

Jan. 15, 1957

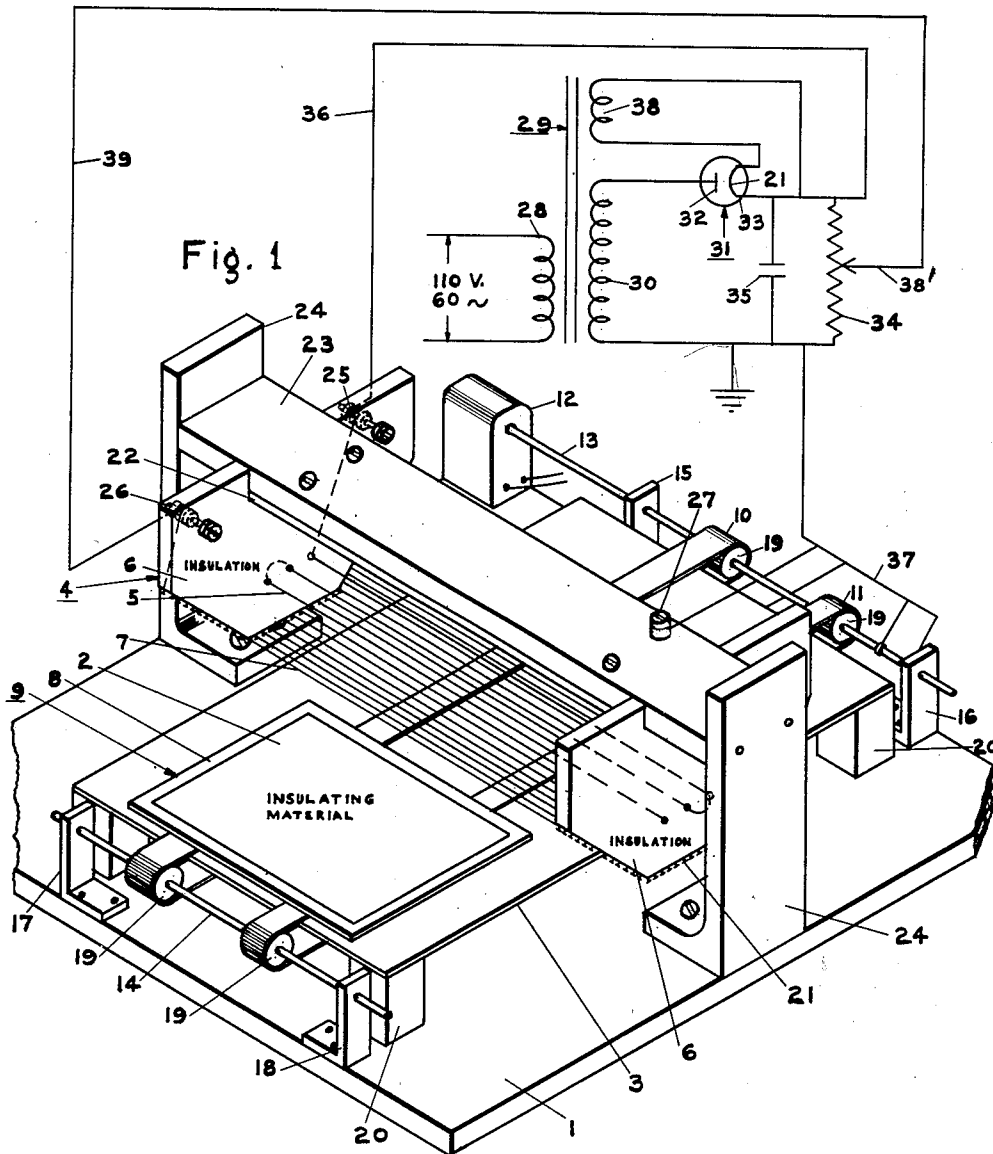
L. E. WALKUP

2,777,957

CORONA DISCHARGE DEVICE

Filed April 6, 1950

3 Sheets-Sheet 1



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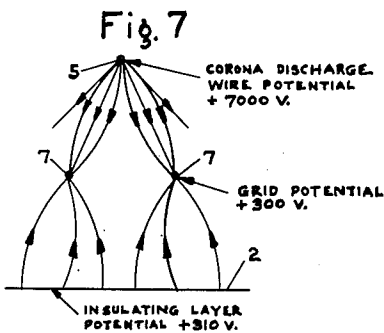
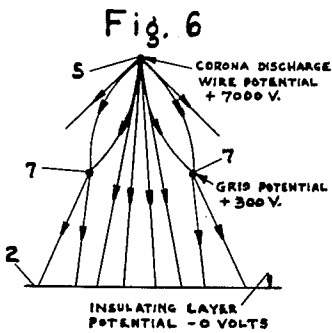
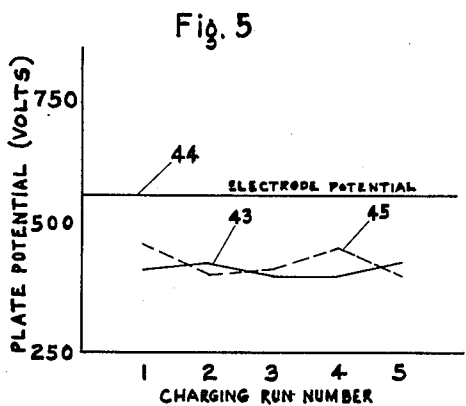
