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J. T. BICKMORE ET AL
DOUBLE SCREEN CORONA DEVICE

2,965,754

Filed March 26, 1958

2 Sheets-Sheet 1

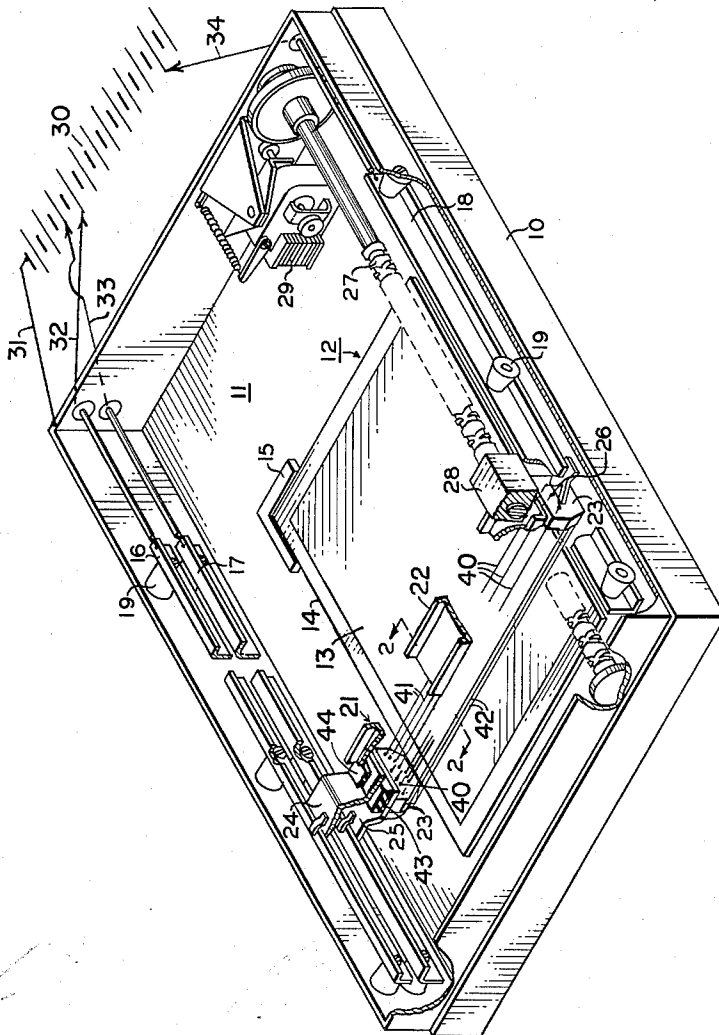


FIG. 1

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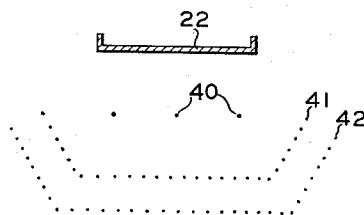


FIG. 2

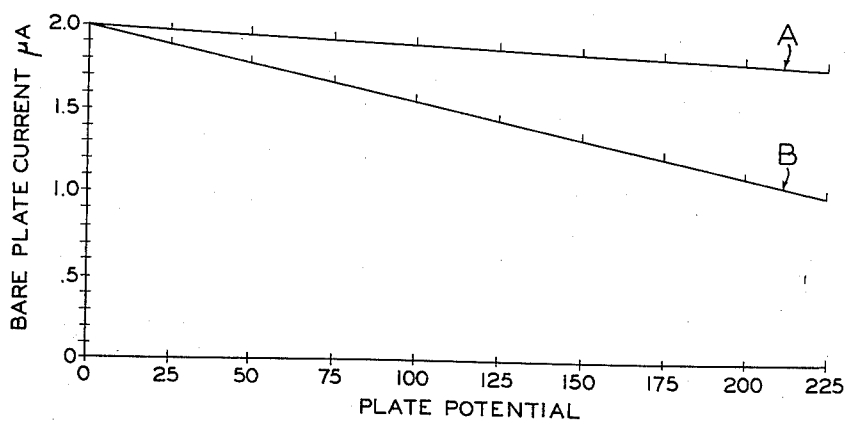


FIG. 3

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DOUBLE SCREEN CORONA DEVICE

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11 Claims. (Cl. 250—49.5)

This invention relates to improved means and methods for electrostatically charging insulating surfaces.

