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Silverberg

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[54] **CORONA GENERATING METHODS AND APPARATUS THEREFOR**

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[73] Assignee: **Xerox Corporation**

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[51] **Int. Cl.** **G03g 13/02**, G03g 15/02

[58] **Field of Search** ..... 250/49.5 ZC, 49.5 TC; 317/262 A

[56] **References Cited**

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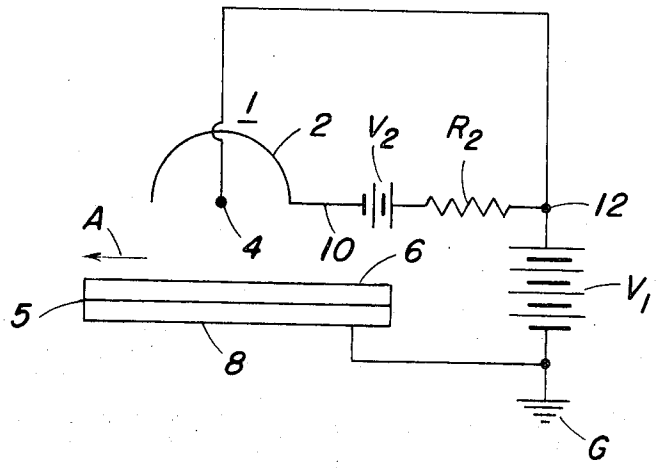
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[57] **ABSTRACT**

Improved corona generating methods and apparatus therefor are provided in accordance with the teachings of this invention wherein a medium in relative motion with a charging station may be rapidly charged to a desired potential in a highly efficient manner. According to one embodiment of the present invention, corona charging apparatus including at least one coronode and having a shield associated therewith is provided and operated in such manner that current flow in the shield is maintained above a selected minimum level during the operation of the corona charging apparatus. The selected minimum level of current flow in the shield is of such value that the coronode will initially supply ion current with a substantially lower threshold energizing potential applied thereto than would be otherwise available and the directivity of the selected minimum level of current flow is such that the potential established at the shield will ensure that a majority of the ion charging current produced at the coronode is delivered to the medium to be charged.

13 Claims, 5 Drawing Figures



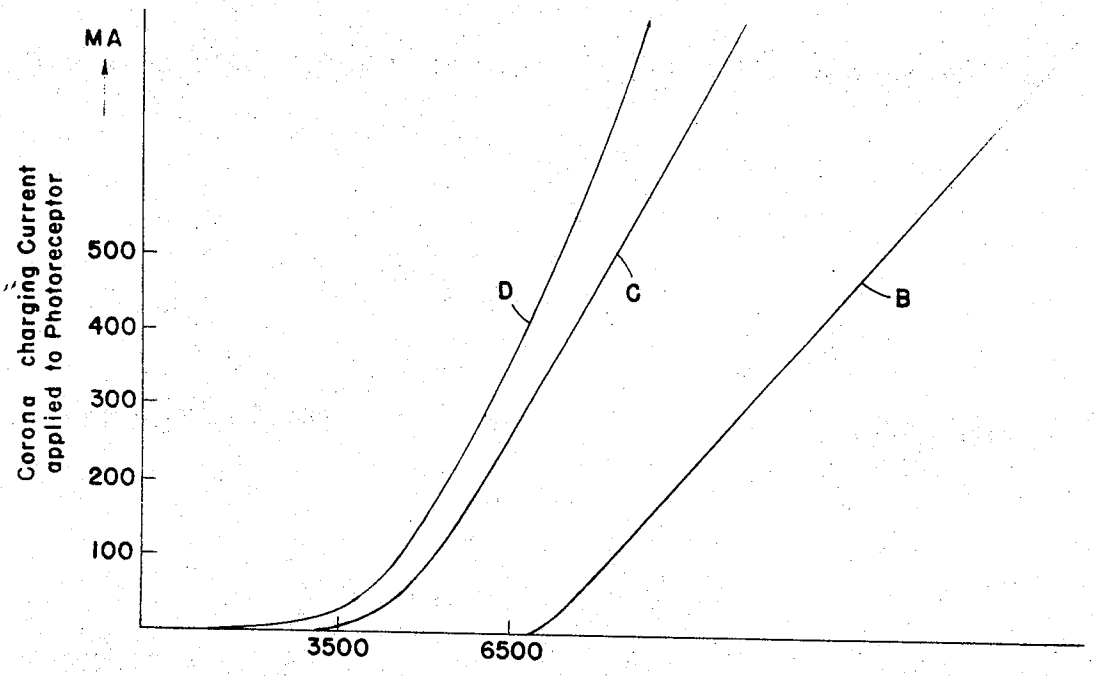


Fig. 2.

Fig. 1.

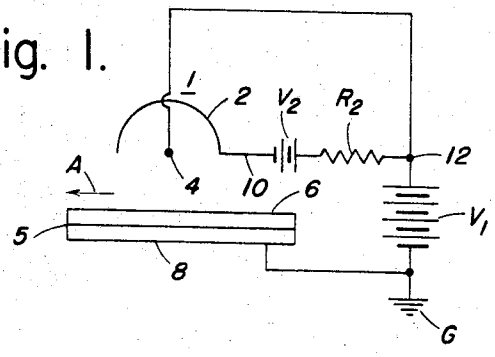


Fig. 3.

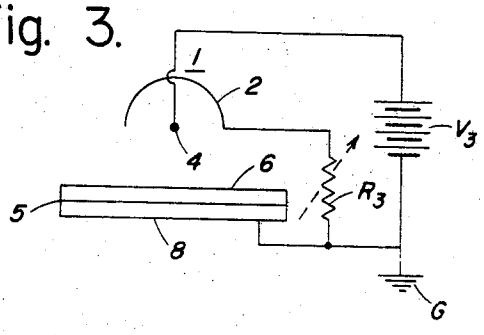


Fig. 4.

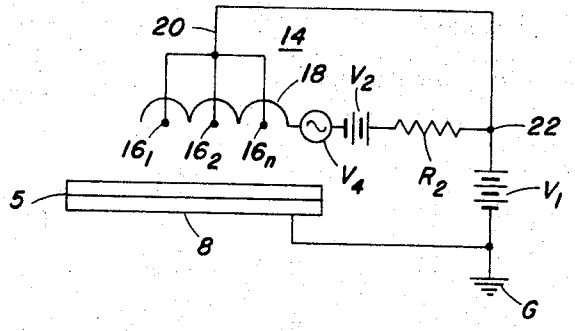
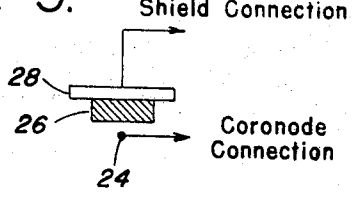


Fig. 5.



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CORONA GENERATING METHODS AND APPARATUS THEREFOR

This invention relates to methods and apparatus for electrostatically charging a surface and more particularly to improved corona generating methods and apparatus therefor usable in electrostatic recording and reproducing equipments or in any other application where it is desirable to efficiently charge a selected medium.