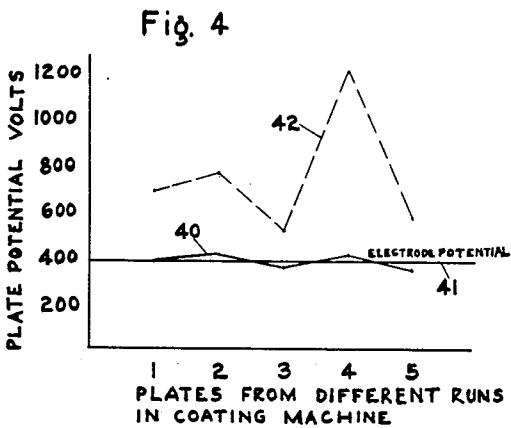
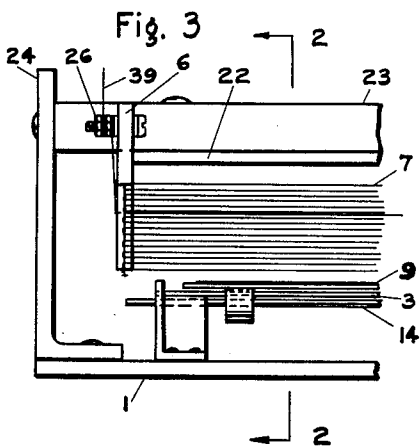
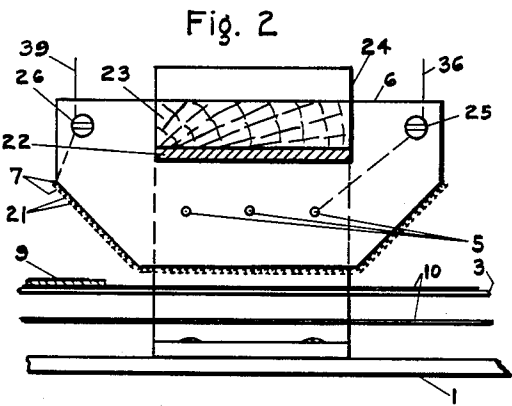
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3 Sheets-Sheet 2



DIAGRAMATIC REPRESENTATION OF
ELECTRICAL FIELDS IN CORONA PLATE
CHARGING APPARATUS CONTAINING
CONTROL GRID.

