

Feb. 1, 1966

J. G. JARVIS ET AL

3,233,156

ELECTROSTATIC CHARGING METHODS AND APPARATUS

Filed June 7, 1961

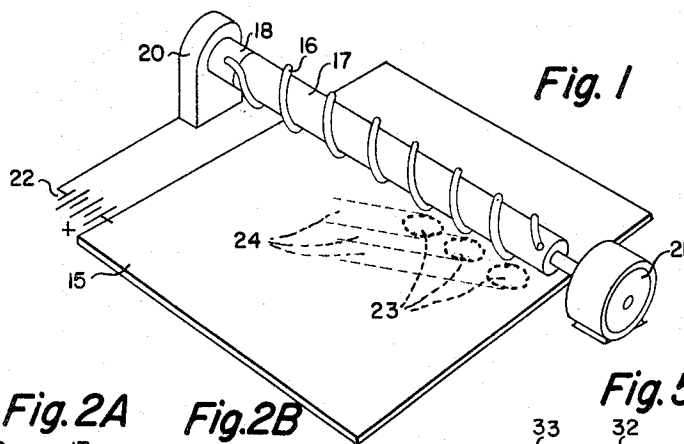


Fig. 1

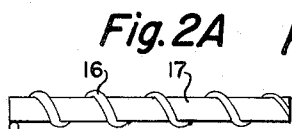


Fig. 2A

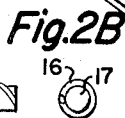


Fig. 2B

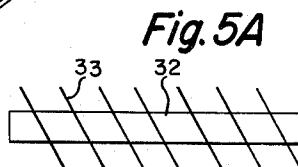


Fig. 5A

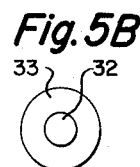


Fig. 5B

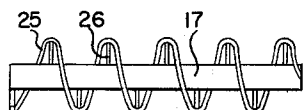


Fig. 3A



Fig. 3B

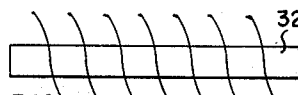


Fig. 6A

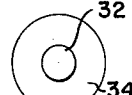


Fig. 6B

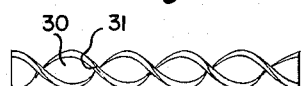


Fig. 4A

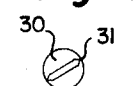


Fig. 4B



Fig. 7A



Fig. 7B

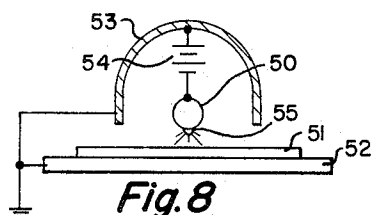


Fig. 8

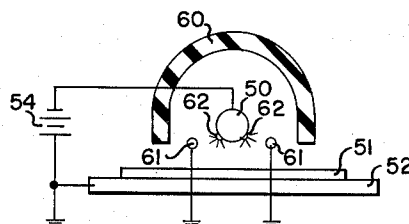


Fig. 9

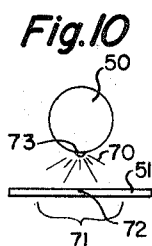


Fig. 10

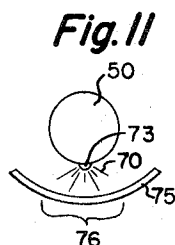


Fig. 11

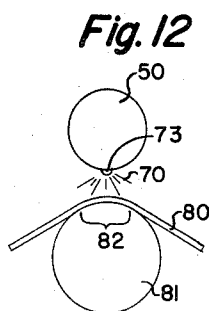


Fig. 12

JAMES G. JARVIS
GENE H. ROBINSON
INVENTORS

BY *R. Frank Smith*
F. W. Emerson Holmes

ATTORNEYS

1

2

3,233,156

ELECTROSTATIC CHARGING METHODS AND APPARATUS

James G. Jarvis and Gene H. Robinson, both of Rochester, N.Y., assignors to Eastman Kodak Company, Rochester, N.Y., a corporation of New Jersey
Filed June 7, 1961, Ser. No. 126,393
8 Claims. (Cl. 317-262)

This invention relates to electrography and particularly to processes and devices for electrostatically charging a surface of an insulator. For example, in xerography the surface of a photoconductive insulator is electrostatically charged, usually before exposure.

It is the object of the invention to provide a high degree of uniformity of charge on such a surface and preferably to provide it rapidly. The invention is limited to corona discharge processes and apparatus. It is customary to provide corona discharge from needle points or fine wires. The corona may be either positive or negative. The present invention is useful with positive corona but for reasons set forth below, it is particularly needed with negative corona. Furthermore negative corona is used in those forms of xerography which employ zinc oxide in resin as the photoconductive layer; such photoconductors will store negative charges on the surface but do not store positive charges easily.

