Jan. 22, 1957 C. R. MAYO 2,778,946

CORONA DISCHARGE DEVICE AND METHOD OF XEROGRAPHIC CHARGING

Filed April 18, 1951

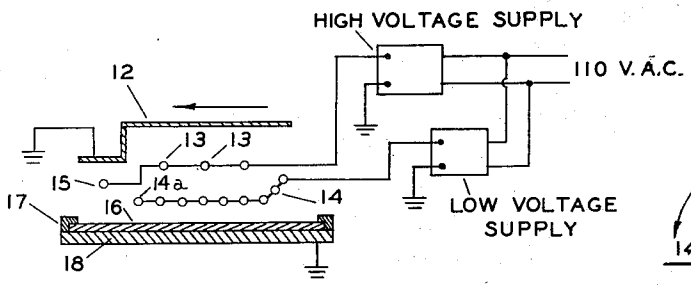



FIG. 2

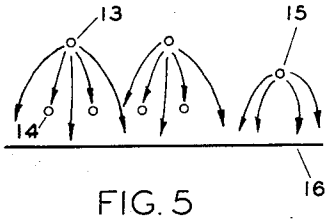



FIG. 5

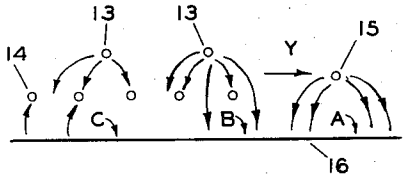



FIG. 6

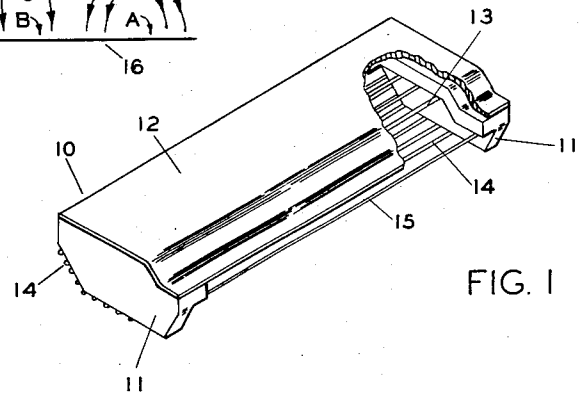



FIG. 1

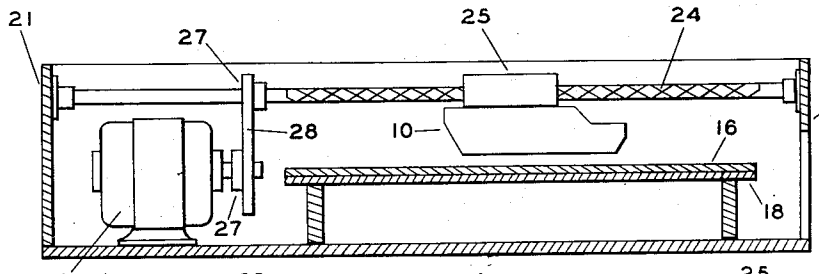



FIG. 4

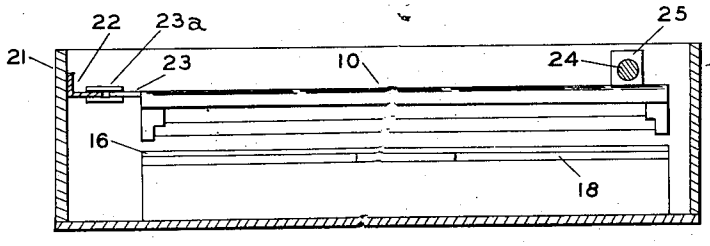



FIG. 3

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United States Patent Office 2,778,946 Patented Jan. 22, 1957



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# CORONA DISCHARGE DEVICE AND METHOD OF XEROGRAPHIC CHARGING

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Application April 18, 1951, Serial No. 221,582

5 Claims. (Cl. 250—49.5)

This invention relates in general to xerography, and in particular to a charging means suitable for electrophotography, and the like.

