic reproduction machine,

FIG. 2 is a diagrammatic perspective view of a corona-discharge apparatus,

FIG. 3 shows the connection diagram for the corona wires in accordance with the invention,

FIGS. 4, 4A and 4B show, further forms of the arrangement for electrically connecting the corona wires, and

FIG. 5 shows the current-voltage characteristic curve of a corona wire.

For the purpose of explaining an important application of the apparatus according to the invention, reference is first made to FIG. 1. In a xerographic reproduction machine, the curved surface of a photoconductive cylinder 1 is electrically charged by a corona-discharge apparatus 2, and is then exposed in an exposure station 3 to produce an electrical charge image. This image is developed in a cascade developing station 4 by the application of toner, and the developed toner image is transferred at a transfer station 5 to a copy-receiving material, which may be, for example, a web of paper 6.

In the case of a xerographic machine, the corona-discharge apparatus 2, of FIG. 1, may consist of the arrangement illustrated in FIG. 2, which has thin wires 7 clamped in a frame 8 in such a way that all the wires 7 are positioned at equal intervals above the surface of the photoconductive cylinder 1. If a high voltage is applied to the very thin wires 7, a corona-discharge takes place as a result of the high electric field-strength which develops at the surfaces of the wires, and the surface of the photoconductive cylinder 1 is thus charged. In the case of high-capacity copying machines, such corona-discharge apparatus use a current density of a magnitude that is just capable of meeting requirements based on the characteristics of the apparatus and the properties of the photoconductive material to be charged. To achieve the optimum charging of the surface, it is desirable to have uniform emission over the available area of the corona-discharge apparatus.

In a first form of the discharge apparatus according to the invention, each of the thin corona wires 7 is connected by way of a high-resistance resistor R_1 to a voltage source V as shown in FIG. 3. A second form of apparatus according to the invention is illustrated in FIG. 4, in which each pair of symmetrically arranged wires 7 are connected together and by way of a resistor R_1, common to the pair, to the voltage source V. As illustrated in FIG. 4A, the two inner pairs of wires may be connected together and voltage applied to them by way of a single resistor, and the outer pair of wires may be connected together and to the voltage source by way of a further resistor; in this case the resistor to which the outer pair of wires is connected is about twice the value of that to which the two inner pairs of wires are connected. Similarly, as illustrated in FIG. 4B, the arrangement may comprise a group of wires and a single wire and where the group of wires comprises two wires the resistor to which this group is connected has a value about one-half of the resistor to which the single wire is connected. In the case of other symmetrical arrangements of discharge wires, the values of the resistors should generally be as if the discharge wires were connected by respective equal resistors to the voltage source V, and then when the wires are connected in groups the parallel connected resistors are replaced by single resistors of the same value as the parallel combination they replace. Thus, if in the case of six wires of which each is connected to a 4 megaohm resistor, when

joined in groups the outer pair of wires can be connected together and to a 2 megaohm resistor, and the two inner pairs of wires can be connected together and to a 1 megaohm resistor. More generally, when there are x wires joined together in each group, the value of the single resistor for each group should be equal to $^{R}1/_{x}$ when R_1 is the value of the resistor that would be employed if the discharge wires were individually connected via a resistor, to the voltage source, rather than being grouped. When the total number of discharge wires is odd, the central wire may be provided with an individual resistor, surrounding symmetrical pairs of wires being grouped and led to appropriately lower resistors, depending on how many pairs are led to the voltage source via a single resistor (see FIG. 4B).

While applicants do not rely on any particular theory underlying the success of their invention, the following explanation is provided, without the invention in any way being intended to be limited thereto. It will be assumed that the discharge wires 7 each have a current-voltage characteristic curve that is very much dependent upon the geometrical arrangement and upon the particular neighboring wire and its current, and that the curve varies from wire to wire. Symmetrically arranged wires are assumed to have the same characteristic curve. The effect of the resistors R_1 connected in the leads to the voltage supply is that the changes in field-strength caused by the neighboring wires can be ignored. It has been found that this is achieved when the compensating resistor R_1 has a considerably higher value than the differential resistance dU/dI of the individual discharge wire, and that it is of no importance that the working resistance of the wire RA = UA / IA can be regarded as being very low compared with R_1.

Reference is made to the graph of FIG. 5 for the purpose of explaining the term "differential resistance dU/dI". In this graph the corresponding values are illustrated by reference to a non-linear current-voltage relationship. Here, U_A and I_A are intended to indicate respectively the working voltage applied to an individual discharge wire 7, and the working current flowing to the particular wire. The differential changes in voltage and current at the working point (U_A, I_A) are designated by dU and dI respectively.

The following is an example of apparatus according to the invention: The apparatus comprises six discharge wires having a diameter of 50 μ, the corona gap being 12 mm. between the wires and the photosensitive surface. The voltage provided by the voltage source is 10,000 Volts. The voltage at the individual wire is approximately 6000 Volts. In a first arrangement, a separate 4 megaohm resistor is connected upstream of each corona wire 7, in the manner illustrated in FIG. 3. In a second arrangement, the first and sixth, the second and fifth, and the third and fourth of wires are connected to each other and to the voltage source by way of 2 megaohm resistors respective to the pairs of wires, as in FIG. 4. Both arrangements gave an equally good result. The emission from the discharge wires was uniform, and only a slight, tolerable amount of ozone which caused no difficulties was generated.

It will be understood that the specification and examples are illustrative but not limitative of the present invention and that other embodiments within the spirit and scope of the invention will suggest themselves to those skilled in the art. The voltage drop across each resistor may be from about 5000 to 10,000 volts and may be advantageously approximately 6000 volts.