When negative corona is used the needle points must be spaced apart more than some specified minimum (on the order of 1/4 inch at usual potentials) in order to be effective and when a wire is used the corona generation sites are centers tend to space themselves along the wire. The spacing is more or less uniform if the wire is uniform and clean but otherwise may occur at imperfections in the wire. In the case of positive corona, on the other hand, the required spacing between needles is less than the distribution along a wire is somewhat more uniform. The employment of corona will be described with reference to negative corona although the invention is useful with positive corona. At normal operating potentials the corona generation site or center is quite visible as a small glowing spot. Emanating from this visible zone and extending several centimeters from it into the atmosphere is a region of ionization. In general this region of ionization is not visible, even at the surface to be electrostatically charged thereby unless such surface happens to luminesce under the action of the impinging charges. An insulating surface brought into the region or zone of ionized gas becomes charged and hence at the surface there is an area of charging or effective charging. In general it is not within the visible zone of the corona discharge but is in the zone of ionized gas. Thus any section or area in the ionized gas zone may be referred to as a charging area; it may be flat or curved. Any insulating surface placed in such an area becomes charged. The charging area is effective when an insulating surface is located in that area. The term "charging area" will thus be used to refer to areas (which are sections of the ionized gas zone) established by the corona discharge from a needle or wire.

It is customary to move the surface to be charged relative to the corona wire or needle. In order to have the corona generation sites effectively close together it has been proposed either to use a staggered array of needles or to vibrate a corona wire longitudinally. Another possibility would be to place a corona wire oblique to the direction of movement of the surface so as to reduce the effective separation of the corona generation sites which are spaced along the wire. To reduce the effective separation of the sites by a factor of 10, however, this would require an obliquity of about 84° and would require an extremely long wire to extend completely across

the area to be charged. It would also have the disadvantage that the surface to be charged would have to be either flat or the corona wire would have to have some inconvenient configuration.

The present invention provides all of the advantages of a highly oblique wire or array of needles with none of the disadvantages. In one simple (less preferred) form (employing an array of needles arranged as a helical spiral described in detail below) it is easy to visualize directly how the effect of a highly oblique line of needles is obtained without any of the disadvantages thereof. A heterogeneous array of needles disposed radially on a cylindrical axis (such as tinsel) is an approximation to the helically arranged needles and hence is similar to this simplified embodiment of the invention, which is satisfactory for many purposes. The more preferred embodiments of the invention employing helical wires have additional advantages. The corona generation sites are not merely brought effectively close together by the equivalence to high obliquity, but actually become a continuum. The "charging areas" on the surface merge.

According to the preferred embodiment of the present invention a number of charging areas are established and these areas sweep across the surface to be charged in a special way.

It is customary to move either the sheet or the corona source so that one moves relative to the other. The present invention is applicable to either system and will be here described with reference to a uniform movement of the sheet to be charged, in a given direction. According to the invention a line of distinct charging areas is set up transverse to this direction of motion so that if the corona sources and associated areas were standing still, the areas would sweep the surface parallel to the direction of motion of the surface. According to the preferred embodiment of the invention, however, the surface is also swept transversely by these charging areas and the combined motions result in a sweeping action in a direction oblique to the line of areas. The size of the areas and the angle of sweep are such that the paths which adjacent areas sweep on the surface, overlap. At the same time, the spot on the wire or needle or other metallic conductor which constitutes the source of the corona discharge of each area is continuously changed. The distance between the surface and each of these sources is maintained constant during these simultaneous sweeping and source changing actions.

This process can be operated with the conductor sources for each area being quite separate from those for the other areas and being fed independently into the operative position during the sweeping operation.

However, the preferred form of apparatus for providing this simultaneous sweeping and source changing procedure is in the form of a helix. Minor modifications involve two or more intertwined helices, or parts of two or more helices. The helix may be a single wire or sharp edge of a ribbon, self-supporting or supported by an insulator in a helical spiral. That is, all the preferred forms of the apparatus for practicing the invention include an electrical conductor with a helical periphery and this conductor is rotatable about the axis of the helix. Moving a sheet of photoconductive insulating material under the helix while the latter is held at high potential creates a line or succession of corona generation sites each approximately at the bottom of each turn of the helix and these produce a line of charging areas on the photoconductive sheet each adjacent to a turn of the helix. If the helix stands still while the sheet is moved under it, each of these charging areas sweeps along the photoconductor surface forming a series of parallel straight paths. However, if the helix is rotated rapidly, these areas sweep

obliquely across the sheet and the paths overlap one another. At the same time, the points of the helix adjacent to the sheet keep changing constantly. Thus the helix provides the sweeping action, the continuously changing corona generation sites and the constant source-to-work surface distance all as required by the preferred embodiments of the present invention.