In processes relating to electrophotography, otherwise known as xerography, it is usual to produce an electrostatic latent image by first applying an electric charge to the surface of an electrophotographically-sensitive member and subsequently selectively dissipating this charge by exposure to a light image, or otherwise to generate an electrostatic latent image. The electrophotographically-sensitive members, which at the present time are preferred for use in this process, are also characterized by being extremely sensitive and easily subject to damage, one particular form of such damage resulting during the charging step and, if electrostatic transfer is used, during the transfer step, and caused by the fact that these members have a maximum potential acceptance above which potential it appears that the insulation value of the member is exceeded and electrical breakdown results. This electrical breakdown causes the formation of permanent defects in the member and has been the subject of a great deal of research with the aim of eliminating these defects.

One method for limiting the formation of these defects has been described in copending application, Serial No. 154,295, filed April 6, 1950, by Lewis E. Walkup. In his invention a controlled charge is applied to the sensitive member by means of a corona discharge electrode having a control electrode associated therewith to control and limit the maximum potential imparted to a member by the corona discharge. This solution to the problem as set forth in that patent application is fully effective in many ways but is not wholly satisfactory, particularly when dealing with large-sized sensitive members. In the first place, there is a strict limitation as to the speed with which a member may be charged by such a controlled corona electrode, and the speed cannot be significantly increased except by rather substantial increase in size and dimensions of the active parts. Furthermore, the device described therein has limitations placed upon it by its high power requirements because a large proportion of the corona current does not actually reach the member to be charged.

It is, therefore, an object of this invention to provide a new charging method and means to impart an electric charge to a selected surface.

It is another object of the invention to provide a new method and means for rapid charging of a large insulating surface.

It is a further object of the invention to provide apparatus for the rapid and safe charging of electrophotographically-sensitive members which are characterized by permanent damage upon overcharging.

It is still another object of the invention to provide a rapid charging means comprising a preliminary corona-discharge electrode for a first charging stage and a further corona-discharge electrode having a coordinating control electrode associated therewith.

Additional and further objects of the invention will in part be obvious to those skilled in the art and will in part be apparent from the following specification and the drawings in which:



Figure 1 is an isometric view of a combination charging electrode according to one embodiment of the invention;

Figure 2 is a diagrammatic side cross section of apparatus according to one embodiment of the invention;

Figure 3 is a front elevation of charging assembly according to this invention;

Figure 4 is a side elevation partially in section of the mechanism shown in Figure 3;

Figure 5 is a diagrammatic side cross section of the charging electrode illustrating conditions at the instant the mechanism is energised;

Figure 6 is a diagrammatic side cross section of the charging electrode illustrating conditions existing during an actual charging operation.

Referring to the figures in detail, there is shown in Figure 1 a charging electrode suitable for operation according to the present invention. This electrode assembly, generally designated 10, comprises two insulating terminal blocks 11 positioned at either end of the assembly and joined together by a conductive ground shield 12 on the upper surface of the assembly. A plurality of fine conductive strands 13 are mounted on the insulating terminal blocks 11 running lengthwise of the assembly from one block to the other and positioned under ground shield 12, these conductive strands forming the controlled corona discharge electrode and being conductively connected to a high voltage power source. The potential of this power source depends to a certain extent on the diameter of wire 13, and with wires almost microscopically fine a potential of about 2000 to 3000 volts is operative, but with wires of conventional size and suitable durability the voltage will normally be at least about 6000 volts D. C., and generally about 7000 volts D. C. or its equivalent. Below this controlled electrode 13 is an array of fine conductors 14 mounted on the insulator blocks 11 and running therebetween, located below strands 13 and optionally positioned along the lower edge of blocks 11. This second set of conductive strands 14 forms the control electrode operating in co-ordination with the corona discharge electrode 13, and is conductively connected to a low voltage potential source preferably of the same polarity as the corona discharge and more nearly in the same general voltage range as that desired on the charged surface. Since the control electrode serves to control or suppress the effective charging potential of electrode 13, these two electrodes 13 and 14 in combination are a controlled potential or suppressed-potential charging unit.