In electrostatic recording and reproducing processes such as the electrophotographic process disclosed in U.S. Letters Patent No. 2,297,691, to Carlsen, and assigned to the Xerox Corporation or in the thermoplastic electrophotographic process set forth in U.S. Pat. application No. 73,406, filed on Sept. 18, 1970 to Lloyd F. Bean and assigned to the Xerox Corporation, it is necessary to sensitize a photoreceptor structure by charging at least one surface thereof to a potential which is preferably uniform. Subsequent to or simultaneously with the sensitizing of the photoreceptor structure in such electrophotographic processes, the photoreceptor structure is exposed so that a photosensitive layer therein is rendered selectively conductive whereupon a latent electrostatic image is formed which may then be developed using either conventional electrophotographic techniques such as are described in U.S. Letters Patent No. 2,297,691, supra, or by enabling a thermoplastic layer present in the photoreceptor structure to deform in the manner set forth in U.S. Pat. application No. 73,406, supra. To aid in the development step for either of the foregoing electrophotographic processes or to achieve specialized results such as image reversal, it is often advantageous to again charge at least one surface of the photoreceptor structure to a selected uniform potential so that a desired charge distribution is obtained prior to or simultaneously with the application of toner or the deformation of the thermoplastic layer as contemplated in a thermoplastic electrophotographic process.

Additionally, in copying apparatus employing electrophotographic techniques such as those discussed above as a basis for the operation thereof, electrostatic charging techniques are often relied upon to accomplish such necessary processing steps as the transfer of an electrostatically formed image from a reusable photoreceptor structure, such as a selenium drum, to a transfer member and/or tacking and stripping operations associated with such transfer member. Furthermore, electrostatic charging techniques similar in nature to those discussed above have found wide areas of application in such diverse fields of use as instrumentation where electrostatic charging and discharging techniques may serve as the basis of operation for measuring and testing devices such as mass flowmeters and in material handling arts where webs or sheets of material may be tacked and stripped while being conveyed by winding and reeling apparatus.

While many forms of acceptable techniques for electrostatically charging a surface are known, corona discharge techniques have generally been preferred in applications such as those mentioned above because such techniques are particularly well suited for applying an electrostatic charge to a moving surface and the use of corona discharge techniques allows a selected surface to be rapidly charged to a relatively high potential. Furthermore, since corona generating apparatus generally

employ a wire-like electrode, they are advantageous because the charging process involved acts to impose a potential level on the surface being charged which tends to be more uniform than that obtained with other surface charging techniques. Conventional forms of corona generating apparatus, are illustrated in U.S. Pat. No. 2,836,725, to Vyverberg, and U.S. Pat. No. 2,879,395, to Walkup, and generally comprise one or more wire-like electrodes, known as coronodes, horizontally disposed above the surface to be charged and a shield, which may take a plurality of structural forms, partially disposed about the coronode. In one conventional mode of operation a high voltage d.c. power supply is connected to the coronode with the requisite polarity for the charging operation which is desired while a conductive layer associated with the surface to be charged is grounded as are the other terminals of the power supply and the shield. In another conventional mode of operation a high voltage a.c. power supply is connected to the coronode while a high voltage d.c. power supply is connected to the shield with the appropriate polarity for the charging operation which is desired and the power supplies and a conductive layer associated with the surface to be charged are grounded. Conventional corona generating apparatus, when used according to either of the foregoing modes of operation, are notoriously inefficient devices in that only about 10 to 20 percent of the corona current produced at the coronode is delivered to the surface to be charged while the remaining 80 to 90 percent of such corona current is diverted to the shield and is thereby wasted from the standpoint of applying an electrostatic charge to a selected surface.

In yet another alternative mode of conventional corona generating apparatus operation, a d.c. power supply is connected between the coronode and a conductive layer associated with the surface to be charged while the shield is left unconnected. This alternative mode of operation is highly efficient from the standpoint of the current delivered because no current may be diverted by the shield; however, it is much less efficient from a power utilization standpoint because the voltage which is required to be applied to the coronode is much larger than in previously mentioned corona generating apparatus configurations and hence the power supplies relied upon must be physically large and capable of producing very large potential levels. These highly inefficient current and power characteristics of conventional corona generating apparatus have required that specialized power supplies capable of continuously delivering current at the limits of safe operation be used as the coronode supply because not only must such power supplies be able to maintain a relatively constant voltage at high levels so that the surface being charged is continually charged to a uniform potential, but in addition thereto, such power supplies must be continually operated under maximum safe current conditions so that charging takes place in a reasonably rapid manner. The need for rapidly charging a selected surface will readily be recognized when it is appreciated that in most copying machines utilizing electrophotographic processes, or in other applications where electrostatic charging is required, the charging operation forms one or more steps of a continuous series of processing steps and hence the rate at which charging takes place is often determinative of the rate at which the entire process can be run.

As the need for faster and faster copying machines using electrophotographic techniques became manifest, designers of electrostatic charging apparatus therefor were faced with the prospects of either developing charging techniques whose speed and efficiency substantially exceeded that of conventional corona generating apparatus, developing techniques for rendering known corona generating apparatus more efficient or operating known corona generating apparatus in such a manner that the current delivered to the coronode exceeded maximum acceptble safety levels and hence entered a death dealing range. For instance, if a given copying machine using a rotating drum is to be made faster by a multiple of three, the drum must be rotated at three times its previous angular velocity and hence each operation which takes place at the various points about the periphery of the rotating drum must be accomplished in one-third the time. As far as the various corona charging operations in such a high speed system are concerned, the corona current delivered to the surface of the drum at each charging station must be three times as great so that the potential to which the drum is charged at such charging station remains constant. Thus, to accomplish a multiplication by a power of three in the charging current delivered to the drum, either new charging techniques whose speed and efficiency substantially exceed those of known corona generating apparatus are required, known corona generating apparatus must be rendered more efficient whereby substantially less of the coronode current is diverted by the shield or the current applied to the coronode must be substantially increased so that despite the notorious inefficiency of known corona generating apparatus, the coronode current delivered to the drum or other surface to be charged would be substantially increased.

Although substantial research efforts have been devoted to the development of charging techniques whose speed and efficiency substantially exceed those of known corona generating apparatus, no commercially practicable charging techniques whose speed and efficiency substantially exceed those of known corona generating apparatus are presently available for inclusion into copying machines using electrostatic modes of operation or the like. Futhermore, although it is clear that in known corona generating apparatus substantial increases in the corona current delivered to the surface to be charged by the coronode may be obtained despite the inefficiency of such devices by increasing the current applied to the coronode; this solution is not suitable for inclusion in faster versions of copying machines which are to be made available to the public. This view is taken because death dealing currents are generally accepted as those whose magnitudes exceed approximately 0.5 ma; and hence, since the currents presently delivered to the coronode in known corona generating apparatus already approach this value, substantially increasing the coronode current in presently utilized corona generating apparatus would introduce unacceptable hazards to the public if this solution was appropriated in the design of faster copying machines using electrophotographic principles. Thus, even though satisfactory current levels could be delivered to the surface to be charged simply by substantially increasing the current applied to the coronode, this approach to solving the problems posed by the design of faster copying machines is presently considered unacceptable as it involves unwarranted risk to those who would use and maintain such faster copying machines.