The sheet need not be held flat as it is moved through the corona areas, but for the sake of uniformity which is the main object of the invention, the band through which the sheet moves while it is being charged should have a center line parallel to the axis of the helix. The sheet may be flat or cylindrically concave or convex, preferably the latter, since this permits the sheet to be moved over a roller held parallel to the helix, for example a grounded metal roller.

The less preferred embodiments of the invention which do not have a continuous helix, strictly speaking do not provide the oblique sweeping action and continuous changing corona site of the helix. A helical array of needles or even a tinsel which is rotated rapidly does provide rapid changing of the corona generation sites but this change is not a continuous one for any particular charging zone or area. Such a system provides a rapid substitution of an entirely new site spaced from each of the others, a finite distance. If the axis of rotation of the array is at right angles to the direction of motion of the surface, the sweeping action for any one site is purely longitudinal (i.e. in the direction of the surface motion). However, the charging areas are so close together that the paths overlap completely and the net result is a uniformity of charging not available with prior systems.

In all embodiments (helical wire or needle array) there is a cylindrical array of electrical conductor spots capable of being corona generating sites when at high electrical potential. Only those along or near the straight edge of the cylinder facing the surface, operate at any one moment or at least the corona concentrates at sites along this line. The cylinder is "generated" (geometrically speaking) by such a straight edge or line, and there are an infinity of such edges on the cylinder. For each such edge the spacing of the sites along the edge is greater than the minimum required for simultaneous corona. However, when all of the sites and edges are considered the spacing along the axis (projected on the axis) is very small. In the case of a continuous helix, there is no axial spacing. In all cases there is no space greater than some fraction (say one-quarter) of the above-mentioned minimum required for simultaneous corona. Even when the space is still one-quarter of the minimum, the uniformity is greatly improved over stationary corona devices. Corona occurs simultaneously at neighboring needle points or points on a wire only when such points are spaced more than some minimum distance referred to above as "the minimum required for simultaneous corona"; this phenomenon is well known.

The invention and its objects and advantages will be fully understood from the following description when read in connection with the accompanying drawing in which:

FIG. 1 is a perspective view partly schematic of a simple preferred form of the invention.

FIGS. 2A and 2B are respectively side and end views of the corona discharge sources shown in FIG. 1.

FIGS. 3, 4, 5, 6 and 7 (A and B in each case) similarly illustrate other forms of the invention.

FIGS. 8 and 9 schematically illustrate the operation of modifications of the invention.

FIGS. 10, 11 and 12 schematically illustrative various forms of the effective corona band.

FIG. 1 shows a metal plate 15 on which the photoconductor or other sheet to be charged is laid, and provision, not shown, is made to move the plate under the corona discharge mechanism which consists of a metal wire 16 wound as a helix on an insulator 17. Prior sys-

tems required the surface to move back and forth or several times in one direction under a charger, but the present invention is so efficient that in general only a single pass is required. The wire is actually very thin to provide intense corona at reasonable electrical potentials, but is shown relatively thick for ease in illustration. Wire whose diameter is .0035 inch requires about 7000 volts to produce useful corona. A metal collar 18 on the insulating rod 17 is supported in a metal bearing 20 and the helix is rotated at high speed by an electric motor 21. Although as pointed out above, the invention is useful with either positive or negative corona, the wire 16 in the embodiment illustrated, is held at high negative potential relative to the plate 15 by a source indicated schematically at 22, the connection being through the bearing 20 and collar 18. The corona generation sites tend to concentrate at the points of the helix nearer the plate 15. A row of charging areas 23 is created by the helix along the plate 15 and along any sheet laid thereon. The corona sites and hence the centers of the charging areas are spaced preferably about one quarter inch apart, but less advantageously may be spaced up to a few inches. The sheet moves under this row of areas and due to rotation of the helix, the areas move along the helix so that the resultant motion of the areas on the sheet to be charged is oblique to the line of charging areas. The areas are large enough and the rotation of the helix fast enough that the paths swept across the sheet by the areas overlap each other. However, the areas are distinct in the sense that the center of each area is more intense than the edges and the centers can be distinguished from one another by the falling off in intensity between the successive centers. There is, of course, no harm in having a number of helix turns per inch up to the number (about 4 or 5) which causes adverse interference with the corona formation.