Since the invention of xerography as disclosed in Carlson U.S. Patent 2,297,691 there has been a need for means of uniformly charging an insulating layer to a uniform potential of the order of several hundred volts. This need has been met by positioning one or more corona generating strands or wires or other ion generating means such as an alpha ray source adjacent to the insulating surface and positioning a set of closely spaced parallel wires known as a "screen" between the ion source and the insulating surface. A device of this type including corona generating wires together with a screen and necessary insulators and mechanical supports has come to be known as a "scorotron." In operation, the corona generating wires are raised to a high corona generating potential, either positive or negative, as measured with respect to the insulating surface, the screen is raised to a much lower potential of the order of several hundred volts and of the same polarity as the corona wires, and the thus energized scorotron structure is relatively moved in respect to the surface of the insulator. This method and apparatus have proven quite satisfactory and are in wide commercial use.

Recent advances in xerography as shown in U.S. Patent 2,817,765 and in copending patent application U.S. Serial No. 706,809, however, depend upon the application of a uniform increment of charge to an insulating surface already bearing a nonuniform charge pattern. Several ways of accomplishing this have been found as shown in the above identified patent and application and also in patent application U.S. Serial No. 556,930, now Patent No. 2,868,989. In each instance there is used a structure bearing at least some semblance to the conventional scorotron and having a structure resembling or corresponding to the scorotron screen but operated at a much higher potential as, for example, of the order of several thousand volts. It has been found that, while these devices will deliver to the insulating surface a charging current which is quite independent of charges or potentials already on the insulator, the high screen potential has the additional effect of accelerating or focusing ions from the corona generating wires to the insulating layer with the result that any nonuniformity in corona generation along the length of the corona generating wires is converted into parallel bands of nonuniform charge on the insulating surface. It is almost impossible to generate a completely uniform corona discharge along a length of wire and, in particular, it is well-known that it is quite impossible to do so with negative corona, which generally takes place at a multiplicity of discrete points along the wire. This problem of nonuniform charging does not arise with the older scorotron because the relatively low screen potentials result in a relatively low ion velocity near the insulating layer, which low velocity permits the ions to diffuse readily, thus blurring any pattern of nonuniform ion generation. This lateral diffusion, however, cannot take place where the screen or its counterpart is operated at

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a high potential as is necessary for applying a uniform increment of charge to an insulating layer. Nonuniform charging is highly undesirable in xerography where charge patterns are ultimately converted into corresponding visual image patterns, since streaks of different charge density are converted into visible streaks.

Now in accordance with this invention it has been found possible to add uniform increments of charge to an insulating surface while eliminating or greatly reducing charge streaking.

It is accordingly an object of this invention to provide improved means and methods for charging insulating surfaces.

It is a further object to provide improved means and methods for eliminating spurious charge patterns in apparatus for depositing uniform increments of charge to an insulating layer overlying a conductive support.

It is a further object to provide a charging device incorporating an ion drift space.

It is a further object to provide a double screen scorotron.

It is a still further object to provide an improved method of applying a uniform increment of charge to an insulating surface overlying a conductive support wherein ions are diffused before being accelerated toward the insulating surface.

These and further objects will be apparent in the following description, claims, and drawings in which:

Figure 1 is an isometric view of a charging apparatus according to the present invention, and;

Figure 2 is a cross sectional view along line 2—2 of Figure 1 showing the arrangement of corona and screen wires.

Figure 3 is a graph showing performance of the charging apparatus under two different operating conditions.