Research devoted to increasing the efficiency of known corona generating apparatus has principally been confined to essentially two areas of inquiry or a combination thereof. The first such area of inquiry has been directed to endeavors which seek to control and optimize the voltage between the coronode and the shield and often are simply experiments which study the effect of increasing the voltage, to be distinguished from the current, applied to the coronode. The second area of inquiry has involved experiments with varying shield configurations and spacing in an effort to increase the efficiency of known corona generating apparatus. While experiments in each of these areas have brought to light highly advantageous techniques for improving the operating characteristics, the longevity and the uniformity of operation with time of known corona generating apparatus; such experiments have not, in the past, been highly successful with regard to improving the efficiency of known corona generating apparatus viewed from the standpoint of charging current delivered or the voltage magnitudes required to be applied. Furthermore, it should be noted that from a design standpoint the cost and size of a given power supply tends to be proportional to the potential level produced thereby and hence it is desirable that the power efficiency of corona generating apparatus be increased so that the voltage rating of the power supplies used in conjunction with corona generating apparatus be as small as possible to minimize the cost and size of copying machines relying upon such corona generating apparatus. Thus, no technique for substantially increasing the current and/or power efficiency of known corona generating apparatus has heretofore been developed and alternative solutions for increasing the rate at which charging is carried out are not practically available.

The present invention proceeds from the discovery that the ion current flow from the coronode of corona generating apparatus to surfaces being charged depends not only upon the potential difference between the coronode and such surface but additionally is a function of the current flowing in the shield. More particularly, it has been found that by controlling the shield current in corona generating apparatus in such manner that a prdetermined minimum current flow is present, ion current flow from a coronode may be initiated at a substantially lower potential difference than is available in the absence of such shield current while vast increases in the ion current delivered from the coronode to the surface being charged are obtained. Thus, corona generating apparatus may be operated, according to the teachings contained herein, at potential levels which are conventional, while markedly higher operating efficiencies are provided,

Therefore, it is an object of this invention to provide corona charging methods and apparatus therefor wherein ion current flow may be established at power levels which are substantially lower than previously thought available.

A further object of this invention is to provide corona charging methods and corona generating apparatus therefor wherein the operating efficiency of the resulting corona generating apparatus is substantially improved.

An additional object of this invention is to provide corona generating methods and apparatus therefor wherein a minimum current flow is established in a corona generating apparatus shield and the ion charging current delivered to a surface to be charged is maximized.

A further object of this invention is to provide corona generating methods and apparatus therefor which enable the development of highly compact corona generating apparatus.

Another object of the present invention is to provide corona generating methods and apparatus therefor wherein a selected corona generating apparatus is operated in such manner that while conventional potential levels are established between a coronode therein and the surface to be charged, the ion charging current delivered to such surface is substantially increased.

A further object of the present invention is to provide corona generating methods and apparatus therefor wherein safe current levels are applied to the coronode while current levels capable of rapidly charging a prdetermined surface to a selected potential level are applied to such surface from the coronode.

Various other objects and advantages of the present invention will become clear from the following detailed description of several exemplary embodiments thereof, and the novel features will be particularly pointed out in conjunction with the claims appended hereto.

In accordance with the teachings of the present invention, corona generating methods and apparatus therefor, including at least one coronode having a shield associated therewith, are provided and operated in such manner that current flow in the shield is maintained above a selected minimum level during the operation of such corona generating apparatus; the selected minimum level of current flow in the shield being of such value that said coronode will supply ion current with a substantially lower potential applied thereto than would be necessary in the absence of said selected shield current and further such selected minimum level of current flow in the shield being so directed that the majority of the ion current produced at the coronode will be delivered to a surface to be charged.

The invention will be more clearly understood by reference to the following detailed description of several exemplary embodiments thereof in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram of a corona generating circuit serving to illustrate one embodiment of the present invention;

FIG. 2 graphically represents the characteristics of the corona generating circuit depicted in FIG. 1 and the characteristics of conventional corona generating circuits;

FIG. 3 is a schematic diagram of a corona generating circuit configuration which serves to illustrate another embodiment of the present invention;

FIG. 4 is a schematic diagram of a multi-coronode corona generating circuit showing another embodiment of the present invention; and

FIG. 5 is a schematic diagram of compact corona generating apparatus illustrating a further embodiment of the present invention.

Referring now to the drawings and more particularly to FIG. 1 thereof, there is shown a schematic diagram of a corona generating circuit which serves to illustrate one embodiment of the present invention. The embodiment of the present invention illustrated in FIG. 1 comprises corona generating apparatus 1, having a shield 2 and a coronode 4 in an operative relationship with a photoreceptor 5 which includes a surface 6 to be charged. The photoreceptor 5 may take any conventional form well known to those of ordinary skill in the art and for the purposes of simplifying the instant disclosure has been illustrated as a simple two layer structure including an insulating layer 6 and a conductive layer or substrate 8. As the photoreceptor 5 forms no part of the instant invention per se, it is here sufficient for an appropriate understanding of this disclosure to appreciate that if the embodiment of this invention depicted in FIG. 1 is employed in conjunction with conventional electrophotographic techniques, the conductive layer 8 may be formed of any suitable conductive material or a nonconductor overcoated with a conductive foil. Similarly, the insulating layer 6 would ordinarily be formed of a material displaying photoconductive characteristics such that the layer 6 is normally insulating and exhibits excellent charge retentivity but may be rendered selectively conductive by the application of electromagnetic radiation thereto through a light and dark pattern representing an object to be copied or alternatively, reflection exposure techniques may be employed. The materials relied upon in the formation of the insulating layer 6 may be selected from any of the well-known group of materials conventionally employed in electrophotographic processes such as amorphous selenium, alloys of sulfur, arsenic or tellurium or selenium doped with materials such as thallium, cadmium sulfide, cadmium selenide, etc., particulate photoconductive materials such as zinc sulfide, zinc cadmium sulfide, French process zinc oxide, phthalocyanine, cadmium sulfide, cadmium selenide, zinc silicate, cadmium sulfoselenide, linear quinacridones, etc. dispersed in an insulating inorganic film forming binder such as a glass or an insulating organic film forming binder such as an epoxy resin, a silicone resin, an alkyd resin, a styrene-butadiene resin, a wax or the like. Other typical photoconductive insulating materials include: blends, copolymers, terpolymers, etc. of photoconductors and non-photoconductive materials which are either copolymerizable or miscible together to form solid solutions and organic photoconductive materials of this type include: anthracene, polyvinylanthracene, anthraquinone, oxidiazole derivatives such as 2,5-bis-(p-amino-phenyl)-1,3,4-oxadiazole; 2-phenylbenzoxazole; and charge transfer complexes made by complexing resins such as polyvinyl carbazole, phenolaldehydes, epoxies, phenoxies, polycarbonates, etc. with Lewis acids such as phthalic anhydride; 2,4,7-trinitrofluorenone; metallic chlorides such as aluminum, zinc or ferric chloride; 4,4-bis (dimethylamino) benzophenone; chloranil, picric acid; 1,3,5-trinitrobenzene; 1-chloroanthraquinone; bromal; 4-nitrobenzaldehyde; 4-nitrophenol; acetic anhydride; maleic anhydride; boron trichloride; maleic acid, cinnamic acid; benzoic acid; tartaric acid; malonic acid and mixtures thereof. The insulating layer 6 may be made either transparent or radiation absorbing in nature by the choice of the photoconductive insulating material selected and as will be appreciated by those of ordinary skill in the art, a multi-layer insulating material could be readily substituted for the single layer 6 illustrated in FIG. 1. Furthermore, where the embodiment of the invention illustrated in FIG. 1 is relied upon

in conjunction with electrophotographic processes employing thermoplastic techniques, the insulating layer 6 on the photoreceptor 5 would be overcoated with an additional layer of thermoplastic material while in cases where the instant invention was employed in material handling equipment or for instrumentation, the material or medium being handled or subjected to test would be substituted for the photoreceptor 5.