The dotted areas 23 schematically represent three of the "charging areas" and as the sheet on the plate 15 is moved longitudinally while the helix is being rotated, these areas 23 sweep out oblique paths across the sheet which overlap each other as shown by the dotted lines 24. Actually the rotation of the helix is quite fast (30 r.p.m. to 3000 r.p.m.) and the areas 23 are usually spaced but may overlap each other. The linear movement of the surface being charged may be at 1 to 300 feet per minute. Neither the rotary or linear speed is critical of course. The charging areas 23 are in a line and the direction of sweep (on the work surface) is oblique to this line at a very small angle.

FIGS. 2A and 2B are included corresponding to FIG. 1 primarily for a comparison with the alternative embodiments shown in FIGS. 3A to 7A inclusive. Even with the best insulators, better corona discharge is obtained if the helix, as shown at 25 in FIGS. 3A and 3B is spaced away from the insulating rod 17 by supports 26. Self-supporting helices would be satisfactory except that this would require fairly coarse wire and an unreasonably high potential source of supply.

A ribbon of metal with sharp (razor blade sharp) edges is twisted so that the periphery is in the form of a helix as shown in FIGS. 4A and 4B and such a ribbon provides a uniform corona. The ribbon 30 has two sharp edges 31 so that there are two intertwined helices in this case.

In FIG. 5A elliptically shaped plane discs 33 are mounted obliquely on a conducting rod 32 so that the end view as shown in FIG. 5B makes the elliptical disc 33 appear circular. Rotation of the corona source in this case causes the spots or areas to move back and forth since effectively each disc approximates sectors of two opposed helices joined together. The sweeping action with simple elliptical discs is not at an absolutely uniform speed. FIGS. 6A and 6B illustrate how this may be remedied. In this case the discs 34 are shaped before mounting on the rod 17 so that the side view as shown in FIG. 6A makes each disc appear as one-half of a full cycle of a sine wave.

5

Again, as shown in FIG. 6B the end view of the warped discs is circular.

FIGS. 7A and 7B illustrate a system which gives uniform charging and which involves a sweeping action of the charging area across the surface in addition to the motion due to the movement of the surface itself. It does not have the obliquity of sweep nor does it have the continuous changing of the corona generation sites for each charging area. A straight metallic rod 40 is provided with needles extending radially therefrom and arranged in a helix. As the rod is rotated rapidly, each needle moves longitudinally with respect to the surface to be charged and the charging area created by each needle sweeps longitudinally a short distance along the surface. The rotation is so fast that the needle comes around again before the surface has moved out of the charging areas and hence each needle creates a path which is continuous longitudinally on the surface. The helix may be set slightly oblique to the direction of movement of the flat sheet so that the path of sweep is oblique but the charging is most effective when the corona source is right at the bottom of its path, so that such obliquity does not gain the full effect of a continuous wire helix. In any case, the adjacent needle produces a charging area which is obliquely offset from the first one considered and the path of this second charging area overlaps that of the first one. Thus one has the full equivalent of a straight row of corona needles spaced far enough apart to provide high intensity discharge but at such a high obliquity that the corona sites and hence the centers of the charging areas are effectively very close together. A heterogeneous or tinsel array of needles on the rotating rod would give a similar effect. In all of these needle embodiments, as well as in the preferred embodiments using a helical wire, all potential sites for corona generation are distributed heterogeneously or helically on the surface of a cylinder rotatable on its axis which cylinder is uniformly spaced from the surface to be charged. The actual corona generation sites concentrate at the side of the cylinder which is adjacent to the surface to be charged. At any one moment, i.e. along any one edge, these sites are spaced adequately for efficient corona formation, but due to the relatively high speed rotation of the cylinder the effect of such spacing is eliminated and effective corona comes from every point on the charging line or from points so close together that the charging effect is uniform at the surface to be charged.

In FIG. 8 a helix 50 is spaced from a photoconductive sheet 51 to be charged which rests on a grounded metallic plate 52. Although the preferred embodiment employs an insulating housing, the particular arrangement shown in FIG. 8 has a grounded housing or shield 53 surrounding the helix 50 and the latter is held at high negative potential with respect to ground by a source illustrated schematically at 54. The grounded sheet 52 tends to attract the corona so that it is concentrated at the point or points 55 of the helix 50 which are nearest to the grounded sheet 52.

A preferred arrangement is shown in FIG. 9 in which the helix 50 is surrounded by an insulating housing 60 and grounded electrodes 61 are located above the sheet 51. These auxiliary electrodes 61 are located with each of them to one side of the helix 50 so that the corona discharge points tend to concentrate at two points 62. That is, the concentration is at two points rather than just at one so that the effective area of the corona adjacent to each turn of the helix is extended slightly giving still greater uniformity.