Turning now to Figure 1, supporting frame 10 serves to position all components and includes a base plate 11 generally made of conductive material upon which is placed chargeable member 12 comprising insulating layer 13 and conductive support 14. Alternatively, and depending on the intended usage of member 12, conductive support 14 may be omitted. Insulating layer 13 must have sufficiently good insulating properties to retain an electrostatic charge for a reasonable length of time, which implies a resistivity at least in the order of 10^{13} ohm centimeters, but it may also have photoconductive properties in which case charging must be carried out in darkness. A locating stop 15 is fastened to base plate 11 as an aid in accurately repositioning chargeable member 12, if desirable. Two conductive rails 16 and 17 are positioned on one side of frame 10 and a third rail 18 is positioned on the other side. Each rail is secured to frame 10 but insulated therefrom by insulators 19. A charging bar or scorotron 21 is slideably mounted in frame 10 to pass over chargeable member 12 at a slight distance therefrom. It comprises a support channel 22, generally of conductive material, carrying at each end insulating blocks 23 between which are strung three sets of wires as shown comprising corona wires 40, inner screen wires 41 and outer screen wires 42. These sets of wires will be more clearly shown in Figure 2. As shown, corona wires 40 are connected to a hanger 26, screen 41 is connected to a hanger 24 and screen 42 is connected to a hanger 25. An insulating block 43 is included to electrically insulate hangers 24 and 25 from each other. Charging bar 21 is supported in frame 10 by the hangers 24, 25, and 26 which slide on rails 16, 17, and 18, respectively. Each hanger is thus connected to a separate set of wires whereby the potential of each set of wires may be controlled by applying an appropriate potential to the corresponding rail. Frame 10 also rotatably supports a

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reversing lead screw 27 which is adapted to move the charging bar 21 back and forth over chargeable member 12 by means of the lead screw block 28 which engages the groove in the lead screw and is attached to support channel 22. Electric motor 29, also attached to frame 10, is used to rotate lead screw 27. High voltage power supply 30, as represented by the symbol for a battery, is connected to base plate 11 and thus to conductive support 14 through wire 31 and is connected to the three sets of wires in charging bar 21 through wires 32, 33, and 34 connected to rails 16, 17, and 18, respectively. Conventional control apparatus such as a microswitch, not shown, may be provided to stop motor 29 and charging bar 21 after bar 21 passes back and forth over chargeable member 12 and returns to the starting position as shown. Alternatively, other mechanical arrangements may be used. For example, the chargeable member may be moved with respect to a stationary charging bar or the chargeable member may be a flexible web or a cylinder and move by charging bar 21 once instead of twice as described above.

In operation chargeable member 12 is placed on base plate 11 against locating stops 15, and power supply 30 and motor 29 are simultaneously energized causing charging bar 21 to pass over chargeable member 12 and deposit charge thereon. The amount of charge applied to the chargeable member 12 may be controlled by varying the speed at which charging bar 21 moves past chargeable member 12 and/or, by varying the potentials supplied by power supply 29 within the operating ranges as will be set forth later.