Since the structure of the photoreceptor 5 forms no part of the present invention, only a plate member has been illustrated in FIG. 1; however, it should be appreciated that the photoreceptor 5 and the corona generating apparatus 1 are adapted for relative motion with respect to each other as indicated by the arrow A and hence if it is assumed that the corona generating apparatus 1 is stationary, the photoreceptor 5 may take the form of a rotatable drum associated with a charging station represented by the corona generating apparatus 1, an endless or open web to which conventional winding and reeling techniques may be applied or a plate-like structure adapted to be conveyed past the charging station represented by the corona generating apparatus 1 by conventional conveying techniques. In any event, the only attribute which must necessarily be associated with the photoreceptor for the purposes of the instant invention, is that a surface or medium capable of being charged be presented to the corona generating apparatus 1 when the same is energized.

The structure of the corona generating apparatus 1 may also be entirely conventional and comprises a coronode or charging electrode 4 disposed in a predetermined relationship with a surface 6 to be charged and a shield 2 associated with such coronode 4. The coronode 4, whose end view is illustrated in FIG. 1, may take the form of a fine strand of conductive wire disposed longitudinally across the width of the surface 6 to be charged and spaced an appropriate distance D_p therefrom. The coronode wire 4 would normally be insulated from the shield 2 positioned thereabout by terminal blocks (not shown) associated with the end portions thereof in the well-known manner and is connected to an appropriate source of high potential V_1. The source of high potential V_1 illustrated in FIG. 1 has been depicted as a d.c. supply whose positive terminal is connected to the coronode 4 so that a positive ion current flow is established from the coronode 4 to the photoreceptor 5 which is commonly connected to ground with the negative terminal of the source of potential V_1. Although in FIG. 1, the positive terminal of a source of potential V_1 has been illustrated as connected to the coronode 4, as will be obvious to those of ordinary skill in the art, the polarity of the source of potential V_1 could be reversed whereupon a negative charging configuration would result or alternatively an a.c. or pulsed d.c. source of potential may be used. If the source of potential V_1 is a d.c. supply connected according to the polarity illustrated in FIG. 1, the potential exhibited thereby, as will be further discussed below, would ordinarily be selected in a range from 3,500 to 8,000 volts while if a negative supply to the coronode 4 was selected, the magnitude of the supply would be somewhat reduced.

The shield 2 may take the conventional form of conductor material disposed in a longitudinal direction about the coronode 4 and fixedly positioned at a selected distance D_s therefrom. Although any of the well-known shield configurations illustrated and/or described for instance in U.S. Pat. No. 2,879,395, to L. E. Walkup, may be relied upon in the practice of the instant invention, a half-round shield configuration has been illustrated in FIG. 1 as exemplary; it being noted that such shield configurations are desirable because the uniform path length between the coronode and shield achieves a more uniform shield current distribution. Rather than being connected to ground in the conventional manner, the shield in this embodiment of the present invention is connected to the positive side of the potential source V_1 and maintained at an intermediate potential by a potential source V_2 and a current limiting resistor R_2. The potential V_2, as illustrated in FIG. 1, should be connected in a current aiding relationship with respect to the current applied to the coronode 4 by the potential source V_1 and thus in cases where a negative discharge is relied upon, the polarity of the potential source V_2 would be reversed while if an a.c. supply was utilized for the potential source V_1 a commonly phased a.c. supply would be utilized for the potential source V_2. The potential which should be exhibited by the potential source V_2 would typically be in the range of approximately 5,000 volts depending upon the value of the potential source V_1; however, as shall be seen hereinafter, higher or lower potential values may be expeditiously selected and a relatively inexpensive supply may be used because the potential source V_2 need not be capable of delivering large amounts of current. The resistor R_2 may be conventional and typically exhibits values in a range of from 50–100 megohms. Although in FIG. 1, the potential source V_2 and the current limiting resistor R_2 have been depicted as a battery in series with a resistor for the purposes of simplicity; it should be noted that the potential source V_2 would ordinarily take the form of a conventional power source and hence the current limiting resistor R_2 could typically take the form of an impedance present in the primary of an output transformer in such power source so that the value of such impedance would be reflected over to the output of said power source as taken from the secondary of said transformer as the square of the turns ratio. Placing the current limiting resistor R_2 in the primary of such a power supply is highly advantageous because it provides a practical technique for adjusting the resistance value since variable high voltage, high impedance resistors are not readily available and would expose an operator to shock hazards if adjustment was carried out during operation. Additionally in such a variable impedance configuration, the transformer of the power supply need only be rated for the operating voltage of the corona generating apparatus while if the current limiting resistor means is physically in series with the potential source V_2, the output of the power supply used therefor would have to exhibit a larger value. The purpose of the intermediate potential shield connection to the coronode 4 through potential source V_2 and the resistor R_2, as will be seen below, is to provide a minimum level of current flow in the shield so that the corona generating circuit depicted in FIG. 1 operates in a range wherein efficiency is markedly increased while the voltage level which must be applied to the coronode 4 to initiate a threshold charging current flow therefrom is substantially decreased over conventional corona generating circuits where there is no shield current as is the case for insulated shield configurations.

The operation of the corona generating circuit depicted in FIG. 1 will be described in conjunction with FIG. 2 which graphically represents the characteristics of the corona generating circuit depicted in FIG. 1 in curves C and D thereof and the characteristics of a conventional corona generating apparatus having essentially no current flow in the shield as illustrated by curve B. The graphical representation of the characteristics set forth in FIG. 2 was made using a circuit similar to that depicted in FIG. 1 wherein an ammeter was inserted in the connection between the conductive layer 8 on a photoreceptor 5 having a selenium layer 6 and ground in a circuit using a ⅜ inch ID, half-round corona generating apparatus. As may be seen upon an inspection of curve B in FIG. 2, when the shield conductor 10 is opened or the potential source V_2 is disconnected so that no shield current may flow, no charging current will be produced by the coronode 4 until the voltage V_1 residing between the coronode 4 and the photoreceptor 5 approaches 6,500 volts. Thereafter the charging current will gradually increase along curve B with increasing voltage applied to the coronode 4 in a manner such that the slope of curve B approximates the reciprocal of the dynamic resistance between the coronode 4 and the photoreceptor 5. Alternatively, if a grounded shield configuration was relied upon, the charging current delivered from the coronode 4 to the photoreceptor 5 would be markedly reduced, as is well known to those of ordinary skill in the art, because from 80 to 90 per cent of the charging current produced by the coronode 4 would be diverted to the shield so that the resulting configuration operates in the highly inefficient mode normally characterizing conventional corona generating apparatus.