Positioned beyond the control electrode strands 14 toward the front of the assembly is a preliminary or primary corona discharge electrode 15 optionally in the form of one or more fine conductive strands mounted between insulator blocks 11 and extending across the width of the electrode frame, this primary electrode likewise being conductively connected to the same or a different high voltage source usually also at least about 6000 volts. Primary corona discharge electrode 15 is positioned substantially in front of the control electrode 14 to operate independently thereof. The actual potentials on the members will vary somewhat, depending on the sizes of the members. Thus, a corona discharge can be obtained from wires and from points maintained at potentials considerably below 6000 volts by the use of fine wires, sharp needles, or the like. In the assembly described in the drawings, operative conditions are maintained with corona wires of .004" gauge and voltages of at least 6000 volts and generally about 7000 volts on both the primary and the controlled corona discharge electrodes. The control electrode shown in the drawing is

actually a row of .010" gauge wires and, depending on its rate of travel across the member being charged may be maintained from slightly below the desired potential on the surface to be charged to a potential about 1000 volts above such potential, and ordinarily is maintained about 500 volts above the desired potential.

The arrangement of parts and their operation is illustrated in Figure 2 which shows diagrammatically the location of ground shield 12, corona discharge electrode 13 thereunder and the control electrode 14. The entire electrode assembly is shown positioned above an electrophotographic plate 16 mounted in a frame 17 and placed on a ground plate 18.

As shown in this figure, the corona discharge electrode 13 is positioned directly under ground shield 12 and above control electrode 14, thereby being sandwiched between these two members. Control electrode 14, in turn, is positioned closely above the member to be charged 16, in such manner that any electric discharge from the corona electrode must pass through or closely around the control electrode 14. Somewhat above the control electrode, but displaced laterally therefrom, being in front of it as determined by the direction motion of the electrode assembly (indicated by the arrow in Figure 2), is the primary corona discharge electrode 15, this electrode operating free from control and limitation by the control electrode, in that ions generated therefrom may pass directly to the insulating surface without coming within the vicinity of the control electrode.

In Figs. 3 and 4 is illustrated a charging mechanism operating through the device and apparatus illustrated in Figures 1 and 2. This mechanism comprises an electrode assembly or carriage 10 mounted on side walls 21 by means of tracks or runners 22 engaging extending feet 23 on the assembly frame optionally through yokes 23*a* mounted on the feet and sliding along the runners. A drive means such as a worm drive 24 operates through ratchet member 25 at one or both sides of the assembly to move it along the tracks 22 at a controlled speed as determined, for example, by an electric motor 26, a spring drive or the like operating through pulley wheels 27 and belt 28. An electrophotographic plate 16 is illustrated positioned on a ground plate 18 in a location to be charged by the electrode as the assembly passes across the plate. The operation of the charging electrode being directional, the apparatus is operated only while the electrode is being moved forward, either by manual switching control or by automatic control.

The operation of the charging apparatus, according to this invention, can perhaps best be understood with reference to Figures 5 and 6 which illustrate the flow of ions under two conditions of charging. Figure 5 shows a charging condition that might occur under some conditions, such as, for example, the instant the mechanism is energized or during operation at a speed in excess of equilibrium conditions. In this figure, the primary corona discharge electrode and the controlled corona discharge electrode are both operating to charge an insulating layer such as, for example, the surface of an electrophotographic member 16. In this condition of charging the primary controlled discharge electrode 15 is maintained at a high potential, either positive or negative, with respect to the ground potential and a corona discharge of ions is passing from this electrode to the insulating layer. Simultaneously with that charging step, the control electrode 14 is maintained at a potential substantially the same as that desired to be imposed on the insulating layer and the controlled corona discharge electrode 13 is maintained at a high potential to produce a corona discharge. A discharge of ions is being formed and carried from the controlled corona discharge electrode 13 in part to the insulating layer and in part to the control electrode 14, and a substantial proportion of the electrical energy is directed toward carrying ions to the control electrode and only a portion is directed toward



charging the insulating surface. Under this charging condition a substantial portion of electric charge that the insulating layer receives is being imposed on it by primary corona discharge electrode 15 and an additional, and preferably minor, portion of electric charge is being imposed on the layer by controlled corona discharge electrode 13.