Figure 2 is a cross sectional view along lines 2-2 of Figure 1 of charging bar 21. Support channel 22 is the same as shown in Figure 1. Three corona wires 40 are positioned beneath channel 22. Beneath the corona wires are two screens 41 and 42 each comprising a set of parallel wires. In a particularly useful embodiment channel 22 is $1\frac{3}{16}$ inches wide and spaced $\frac{1}{2}$ inch from the corona wires which are $3\frac{1}{2}$ mils in diameter with a wire-to-wire spacing of $\frac{1}{2}$ inch. The first screen is spaced $\frac{7}{16}$ inch from the corona wires and the second screen is spaced $\frac{1}{4}$ inch from the first and is in turn spaced $\frac{1}{4}$ inch from the surface of insulating layer 13 of Figure 1. The screens are each made of 10-mil wires with a $\frac{3}{32}$ inch interwire spacing. In normal operation channel 22 is generally operated at the same potential as base plate 11, normally maintained at ground potential, and it is presently believed that channel 22 may be dispensed with in some cases. The corona wires are operated at a sufficiently high voltage positive or negative to create a corona discharge. This potential depends to a large extent on the wire diameter but for wires approximately three and one-half mils in diameter the voltage will be in the range of 5,000 to 8,000 volts. Smaller wires require lower voltages and larger wires require higher voltages as is well known. While three corona wires are shown, other numbers may be used. While the screens have been described as composed of parallel strands of wire, they may be formed of various other conductive materials such as woven wire screen, and they may also take other shapes or forms, which provide apertures bordered by conductive material. This is equivalent to saying that the screens must be reasonably permeable to ions and define reasonably equipotential surfaces. Since the current flowing in the screens is generally less than a milliampere only a negligible degree of conductivity is required of the screens and they may be formed of any metal as well as many semiconductors, poor insulators or materials such as carbonized string, or the like. The corona generating strands likewise for electrical reasons need not be made of a good conductor but are nevertheless preferably made of a metal for mechanical strength and resistance to ion bombardment.

A normal speed of $2\frac{1}{2}$ inches per second has been found suitable for charging bar 21. Figure 3 is a graph

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showing the performance of a charging bar constructed as shown in Figure 2 under two different operating conditions. In each case the ordinate represents the current delivered to a chargeable member as a function of the potential on the chargeable member as shown on the abscissa. The charging current may be conveniently determined by substituting for the chargeable member 12 of Figure 1 a metal plate insulated from base plate 11 and connected to it through a microammeter and a power supply adapted to maintain it at a controllable potential. Curve A shows the relation between charging current and voltage when screen 41 is operated at a potential of 1,900 volts and screen 42 is operated at a potential of 1,800 volts. It is apparent that the current delivered to a surface under these conditions is quite independent of the potential on the surface, which represents one of the objects of the present invention. Curve B represents a set of measurements taken under similar conditions except that screen 42 was operated at 400 volts. In this case the charging current delivered to the test surface was excessively dependent upon the potential at that surface.

In order to deposit charge on insulating layer 13 at a rate which is substantially independent of any charge pattern already on layer 13, it is necessary to operate screen 42 at a potential at least four and preferably ten times as high as the maximum to which layer 13 will be raised. A voltage in the order of 2,000 volts is quite suitable and will be of the same polarity as that applied to the corona wires 40. Screens 41 must be operated at a potential relatively close to that of screen 42 in order to accomplish the results of the present invention. It has been found that for any given potential of screen 41 the current delivered to layer 13 rises as the potential on screen 42 is raised until the potential reaches about two-thirds of that on screen 41. As the potential on screen 42 is raised further the current decreases to a rather low value when the potential equals that on screen 41, and ceases entirely at a potential from 200 to 400 volts higher than that of screen 41. It has accordingly been found desirable to operate screen 42 at a potential of about one hundred volts less than that of screen 41.

It is to be realized that the forms of the screens as seen in a cross-sectional view such as Figure 2 may be altered over a wide range without interfering with their usefulness and the term "parallel" as used in the claims is intended only to refer to the relation existing in planes parallel to the length of the corona wires or strands and intersecting the screens.

While the operation of the present invention is a demonstrated fact independent of theory, it may be conveniently explained in terms of conventional theory. Corona wires 41 are used to generate a corona discharge which is a rich source of positive and negative gaseous ions. Since screen 41 is at a lower potential than the corona wires, ions having the same polarity as the corona wires are accelerated toward and through screen 41. In the absence of screen 42 the ions drawn through screen 41 would be strongly accelerated toward the surface of insulating layer 13 by the strong electric field maintained between screen 41 and conductive support 14. Although the minimum free path for ions in air is very small, in presence of high fields they closely follow the electrostatic field lines in spite of repeated collisions with air molecules. Any nonuniformities in the generation of ions to the corona wires 40 would accordingly be reproduced as a variation in current arriving at the surface of insulating layer 13 since the ions are effectively focused from the corona wires 40 to insulating layer 13. In earlier charging devices incorporating only one screen, and generally used for other purposes than those intended for the present device, this objectionable focusing effect did not occur because the screen was operated at a very much lower potential, causing ions to travel from the screen to the insulating layer 13 at a much slower speed thereby permit-