The operation of the embodiment of this invention illustrated in FIG. 1, as graphically shown by curves C and D in FIG. 2, is markedly different from either the open or grounded shield configurations discussed above. This occurs because the instant invention proceeds upon the recognition that the ion current flow from corona generating apparatus 1 to a surface 6 being charged is a function of the voltage difference between the coronode 4 and the surface 6 being charged as well as a function of the presence of a shield current. In the embodiment of the invention depicted in FIG. 1, such recognition is implemented by connecting the shield 2 to the coronode 4 through potential source V_2 and an impedance R_2 maintained at an intermediate potential level in such manner that current supplied by the high voltage potential source V_1 is foreclosed from a path shunting the ion current path between the coronode 4 and the photoreceptor 5 due to the polarity of the potential source V_2 while current flow in the shield is maintained at a predetermined level due to the values selected for the potential source V_2 and the resistor R_2. Thus, when current flow in the shield is maintained at a selected level, essentially all of the current provided to the coronode 4 by the high voltage potential source V_1 will be applied in the form of ion charging current to the photoreceptor 5 whereby markedly higher operating efficiencies than were previously available are obtained in the resulting corona generating apparatus while the threshold potential at which ion charging current will flow from the coronode 4 will be markedly reduced. This will be appreciated upon an inspection of curves C and D in FIG. 2 which clearly illustrate that when the values selected for the potential source V_2 and the resistor R_2 were such that a shield current of 1 microampere per inch of coronode was maintained in the shield as shown by curve C, ion charging current flow was initiated from the coronode 4 to the photoreceptor 5 when the potential difference therebetween was only 3,500 volts and as the magnitude of the voltage difference beteen the coronode 4 and the photoreceptor 5 was increased, the magnitude of charging current delivered to the photoreceptor 5 by the coronode 4 was markedly increased. However, what is even of greater significance is that the instant invention enables mauch higher levels of charging currents to be delivered by the coronode 4 to the photoreceptor 5 without an increase in the magnitude of the potential source V_1, allows essentially no portion of the current supplied to the coronode 4 by the potential source V_1 to be diverted to the shield while only an insignificantly small shield current need be provided by the potential supply V_2 thereby allowing a low current and power source to be selected for use as the potential supply V_2. This means that the instant invention allows vastly larger charging currents to be delivered to a surface to be charged with relatively low input power and hence allows much higher speeds of operation for copying machines employing the present invention since the potential to which a surface is to be charged may be assumed to be constant while such high charging currents are achieved without introducing dangerous or death dealing currents into the system because essentially all of the current provided by the high potential, high current source V_1 is delivered to the photoreceptor 5. Thus, the high current efficiency of conventional insulated shield corona generating apparatus is here obtained while the low voltage requirements of a grounded shield configuration is retained in corona generating apparatus according to the instant invention.

Similarly, as illustrated by curve D in FIG. 2, when the values selected for the potential source V_2 and the resistor R_2 were such that a shield current of 10 microamperes per inch was maintained in the floating shield, ion charging current flow was initiated from the coronode 4 to the photoreceptor 5 when the potential difference therebetween was less than 3,500 volts and as the magnitude of the voltage difference between the coronode 4 and the photoreceptor 5 was increased, the magnitude of charging current delivered to the photoreceptor 5 by the coronode 4 increased at even a greater rate than that exhibited by curve C. In this regard, higher shield currents than 10 microamperes per inch were experimented with; however, no substantial reductions in the threshold voltage or other advantageous characteristics were observed.

In the actual operation of the embodiment of this invention depicted in FIG. 1, the voltage difference which exists between the coronode 4 and the grounded conductive layer 8 of the photoreceptor 5 is imposed by the high potential source V_1 and if a value of 6,500 volts is assumed as that selected for the high potential source V_1, this potential difference would exist between the coronode 4 and the photoreceptor 5. Additionally, as is true in conventional corona generating circuits, the high potential source V_1 would be required to supply the majority of the charging current produced by the coronode 4 and hence even though the high potential source V_1 has been illustrated as a simple battery supply; in practical embodiments of this invention,

the high potential source V_1 would take the form of a highly regulated supply of the type conventionally employed in known corona generating circuits. In contradistinction to the high potential source V_1, the potential source V_2 need not be capable of delivering large amounts of current as it need only function to maintain a properly directed minimum current flow in the shield whose level preferably resides in a range of from 1 to 10 microamperes per inch so that a current level thus selected circulates in the loop formed by the shield, the potential source V_2, the resistor R_2 and the coronode 4 in a counter-clockwise direction. The potential source V_2 is connected in an intermediate potential configuration, as aforesaid, so that if the potential source V_2 is arbitrarily selected to have a value of 5,000 volts, the resistor R_2 is arbitrarily selected to have a value of 100 MΩ and the shield current is assumed to be 1 μa/in. in a corona generating circuit having a 10 inch coronode; the potential at junction 12 would be 6,500 volts, the drop across resistor R_2 would be 1,000 volts, the positive terminal of the potential source V_2 would reside at 7,500 volts while the shield and hence the negative side of the potential source V_2 would reside at 2,500 volts. Thus, in this manner the potential source V_2 is connected in an intermediate configuration while a selected shield current is maintained or at least the shield current is maintained above a selected minimum value.

Furthermore, although the potential sources V_1 and V_2 and the resistor R_2 have been illustrated as fixed in value, it will be understood by those of ordinary skill in the art that at least the potential sources V_1 and V_2 may be made variable so that both the potential applied to the coronode 4 and the current level in the shield may be independently adjustable whereby the operation of the depicted corona generating circuit could be optimized regardless of variations in ambient conditions such as humidity or the condition of the coronode which might vary the characteristics of the operation of this circuit. Additionally, since the shield 2 ordinarily acts to stabilize the process of delivering ion charging current to a moving surface, the stabilizing effect of the shield could be enhanced by selecting a value for the resistor R_2 and/or a regulated supply for the potential source V_2 such that the combination of the potential source V_2 and the resistor R_2 acts as a constant current supply. This could be done for instance by selecting a value for R_2 which is large compared to the dynamic impedance between the coronode 4 and the shield 2 which normally has a value in the range of 1 to 10 megohms or alternatively selecting an electronically regulated supply for the potential source V_2. In addition, whenever the potential source V_2 and the resistor R_2 form a constant current supply or if the shield current is very small when compared to the charging current, constant current charging of a surface may be achieved by the selection of a constant current supply for the high potential source V_1. This may here be accomplished by selecting a highly regulated supply for the potential source V_1 and/or placing a resistance whose value is large compared to the dynamic impedance between the coronode 4 and the photoreceptor 5 in series with the high potential source V_1 because essentially all of the current applied to the coronode 4 by the high potential source V_1 is delivered to the photoreceptor 5 in the form of charging current.

The present invention is also highly advantageous because as the shield current is controlled, the voltage difference between the coronode and the shield is automatically established at the proper value. This attribute of the instant invention allows highly compact corona generating apparatus to be constructed with closer spacing between the shield and coronode than is possible with grounded shields and closer spacing between the coronode and the surface to be charged than is possible in an insulated shield configuration.

Furthermore, "flash overs" to the surface being charged may be substantially reduced and in this regard it should be noted that when the spacing between a coronode and a selenium photoreceptor was of the order of ¼ to ½ an inch, "flash overs" to the selenium were eliminated when the shield current was maintained in the range of 2 to 10 microamperes per inch as compared to a zero shield current condition where "flash overs" frequently occurred. The ability to control the shield current and hence automatically establish appropriate coronode to shield potentials not only enables the successful operation of highly compact corona generating apparatus, wherein the spacing D_s between the coronode and shield is less than the coronode to photoreceptor spacing D_p but also enables the spacing D_p between the coronode and the photoreceptor to be substantially increased in such applications where this is desirable to the extent that extremely large ion current may be delivered to the photoreceptor when the coronode to photoreceptor spacing D_p is equal to or greater than 1 inch. When D_s is greater than D_p a shield potential source V_2 is always required; however, when D_s is less than D_p it is possible to modify the instant invention in a manner such that a separate shield potential supply is not required. An embodiment of the present invention wherein an individual shield potential supply is not required is illustrated in FIG. 3; however, it is noted that the removal of the shield supply V_2 is attended by a loss of the ability to independently vary the potential applied to the coronode and the current flowing in the shield and relies on the closer spacing of the coronode and shield and consequent reduction in the necessary voltage below that required between the coronode and the surface to be charged.