A subsequent charging stage is illustrated in Figure 6, diagrammatically illustrating operating conditions which may exist during an actual charging operation, wherein primary charge electrode 15, controlled corona discharge electrode 13, and controlled electrode 14 are energized and are moving across the insulating layer in the direction illustrated by arrow "Y" at a speed which may be visualized as equilibrium speed of operation. As illustrated in this figure, primary corona discharge electrode 15 is imposing a charge on the insulating layer in position "A" in the same manner as described in conjunction with Figure 5. At position "B," controlled corona discharge electrode 13 is operating through control electrode 14 to impose an additional charge on the partly charged insulating layer, also as discussed in conjunction with Figure 5. However, at position "C" the insulating layer has already received an electric charge by being subjected to the conditions existing at positions "A" and "B," the potential of this charge being substantially in the same range with the potential of control electrode 14. At position "C," therefore, substantially all the corona discharge from electrode 13 passes to and is received by control electrode 14 and an extremely small portion thereof is transmitted through the control electrode, this flow of ions serving principally to "smooth off" any unevenness in charge on the layer. At position "C," the layer has the total charge imposed on it by the corona discharge at locations "A" and "B," and this is generally in the range of the potential on the control electrode 14. At faster than equilibrium conditions it may differ therefrom by several hundred volts, but at slower operating conditions which permit build up of equilibrium potential on the member being charged, the potential on control electrode 14 may actually be somewhat less than the potential on member 16. In this case, a slight reverse electric field exists between the control electrode 14 and layer 16, whereby an electric discharge passing through the control electrode is reversed and returned to the electrode by this electric field. It should be realized that corona discharge electrodes 13 and 15 and control electrode 14 may be maintained at either positive or negative polarity and that the corresponding polarity of charge will thus be imposed on layer 16.

With reference again to Fig. 2, it is observed that the rear end of control electrode 14 is inclined upwardly to shield the corona electrode 13 from the rear. Under certain conditions in the absence of such rear shielding, a noncontrolled corona discharge can by-pass the control electrode and reach the member being charged. As a corollary to this, it is possible to omit the separate structural member 15 and, preferably, at least the front control wire 14*a*, whereby the front wire 13*a* of secondary corona discharge electrode 13 acts functionally as the primary discharge electrode in that a portion of its discharge physically by-passes the control electrode and directly reaches the member being charged.

In the procedural steps according to this invention, it is seen that the charging method comprises two steps successively operating on a given area. In the first step a substantial charge is imposed on the surface to be charged, the charging source being a high potential source such as a corona discharge member whose effective potential is free from secondary limitation and is dependent on the corona discharge electrode potential and on the time of operation. Inasmuch as corona discharge voltages are necessarily upwards of several thousand volts, usually within the range of 6000 to 7000 volts and at equilibrium conditions are far in excess of the desired

potential to be imposed on the surface, the principal variable control factor in this step is the speed of operation. In the second step, an additional charge is imposed by a suppressed-potential charged source, wherein the effective charging potential is secondarily regulated, preferably in co-ordination with the length of time the source is operating on a given area, this regulation or potential suppression being operable independently of the corona discharge voltage.

Because this invention relates essentially to the flow of electrons and ions, the size and construction of the electrical elements is best expressed in absolute distances and rather than in proportions. It has been found that the electrical distances involved must be controlled within reasonable limits but not to an exact critical size. Thus, for example, a spacing of about one-quarter to one inch, usually about one-half inch, is desired between parallel conductive strands of any one corona discharge electrode. In the same manner, preferred spacings are about one-half inch between the corona discharge electrode and the ground shield **12**, a space of somewhat less than one-half inch, for example seven-sixteenth inch, between corona discharge electrode **13** and control electrode **14**, and a spacing of about one-quarter inch between the paths of control electrode **14** and layer **16**. The primary corona discharge electrode **15** likewise may be a single corona discharge wire or a plurality of wires spaced about one-half inch apart, and is optionally positioned somewhat less than one-half inch from layer **16**, for example seven-sixteenth inch therefrom.