ting the ions to diffuse laterally and blur out any non-uniformity in the stream of ions passing through the screen. This diffusion, however, cannot occur when the single screen is operated at the high potentials necessary to give charge deposition substantially independent of any charges or potential pre-existing on a chargeable surface. However, when two adjacent screens are used and operated at approximately equal potentials there is provided a relatively field-free drift space between the two screens. With this arrangement ions formed at the corona wires 40 are accelerated toward and through screen 41 into the relatively field-free region existing between screens 41 and 42 where they are free to spread and diffuse thereby forming a relatively uniform concentration of ions. Ions which diffuse past screen 42 or which are forced through 42 by the relatively small potential maintained between screens 41 and 42, are then strongly accelerated toward the surface of insulating layer 13 and because of the diffusion which takes place between screens 41 and 42 a substantially uniform deposition of charge takes place independent of variations on the surface and in spite of inevitable non-uniformity of corona discharge along corona wires 40.

It is obvious that many variations in structure may be made without departing from the present inventive concept and such variations are intended to be covered in the appended claims.

What is claimed is:

1. A unitary structure adapted to operate in air to apply uniform increments of charge to a surface comprising an elongated gaseous ion source, a first equipotential foraminous conductive screen extending substantially parallel to said elongated ion source and electrically insulated therefrom, a second equipotential foraminous conductive screen extending substantially parallel to said first foraminous screen while spaced apart and electrically insulated therefrom, said first screen being positioned between said second screen and said ion source, and means to apply independently adjustable potentials to each of said ion source said first screen and said second screen to provide a substantially electric field-free drift zone between said gaseous ion source and the surface to be charged.

2. A unitary structure adapted to operate in air to apply uniform increments of charge to a surface comprising an elongated corona discharge source, a first equipotential foraminous conductive screen substantially co-extensive in length with said discharge source positioned and disposed substantially parallel to said discharge source and electrically insulated therefrom, a second equipotential foraminous conductive screen substantially co-extensive in length with said first screen positioned and disposed substantially parallel to said first screen while spaced apart and electrically insulated therefrom, said first screen being positioned between said second screen and said discharge source, and a power supply electrically connected to each of said discharge source, said first screen and said second screen and adapted to supply independent D.C. potentials to each of said ion source, said first screen and said second screen, said first screen and said second screen being adapted to provide a substantially electric field-free drift zone between said corona discharge source and the surface to be charged.

3. A unitary structure adapted to operate in air to apply uniform increments of charge to a surface comprising a linear structural member, two insulating elements fastened to and spaced apart by said structural member in a facing relationship with each other, a corona discharge element comprising at least one corona generating wire extending between said insulating elements, a first equipotential foraminous conductive screen extending substantially parallel to said corona discharge element and spaced apart therefrom, a second equipotential foraminous conductive screen extending between said insulating elements substantially parallel to said first foraminous screen while spaced apart therefrom, said first

screen being positioned between said second screen and said corona discharge element with corona discharge element closer to said structural member than said first conductive screen, and said discharge element and each of said screens being electrically insulated each from the other, said first screen and said second screen being adapted to provide a substantially electric field-free drift zone between said discharge element and the surface to be charged.

4. Charging apparatus adapted to operate in air to apply charge to an insulating layer comprising supporting means to support an insulating layer in a charging position, and to support a unitary scorotron structure, said structure comprising discharge means to create corona discharge positioned spaced apart and substantially parallel to said supporting means, a substantially electric field-free drift zone between said supporting means and said discharge means, and means to apply a potential independently to each of said supporting means, said field-free drift zone and said discharge means.