FIG. 3 schematically illustrates a second embodiment of a corona generating circuit according to the present invention wherein an independent source of potential is not required to be present in the shield connection. In the embodiment of this invention illustrated in FIG. 3, a large number of the elements previously illustrated and described in conjunction with FIG. 1 have again been relied upon; threfore, in order to avoid undue reiteration, elements relied upon in the FIG. 3 embodiment of this invention which correspond to structure previously described in conjunction with FIG. 1 have retained previously adopted reference numerals and the description thereof shall proceed by way of reference to the description of the FIG. 1 embodiment of this invention. The embodiment of the present invention illustrated in FIG. 3 comprises corona generating apparatus 1 having a shield 2 and a coronode 4 in an operative relationship with a photoreceptor 5 which includes a surface 6 to be charged. The corona generating apparatus 1 and the photoreceptor 5 may take any of the forms described in conjunction with FIG. 1 and the photoreceptor 5 and the charging staton represented by the corona generating apparatus 1 are

adapted for relative motion in the same manner as discussed in FIG. 1. However, in the embodiment of this invention depicted in FIG. 3, the spacing D_p between the coronode 4 and the surface 6 to be charged is greater than the coronode 4 to shield 2 spacing D_s which was not necessarily a condition present in the FIG. 1 embodiment of this invention. The spacing D_s between the coronode 4 and shield 2 is normally measured between the coronode 4 and the closest point on the shield 2 thereto; however, as a half-round shield configuration is illustrated in FIG. 3, a determination of the coronode 4 to shield 2 spacing D_s would not here pose a problem.

The coronode 4 is ilustrated in FIG. 3 as connected to a high potential source V_3 at the positive terminal thereof; however, as was the case for the potential source V_1 discussed in conjunction with FIG. 1, depending upon the nature of the charging desired, the coronode 4 may be connected to the positive or the negative terminal of an appropriate d.c. source or alternatively an a.c. or pulsed d.c. supply could be used. The characteristics of the high potential source V_3 selected are similar to those described with regard to the potential source V_1 and hence either a conventional, highly regulated power supply capable of maintaining a desired constant potential and hence supplying a current which is modulated by the potential of the charged surface or a constant current source capable of uniformly supplying the requisite current magnitudes to the coronode 4 should be selected. The magnitude of voltage exhibited by the high potential source V_3 may be similar to those discussed anent FIG. 1; however, if the coronode 4 to surface 6 spacing D_p is increased, the voltage exhibited by the high potential source V_3 would ordinarily be substantially increased. The negative terminal of the high potential source V_3 is grounded as illustrated in FIG. 3 as is the conductive layer 8 of the photoreceptor 5.

The shield 2 of the corona generating apparatus 1 is connected to a common gound G through a current limiting resistor R_3 which may be adjustable in magnitude as indicated. The values of resistance which may be selected for the current limiting resistor R_3 may typically fall within the range of 10 to 1 hundred megohms, depending on the spacings D_p and D_s selected, so that a shield current flow which is preferably in the range of 1 to 10 microamperes per inch, as aforesaid, may be established.

In the operation of the embodiment of this invention illustrated in FIG. 3, the corona generating circuit is initially energized and the resistor biased shield 2 is adjusted for optimum operating conditions. This is accomplished upon the energization of this embodiment of the invention by adjusting the value of the current limiting resistor R_3 until the desired shield current is obtained. The value of the high potential source V_3 is then adjusted to deliver the desired charging current to the surface of the photoreceptor and then the value of the current limiting resistor is reset to maintain the desired shield current. This procedure may require another repetition to achieve a final setting. Once the appropriated value of R_3 is found, the value of the current limiting resistor R_3 may be fixed. Using the resistor biased shield embodiment of this invention, as shown in FIG. 3, the current flowing in the shield is controlled within predetermined limits and hence the shield may not act to divert large portions of the ion charging current produced by the coronode 4 from the photoreceptor. Furthermore, in the instant embodiment of the present invention not only is the shield foreclosed from diverting substantial portions of the ion charging current produced at the coronode 4, but in addition thereto, the shield may not act to substantially load the power supply which here takes the form of the high potential source V_3. Thus, it will be seen that in the embodiments of this invention illustrated in FIGS. 1 and 3, the operation of corona generating apparatus is rendered highly efficient in terms of the charging current delivered from a coronode to a surface to be charged by insuring that a predetermined minimum current flow is maintained in the shield.

FIG. 4 is a schematic diagram of a multi-coronode corona generating circuit which serves to illustrate another embodiment of the present invention. The embodiment of the invention illustrated in FIG. 4 comprises a multi-coronode corona generating apparatus 14 including a plurality of coronodes $16_1 - 16_n$ together with an associated shield 18 in an operative relationship with a photoreceptor 5 having a surface 6 disposed in an appropriate charging relationship with said corona generating appartus 14. The multi-coronode corona generating apparatus 14, illustrated in FIG. 4 comprises a pluralty of coronodes $16_1 - 16_n$ longitudinally disposed across the width of the surface 6 to be charged and each of said plurality of coronodes $16_1 - 16_n$ may be formed of a fine conductive strand of material in the same manner as a single coronode is formed. Each of the plurality of coronodes is commonly connected to conductor 20 which, as will be seen below, is connected to a source of high potential V_1. The shield 18 illustrated in FIG. 3 takes the form of a unitary shield disposed lengthwise about the coronodes $16_1 - 16_n$ and configurated in a manner such that the corss-section thereof forms a plurality of interconnected half-round shields respectively associated with an individual coronode. Thus, although any of the shield configurations mentioned in conjunction with the description of the FIG. 1 embodiment of this invention may be here relied upon for the form of shield 18, the shield configuration depicted in FIG. 4 is highly advantageous because it acts as if an individual half-round shield was associated with each of the plurality of coronodes $16_1 - 16_n$. The photoreceptor 5 may take any of the conventional forms described in conjunction with FIG. 1 and is adapted for relative motion with respect to the corona generating apparatus 14 in the same manner as was discussed in the description of the embodiment of this invention illustrated in FIG. 1.

The conductor 20 which is commonly connected to each of the plurality of coronodes $16_1 - 16_n$ is connected to one terminal of the high potential source V_1 while the opposite terminal of the high potential source V_1 is connected to ground G as is the conductive layer 8 of the photoreceptor 5. The high potential source V_1, as indicated by the common reference, may take the same form as the high potential source V_1 discussed in conjunction with FIG. 1 and accordingly admits of each of the variations and alternatives mentioned in association therewith. However, for the purposes of the description of the embodiment of the invention illustrated in FIG. 4, the high potential source V_1 should be considered to comprise a well regulated d.c. power supply capable of maintaining a relatively constant voltage

and supplying relatively uniform current levels to the plurality of coronodes $16_1 - 16_n$.