By proper co-ordination of the rate of motion between the electrode assembly and the insulating layer on the one hand, and the electrode potentials and dimensions on the other hand, optimum results can be obtained in the form of extremely rapid charging of an insulating layer including, if desired, charging for the purpose of electrostatic transfer of a powder image, the sensitization by charging or transfer by charging being accomplished without damage or potential damage to the insulating layer. There are several methods for obtaining this co-ordination. For example, the output of a corona discharge electrode can be increased by increasing its effective area: Two or more separate parallel conductive strands spaced apart over an area of several inches will create a discharge of substantially increased total current flow as compared with the corona discharge from a single strand. A slight, but only slight, increase can also result from additional conductive strands added in an equal area. In addition, charging efficiency from a given area can be increased by adding to the area of the primary electrode while subtracting from the area of the controlled corona discharge electrode, but in this case by decreasing the ability of the controlled electrode to smooth out unevenness in charging.

In one balance of conditions and structure to achieve good results, the rate of motion between the electrode assembly and the insulating layer may be adjusted and maintained at a speed such that the primary corona discharge electrode imposes on insulating layer an electric charge of a predominant proportion such as more than fifty percent of the ultimately desired potential. Within this broad range, it generally is desirable to adjust conditions and structures so that an initial charge of about eighty percent of the total charge received by the insulating layer, averaged over its total area, is imparted thereto by the primary corona discharge electrode and the remaining twenty percent is imparted thereto by the controlled corona discharge electrode to produce the final uniform charge potential. Under these conditions, most of the power output is through the more efficiently operating and more rapidly charging primary corona discharge electrode and only a minor proportion of the power output operates through the much less efficient controlled corona discharge electrode, thereby resulting in greatly increased charging speed, in reasonable economy and efficiency of operation. The efforts toward charging speed, however, must not be carried too far, because it is necessary for a significant amount of charge such as at least about 5% at all areas to be imposed on the layer through the operation of the controlled corona discharge electrode, since only in this way is adequate uniformity of final charge achieved. By this proper balancing of all the factors, safe and adequate charging can be achieved to yield a uniform charge over any desired voltage range such as, for example, a commonly desired range of 300 to 500 volts, without overcharging either locally or over a wide area, at a rate of about 4 linear inches per second with a single strand primary corona discharge electrode and a three strand controlled corona discharge electrode.

What is claimed is:

1. In a charging apparatus for electrophotography comprising a support for an electrophotographic member and an adjacent support for a charging device, said electrophotographic member and charging device being relatively movable on their supports, said charging device adapted to be relatively moved in one direction across said electrophotographic member to be charged and comprising a plurality of regulating wires extending transversely to the direction of movement, a shield extending along the length of said wires, a first corona discharge source positioned between said shield and said wires, a second corona discharge source positioned beneath said shield and first in the direction of movement, means to generate corona discharge from said discharge sources, and means to apply a field regulating potential between said regulating wires and said electrophotographic member.

2. A method of rapidly imposing an electrostatic charge on an insulating surface characterized by permanent damage upon overcharging, said method comprising imparting to the surface a substantial initial charge less than the total charge acceptance, and subsequently through regulation of the electric field causing charge deposition on said surface, depositing on said surface an additional charge to raise all areas of said surface to a substantially uniform charge potential.

3. A corona discharge device adapted to be relatively moved in one direction across a surface to be charged comprising a plurality of regulating wires extending transversely to the direction of movement, a shield extending along the length of said wires, a first corona discharge source positioned between said shield and said wires, a second corona discharge source positioned beneath said shield and first in the direction of movement, means to generate corona discharge from said discharge sources, and means to apply a field regulating potential to said regulating wires.

4. A corona discharge electrode adapted to be relatively moved in one direction across a surface to be charged comprising at least one corona discharge wire extending transversely to the direction of movement, a conductive shield positioned spaced apart from said discharge wire and extending along its length, a plurality of regulating wires spaced apart from said discharge wire and extending along its length on the side of said wire opposite said shield, at least one additional corona discharge wire positioned along the length of said shield and first in the direction of movement, and means to apply a potential source to said discharge wires and said regulating wires.

5. A corona charging device adapted to be relatively moved in one direction across a surface to be charged comprising at least one corona discharge wire extending transversely to the direction of movement, a conductive shield positioned spaced apart from said discharge wire and extending along its length, a plurality of regulating wires spaced apart from said discharge wire and extending along its length on the side of said wire opposite said shield, at least one additional corona discharge wire positioned along the length of said shield and first in

the direction of movement, and means to apply a corona generating potential of the same polarity to the corona discharge wires.

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