5. Charging apparatus according to claim 4 including means to bring about relative motion between said unitary scorotron structure and said supporting means and means to maintain said unitary scorotron structure substantially parallel and equidistant from said supporting means.

6. Charging apparatus adapted to operate in air to apply uniform increments of charge to an insulating layer comprising supporting means to support an insulating layer in a charging position, and to support a unitary scorotron structure comprising discharge means comprising at least one conductive corona generating wire, a first equipotential foraminous conductive screen extending substantially parallel to said discharge means while spaced apart and electrically insulated therefrom, a second equipotential foraminous conductive screen extending substantially parallel to said first foraminous screen while spaced apart and electrically insulated therefrom, said first screen being positioned between said second screen and said discharge means and said second screen being positioned facing and nearest to said insulating layer when in charging position, and means to apply independent potentials to each of said ion source, said first screen said second screen and said supporting means, said first screen and said second screen being adapted to provide a substantially electric field-free drift zone between said discharge means and the insulating layer to be charged.

7. Apparatus according to claim 6 including means to cause relative motion between said unitary scorotron structure and said supporting means and means to maintain said scorotron structure substantially equidistant and substantially parallel from a layer to be charged on said supporting means.

8. Apparatus according to claim 7 including means to apply a corona generating potential to said discharge means and to apply a potential of the same polarity as that applied to said discharge means to said first and said second screens, said screen potentials being substantially equal to each other while at least 4 times the potential to be applied to an insulating layer on said support means.

9. Corona charging apparatus adapted to operate in air for applying a uniform increment of charge density to an insulating layer overlying a conductive support comprising in combination a double screen scorotron, a power supply, and moving means, said scorotron comprising at least one conductive corona generating strand, a second equipotential foraminous screen positioned adjacent and parallel to said corona generating strand, a first equipotential foraminous screen positioned between said second screen and said corona generating strand and insulating supports to maintain said screens and said corona generating strand in a fixed relationship, said power supply being adapted to supply a high corona generating potential to said corona generating strand and lesser

potentials of the same polarity to the screens, said first screen and said second screen being adapted to provide a substantially electric field-free drift zone between said corona generating strand and the insulating layer to be charged and each of said screen potentials being approximately equal and at least ten times the maximum potential to be applied to the insulating surface, said moving means being adapted to bring about relative motion between said scorotron and the insulating surface in a direction perpendicular to the length of the corona generating strand while maintaining said second screen parallel to the surface and at a small uniform distance therefrom.

10. The method of applying uniform increments of charge in air and at atmospheric pressure to an insulating surface comprising creating corona discharge at a corona discharge element, accelerating at least some of the gaseous ions formed in said discharge into a substantially electric field-free region, permitting said ions to diffuse in said field-free region and out of said field-free region in a direction opposite to that at which the discharge is created, and strongly accelerating said ions which have passed through said field-free region to the insulating surface to be charged.

11. The method of applying a uniform increment of

charge in air and at atmospheric pressure to an insulating surface comprising forming a corona discharge about at least one unipotential strand, accelerating at least some of the gaseous ions formed in said corona discharge through a first unipotential grid adjacent and parallel to said strand and into a substantially field-free region maintained between said first grid and a second adjacent parallel unipotential grid, permitting said ions to diffuse in said field-free region and through said second grid, and strongly accelerating said ions from the second grid to the insulating surface, said surface being substantially parallel to said second grid.

References Cited in the file of this patent

UNITED STATES PATENTS

940,429	Chapman	Nov. 16, 1909
2,712,607	Orlando	July 5, 1955
2,808,328	Jacob	Oct. 1, 1957
2,885,556	Gundlach	May 5, 1959
2,890,343	Bolton	June 9, 1959

FOREIGN PATENTS

679,974	Great Britain	Sept. 24, 1952
781,497	Great Britain	Aug. 21, 1957