The shield 18 is connected to coronode conductor 20 and the positive terminal of the high potential source V_1 at junction point 22 through modulating source V_4, high voltage source V_2 and current limiting resistor R_2. The high voltage source V_2 and the current limiting resistor R_2, as indicated by their respective reference designations, may take the same form and function in the same manner as their correspondingly annotated counterparts described in conjunction with FIG. 1. The modulating source V_4 may take the form of a conventional a.c. or pulsed d.c. source which exhibits a terminal voltage of approximately 1,000 volts; however, lower or higher voltage levels are clearly available. Additionally, the modulating source V_4 may be adapted to receive an information signal to lbe modulated (not indicated) whereupon an amplitude, angle or pulse code modulated waveform is produced thereby. As shall be seen below, the modulating source V_4 serves to provide the embodiment of this invention depicted in FIG. 4 with power amplifying or ion current switching capabilities and hence may be omitted if the continuous type of charging station operation of corona generating apparatus as was contemplated in FIGS. 1 and 3 is desired.

If the modulating source V_4, is initially assumed to be omitted in the embodiment of the invention illustrated in FIG. 4, it will be immediately appreciated that shield 18 is connected to junction point 22 through the high potential source V_2 and the current limiting resistor R_2 so that the shield 18 is connected to the coronode conductor 20 through the same intermediate potential path as was utilized in the embodiment of the invention illustrated in FIG. 1. When these conditions obtain the operation of the embodiment of the invention illustrated in FIG. 4 will be precisely the same as that described above for the FIG. 1 embodiment of this invention with the single exception that ion charging current is produced by each of the plurality of coronodes $16_1 - 16_n$ and delivered to surface 6 of the photoreceptor 5 to be charged. This mode of operation, wherein several coronodes are utilized, has been generally preferred in conventional corona generating circuits because a plurality of coronodes can act in combination to deliver substantially more ion charging current to a moving surface to be charged than is generally available from a single coronode. This feature of multi-coronode operation is generally wholly unnecessary with corona generating circuits according to the instant invention because, as was fully described in conjunction with FIG. 1, the inability of the shield to divert large amounts of ion charging current from the coronode results in a substantial increase in the efficiency of corona generating circuits according to the instant invention and hence a vast increase in the magnitude of the ion charging current delivered to the surface to be charged. However, as is well known to those of ordinary skill in the art, the ion charging current produced at discrete portions along the length of a coronode tends to vary and this phenomenon tends to become more pronounced when a negative potential is applied to the coronode. Therefore, the multi-coronode structure illustrated in FIG. 4 is advantageous because the ion charging current variations along the length of one coronode will not correspond to those which obtain along the length of another coronode so that the charging current received across the width of a surface to be charged which passes under a plurality of parallel coronodes $16_1 - 16_n$ tends to be substantially more uniform. Thus, under conditions where a highly uniform charge is sought, the multicoronode corona generating structure illustrated in FIG. 4 will prove highly advantageous.

As will be recalled from the structural description of the embodiment of this invention set forth above, the modulating source V_4 may take the form of a conventional a.c. or pulsed d.c. source which exhibits a terminal voltage of approximately 1,000 volts and may receive an information signal to be modulated whereupon an amplitude, angle or pulse code modulated waveform is produced thereby. If it is assumed for the purposes of this description, that a simple a.c. supply producing a sinusoidal output of 1,000 volts peak to peak is used in the FIG. 4 embodiment of this invention and if it is further assumed that corona generating circuit depicted in FIG. 4 has parameters such that it is operated substantially along curve C in FIG. 2 when the output of the modulating source V_4 has a phase of $\pi/2$ and V_1 and V_2 equal 6,000 and 4,000 volts, respectively; it will be appreciated that when the phase of the output of the modulating source V_4 reaches $(3\pi/2)$, a substantial reduction in the total voltage applied to the intermediate potential shield current path by the high potential source V_2 and the modulating source V_4 will result. This reduction in voltage will result in a substantial reduction in the shield current becuase the impedance in the current loop formed by the modulating source V_4, the high potential source V_2, the current limiting resistor R_2, the junction point 22, and the conductor 20 becomes large since the voltage then present between the plurality of coronodes $16_1 - 16_n$ and the shield 18 will no longer be sufficient to maintain current flow therebetween and hence the dynamic impedance between the plurality of coronodes $16_1 - 16_n$ and the shield 18 becomes excessive. Therefore it will be seen that such corresponding reduction in the shield current will shift the operating characteristics of the embodiment of this invention depicted in FIG. 4 from that indicated by curve C in FIG. 2 toward the range of operation indicated by curve B whereupon the amount of current delivered to the photoreceptor 8 by the plurality of coronodes $16_1 - 16_n$ will be substantially reduced whenever the phase of the modulating source V_4 is $3\pi/2$. Thus, under the conditions here under consideration, when the modulating source V_4 takes the form of a simple a.c. supply, the magnitude of the charging current delivered to the surface to be charged by the plurality of coronodes $16_1 - 16_n$ will take on a periodic variation whose frequency is the same as that exhibited by the modulating source V_4.

In a similar manner, when the modulating source V_4 is adapted to receive information or control signals and to produce an amplitude, angle or pulse code modulated waveform in response thereto, the ion charging current produced by the plurality of coronodes $16_1 - 16_n$ and delivered to the surface to be charged will vary in magnitude in the manner dictated by the shield current variations established by such modulated waveform and will exhibit a periodicity which is the same as that of said modulated waveform. Thus in the embodiment of this invention illustrated in FIG. 4, the modulating source V_4, whose nature may vary, allows power amplification or ion current switching to be accomplished by the modulation of the shield current. There-

fore, according to this aspect of the embodiment of this invention depicted in FIG. 4, the ability to selectively vary the potential applied to the intermediate potential current path established for the shield allows relatively small modulating voltages to control hundreds of microamperes of ion charging current to be delivered to the surface to be charged.

FIG. 5 is a schematic diagram of compact corona generating apparatus according to a further embodiment of this invention and more particularly FIG. 5 depicts a highly compact corona generating apparatus whose structure is rendered possible by the minimum shield current techniques taught herein and the manner in which an appropriate voltage between the shield and the coronode is automatically established. The compact corona generating apparatus illustrated in FIG. 5 comprises a coronode 24, insulating means 26 and shield means 28. The coronode 24, whose end view is shown in FIG. 5, may take the form of a conductive wire or filament as described in conjunction with preceding embodiments of this invention or alternatively, unusually fine coronode filaments could be employed. The coronode 24 is fixedly disposed beneath the insulating means 26 by suitable terminal blocks, not shown, in the conventional manner and although the coronode 24 may be in contact with the insulating means 26, it is preferred that the coronode 24 be spaced therefrom, as indicated, by a distance of 10 to 15 mils (10–15) mils to avoid contact with toner material which may deposit on the lower surface of the insulating means 26 during the operation of the depicted corona generating apparatus and form a discharge path to the shield. The insulating means 26 may be formed of any insulating material such as "Teflon" or "Mylar" capable of withstanding a potential of from 5,000 to 10,000 volts (5000–10000 V) thereacross. The insulating means 26 may typically have a thickness of from 5 to 10 mils (10–15) mils although clearly thicker layers could be used. The width of said insulating member 26 would ordinarily be of the order of an eighth to a quarter of an inch (⅛–¼ inch); however, the width of such insulating means 26 would widely vary depending on the shield configuration employed. The shield means 28 may take the form of a conductive substrate, as indicated, on which the insulating member 26 is disposed, or alternatively the shield means 28 may take the form of a portion of a larger conductive member, a plurality of wires or a conductive stripe formed or disposed on the upper surface of the insulating means 26 with conductive foil or paint. The coronode 24 and the shield means 28 are connected through the conductors indicated in FIG. 5 into either the two power supply circuit configuration illustrated in FIG. 1 or the resistor biased circuit configuration shown in FIG. 3, it being understood that the resistor biased circuit configuration shown in FIG. 3 would only be applicable where the coronode 24 to photoreceptor spacing D_p is greater than the equivalent coronode 24 to shield means 28 spacing D_{se} which ordinarily would be a condition which obtains in the compact corona generating apparatus depicted in FIG. 5.