The precise value of the resistor used in the invention will, of course, be determined by the worker skilled in the art to suit a particular purpose. However, it has been found that it is desirable to provide such a resistance that the voltage drop across the resistor is from 0.5 to 10 of the voltage drop across the corona discharge element, i.e. the discharge voltage; it has been found that the higher resistor voltage drops generally result in better performance, i.e. in a more uniform corona discharge field strength. However, it may of course be practically undesirable to provide that large a resistor and it is usually preferred to operate from 0.5 to 2 times the corona discharge voltage drop. More preferably, it is desirable to work with a voltage drop which is 1 to 1.5 of the discharge voltage and, as explained above, this ratio may be optimally about 1:1.

What is claimed is:

1. A corona-discharge apparatus for applying a substantially uniform electrostatic charge to a grounded photoconductive surface, comprising frame means, a plurality of at least three thin corona discharge wires clamped in said frame means and disposed above and substantially parallel to said photoconductive surface, and a plurality of resistors, each resistor being connected at one end to one single high voltage and at the other end to a group of said wires, wherein said discharge wires are in sufficiently close proximity to one another to provide a substantially uniform electrostatic discharge over said photoconductive surface.

2. Apparatus as claimed in claim 1 in which said thin wires are arranged in a plurality of symmetrical groups, the wires of each group being electrically connected to each other, and wherein each of said groups of interconnected wires is connected, via its respective resistor, to the voltage.

3. Apparatus as claimed in claim 2, comprising n parallel wires, of which the first and the nth wires are interconnected to form a first symmetrical group of wires, the second and (n-1)th wires are interconnected to form a second symmetrical group of wires, and so forth each pair of wires being connected to its respective resistor.

4. Apparatus as claimed in claim 3, in which n is an odd number, and the central wire is connected to a separate resistor.

5. Apparatus as claimed in claim 3, wherein said voltage drop is from 0.5 to 2 of the value of the discharge voltage.

6. Apparatus as claimed in claim 5, wherein said voltage drop is from 1 to 1.5 of the value of the discharge voltage.

7. Apparatus as claimed in claim 2, wherein the wires are substantially parallel to each other, in which the two outermost wires are connected together to form a pair and wherein all the other discharge wires are connected together to form a group of wires, and the pair of wires and the group of wires are connected via respective resistors to the voltage.

8. Apparatus as claimed in claim 2, wherein the resistors are all of the same value.

9. Apparatus as claimed in claim 1 comprising at least one group of thin wires connected together, which group is connected through a single resistor to the voltage and wherein the resistance value of said single resistor is equlvalent to that of the parallel combination

it replaces if the wires in said group were not connected together.

10. Apparatus as claimed in claim **1**, wherein the value of the resistors is such that the voltage drop across the resistors is at least 0.5 of the discharge voltage from said discharge element.

11. Apparatus as claimed in claim **1**, wherein the value of the resistors are such that in operation of the apparatus the voltage drop across the resistors are of the same order of magnitude as the discharge voltage from said discharge elements.

12. Apparatus as claimed in claim **11**, wherein said voltage drop across each resistor is from about 5,000 to about 10,000 volts.

13. Apparatus as claimed in claim **12**, wherein said voltage drop is approximately 6,000 volts.

14. In a xerographic copying machine the combination comprising:

a grounded photoconductive element and, in operative relation therewith,

ii. a charging station for applying a substantially uniform electrostatic charge to the photoconductive element, said charging station comprising frame means and a plurality of at least three thin corona discharge wires clamped in said frame means, wherein said discharge wires are in sufficiently close proximity to one another to provide a substantially uniform electrostatic discharge over said photoconductive surface,

iii. an imaging station generating a latent charge image on the photoconductive element,

iv. a developing station producing an image,

v. a transfer station for transferring the image to a receiving material, the improvement comprising, in said charging station (ii), a plurality of resistors, each resistor being connected at one end to one single high voltage and at the other end to a group of said wires.

15. A corona-discharge apparatus for applying a substantially uniform electrostatic charge to a grounded photoconductive surface, comprising frame means, a plurality of at least three thin corona discharge wires clamped in said frame means and disposed above and substantially parallel to said photoconductive surface, and a plurality of resistors, each resistor being connected at one end to one single high voltage and at the other end to one of said wires, wherein said discharge wires are in sufficiently close proximity to one another to provide a substantially uniform electrostatic discharge over said photoconductive surface.

16. Apparatus as claimed in claim **15**, wherein the value of the resistors are such that in operation of the apparatus the voltage drop across the resistors are of the same order of magnitude as the discharge voltage from said discharge elements.

17. Apparatus as claimed in claim **16**, wherein said voltage drop across each resistor is from about 5,000 to about 10,000 volts.

18. Apparatus as claimed in claim **17**, wherein said voltage drop is approximately 6,000 volts.

19. Apparatus as claimed in claim **15**, wherein the value of the resistors is such that the voltage drop across the resistors is at least 0.5 of the discharge voltage from said discharge element.

20. In a xerographic copying machine the combination comprising:

i. a grounded photoconductive element and, in operative relation therewith,

ii. a charging station for applying a substantially uniform electrostatic charge to the photoconductive element, said charging station comprising frame means and a plurality of at least three thin corona discharge wires clamped in said frame means, wherein said discharge wires are in sufficiently close proximity to one another to provide a substantially uniform electrostatic discharge over said photoconductive surface.

iii. an imaging station generating a latent charge image on the photoconductive element,

iv. a developing station producing an image,

v. a transfer station for transferring the image to a receiving material, the improvement comprising, in said charging station (ii), a plurality of resistors, each resistor being connected at one end to one single high voltage and at the other end to one of said wires.

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