As shown in FIG. 10 the helix 50 provides an ionized zone 70 extending to some distance below the helix. The sheet 51 to be charged is flat in this case and the charging area or areas constitute a flat band whose width is shown at 71. This width is only approximate since the corona discharge ionization zone does not cut off sharply at any one distance from the source. However, there is a band whose center line is parallel to the axis of the helix 50

6

and which extends to some distance on either side of this center line. In FIG. 11 the sheet 75 to be charged is curved upward slightly so that the band 76 of charging areas is concave upward and slightly wider than the band 71. In FIG. 12 the sheet 80 to be charged is supported by and moved over a grounded roller 81 so that the sheet is bent downward. The band in which charging takes place has a width illustrated at 82 in this case. Thus the band of charging areas has a definite center line although its width and shape may vary.

The preferred helical embodiments of the invention as illustrated in FIGS. 1 to 4B and all of the other embodiments including the helical array of needles shown in FIGS. 7A and 7B and a heterogeneous or tinsel array of needles, can be described with respect to FIG. 10. In all embodiments, the surface to be charged is moved (or at least effectively moved by being held stationary while the corona source is moved transversely above it) through the center line 72 of a charging area band 71. A plurality of corona sites 73 are moved with a cylindrical motion through a line (indicated at 73) parallel to and spaced from the center line 72. The distance of this spacing is such that the center line 72 is within the charging zone 70 of the corona. Actually the sites for the corona are distributed around the cylinder although the actual corona remains concentrated at the side of the cylinder nearer the surface to be charged. According to the invention these corona generating sites are moved through this line 73. The sites which at any one moment are on the line 73 and are hence active, are spaced from each other a distance greater than the minimum necessary for independent corona. However, the sites arriving successively at the line 73 fill in the spaces between the sites that are on this line at any one moment. In the preferred embodiments using a continuous helix, the interstices are completely filled in. In the case of needles there are still some spaces along the line 73 which do not ever contain a corona site, but these spaces are very small indeed, much less than half and preferably less than one-quarter the minimum space between sites which will support corona simultaneously.

Having described several preferred embodiments of our invention we wish to point out that it is not limited to these specific processes and structures but is of the scope of the appended claims.

We claim:

1. The method of uniformly charging a surface which comprises simultaneously sweeping the surface with a line of distinct corona produced charging areas, which areas move along paths in a direction oblique to said line, each path overlapping the adjacent path and continuously replacing the corona source of each charging area with another corona source while maintaining the distance between the surface and the corona sources constant.

2. The method of uniformly charging a surface which comprises effectively moving the surface across the center line of a charging area band and more rapidly moving with cylindrical motion a plurality of corona sites through a line parallel to and spaced from said center line a distance within the charging zone of corona, the sites on the parallel line at any one moment being spaced more than the minimum space required for simultaneous corona but the projection of all the sites to said parallel line approximately filling the line and leaving no space greater than one quarter said minimum space.

3. Surface charging apparatus for use in xerographic processes comprising an electrical conductor with a helical periphery rotatable about the axis of the helix, electrical potential means connected to the conductor for creating a corona discharge along said periphery and effectively extending to a band outside said periphery, the center line of said band being parallel to said axis, means for moving a surface to be charged transversely and at a uniform rate across said band and means for simultaneously

7

rotating the conductor to sweep the discharge along the band.

4. Apparatus according to claim 3 in which the electrical conductor is a fine wire supported by an axially rotated insulator.

5. Apparatus according to claim 3 in which the electrical conductor is a twisted metal ribbon with sharp edges forming two helices.

6. Apparatus according to claim 3 in which the electrical conductor consists of a series of sharp edged parallel metal discs obliquely mounted on a conducting core with the end view of the discs circular.

7. Apparatus according to claim 3 in which the electrical conductor consists of a metal rod with radially extending needles terminating at the helix.

8. Surface charging apparatus for use in xerographic processes comprising a cylindrical array of electrical con-

8

ductor spots capable of being corona generating sites when at high electrical potential, the spacing of the sites along a straight line of said cylindrical array being greater than the minimum spacing required for simultaneous corona and the perpendicular projection of said sites onto the axis of said cylindrical array being approximately continuous and with no space greater than one-quarter said minimum spacing.

References Cited by the Examiner

UNITED STATES PATENTS

2,207,677	7/1940	Chapman	317—2
2,300,324	10/1942	Thompson	317—262
2,503,224	4/1950	Trump et al.	317—262 XR

SAMUEL BERNSTEIN, *Primary Examiner.*