The operation of the embodiment of this invention illustrated in FIG. 5 will be precisely that described above in conjunction with FIG. 1 or FIG. 3 depending upon whether the two-power supply or resistor biased mode of operation is selected. It should be appreciated, however, that the equivalent distance between the coronode 24 and the shield means 28 is somewhat larger than that associated with the physical spacing between the coronode 24 and the shield means 28 due to the effect of charge buildup on the lower surface of the insulating means 26.

The compact corona generating apparatus depicted in FIG. 5 is highly advantageous because the unusually compact nature of this configuration allows it to be employed in spaces within electrophotography equipment which are entirely too small for ordinary corona generating apparatus. Additionally, as will be apparent to those of ordinary skill in the art, a multi-coronode corona generating apparatus which is highly compact may be formed by utilizing several of the compact corona generating apparatus illustrated in FIG. 5 in a configuration similar to that illustrated in FIG. 4. Thus, it will be seen that the ability to automatically establish the proper coronode to shield voltage and an appropriate minimum shield current level below the "flash over" point, as taught by the instant invention, enables the development of highly compact corona generating apparatus which may operate at closer coronode to charging surface spacings than are possible in the absence of shield current.

Therefore it is seen that methods and apparatus taught by the instant invention allow corona generating apparatus to function within an advantageous and heretofore unknown region of operation wherein ion current flow from a coronode to a surface to be charged may be initiated at lower threshold potentials than in the absence of shield current and with smaller shield current than was previously attempted. Additionally, the operating power efficiency and the magnitude of currents deliverable is markedly increased. Furthermore, by controlling the shield current in the intermediate potential current path established for the shield, corona generating circuits operated according to the teachings of the instant invention may be selectively driven into and out of the advantageous range of operation taught herein whereby power amplification or ion charging current switching can be obtained.

Although several of the exemplary embodiments of the invention disclosed herein have been illustrated under conditions wherein d.c. potential sources were relied upon, a positive corona discharge was employed, and essentially only half-round shield configurations or direct modifications thereof were utilized; it will be appreciated that many modifications thereto are available within the scope of the present invention. For instance, d.c. potential sources may be relied upon in any polarity whereby positive or negative ion charging may be obtained, and constant current sources may be substituted for the d.c. potential sources illustrated whereupon constant current charging of a surface may be achieved. Similarly, a.c. or pulsed d.c. potential sources may be substituted for the d.c. potential sources illustrated while any known shield configuration may be relied upon without any deviation from the teachings set forth herein. Furthermore, although the shield potential sources discussed herein have been generally indicated as manifesting a similar or lower potential than the potential source connected between the coronode and photoreceptor, it will be readily appreciated by those of ordinary skill in the art that such relationship need ot necessarily obtain especially under conditions where large shield area corona generating apparatus is desired so as to reduce the effects of dirt on the shield, and the spacing between the coronode and the surface

to be charged is smaller than the coronode to shield spacing.

While the invention has been described in connection with several exemplary embodiments thereof, it will be understood that many modifications will be readily apparent to those of ordinary skill in the art; and that this application is intended to cover any adaptations or variations thereof. Therefore, it is manifestly intended that this invention be only limited by the claims and the equivalents thereof.

What is claimed is:

1. In a corona generating circuit including at least one coronode means, shield means associated with said coronode means and means for applying a potential between said at least one coronode means and a medium to be charged, the improvement comprising:

means for electrically connecting said shield means to said at least one coronode means at a point electrically intermediate to said at least one coronode means and said means for applying a potential between said at least one coronode means and said medium to be charged to thereby establish a current path between said shield means and said at least one coronode means; and

means for maintaining a predetermined minimum current flow in said means for electrically connecting said shield means to said at least one coronode means to deliver a major portion of the current applied to said at least one coronode means by said potential applying means to said medium to be charged, said means for maintaining said predetermined minimum current flow being electrically disposed in said means for electrically connecting said shield means to said at least one coronode means.

2. The improved corona generating circuit according to claim 1 wherein said established current path between said shield means and said at least one coronode means takes the form of a closed current loop.

3. The improved corona generating circuit according to claim 1 additionally comprising insulating means positioned intermediate said coronode means and said shield means, said insulating means being disposed on a surface of said shield means proximate to said coronode means, whereupon said coronode means may be positioned in a physically close relationship to said surface of said shield means upon which said insulating means is disposed.

4. In a corona generating circuit including at least one coronode means, shield means associated with said coronode means and means for applying a potential between said at least one coronode means and a medium to be charged, the improvement comprising:

means for electrically connecting said shield means to said at least one coronode means at a point electrically intermediate to said at least one coronode means and said means for applying a potential between said at least one coronode means and said medium to be charged to thereby establish a current path between said shield means and said at least one coronode means; and

means including potential source means connected to impedance means for maintaining a predetermined minimum current flow in said means for electrically connecting said shield means to said at least one coronode means, the combination of said potential source means and impedance means being electrically disposed in said means for electrically connecting said shield means to said at least one coronode means.

5. The improved coronoa generating circuit according to claim 4 wherein said potential source means exhibits a polarity with respect to said at least one coronode means which is the same as that exhibited by said means for applying a potential between said at least one coronode means and said medium to be charged.

6. The improved corona generating circuit according to claim 5 wherein said impendace means exhibits a value of resistance greater than the value of dynamic resistance exhibited between said at least one coronode means and said shield means.

7. The improved corona generating circuit according to claim 6 wherein said potential source means and said impedance means are connected in series.

8. The improved corona generating circuit according to claim 7 wherein means for maintaining said predetermined minimum current flow additionally comprises means for selectively modulating the current flow in said means for electrically connecting said shield means to said at least one coronode means, said means for selectively modulating said current flow being disposed in said means for electrically connecting said shield means to said at least one coronode means and serially connected to said potential source means and said impedance means, said means for selectively modulating said current flow acting to periodically interrupt said predetermined minimum current flow.

9. The improved corona generating circuit according to claim 7 wherein said established current path between said shield means and said at least one coronode means takes the form of a closed current loop.

10. The improved corona generating circuit according to claim 7 additionally comprising a plurality of coronode means, each of said plurality of coronode means being disposed in a parallel relationship with said at least one coronode means and electrically connected in parallel therewith.

11. The improved corona generating circuit according to claim 7 wherein said potential source means and said impedance source means exhibit the characteristics of constant current source means.

12. The improved corona generating circuit according to claim 11 wherein said means for applying a potential between said at least one coronode means and a medium to be charged exhibits the characteristics of constant current source means.

13. The method of charging a medium with a corona generating apparatus including at least one coronode means and shield means associated with said at least one coronode means comprising the steps of:

applying a potential between said at least one coronode means and said medium to be charged;

establishing a current path between said shield means and said at least one coronode means by electrically connecting said shield means to said at least one coronode means at a point electrically intermediate said at least one coronode means and a position at which said potential is applied between said at least one coronode means and said medium to be charged; and

maintaining a predetermined minimum current flow in the current path established between said shield means and said at least one coronode means by inserting a potential source means connected to impedance means in said current path.

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