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3 Sheets-Sheet 3

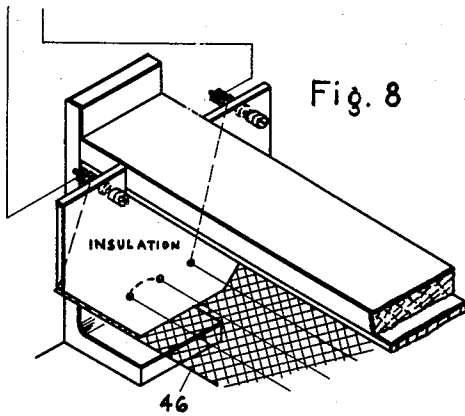


Fig. 8

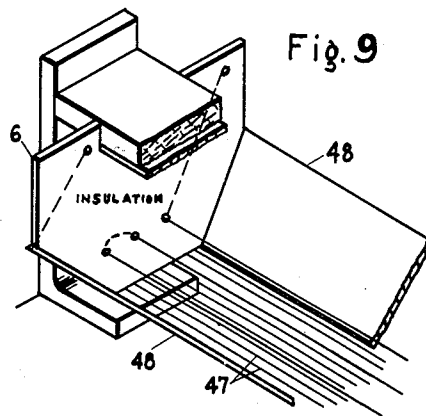


Fig. 9

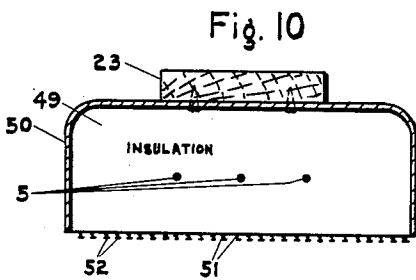


Fig. 10

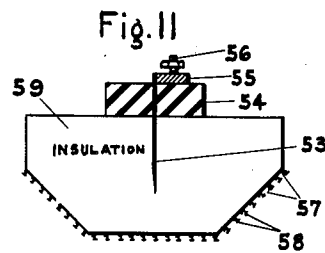


Fig. 11

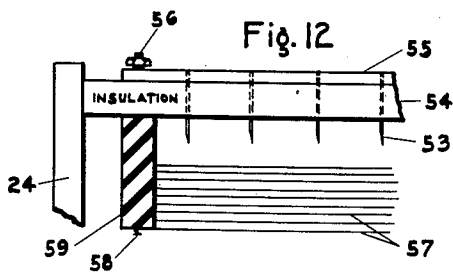


Fig. 12

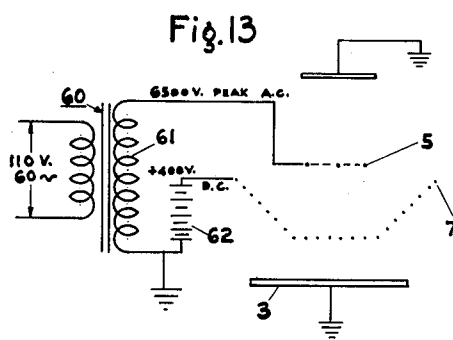


Fig. 13

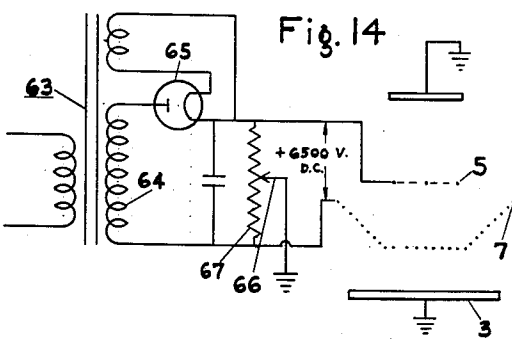


Fig. 14

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2,777,957

CORONA DISCHARGE DEVICE

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Application April 6, 1950, Serial No. 154,295

2 Claims. (Cl. 250—49.5)

This invention relates to apparatus for electrically charging an insulating layer to a potential below the maximum electrostatic potential that the insulating layer will hold without electrical breakdown and has for a particular purpose thereof to afford a practical and efficient device for applying an electrostatic charge of predetermined potential to a photoconductive insulating layer, such as the photoconductive coating of an electrophotographic plate.

In producing copies by electrophotography it has been proposed to charge electrophotographic plates by using a corona charging device, such as is disclosed in the copending application of John J. Rheinfank, Serial No. 55,526, filed October 20, 1948, entitled, "Method and Apparatus for Electrostatically Charging Image Layers," now abandoned. Such a device has been used successfully to charge electrophotographic plates. However, the device is difficult to control in such a manner as to place a predetermined potential on the photoconductive insulating layer. An accurately-timed drive mechanism is required to pass the plate under the charging device at a controlled rate of speed in order that the amount of charge deposited on any area of the plate coating does not exceed the electrical breakdown strength of the coating. Even with a controlled rate of travel of the plate under the charging device potential variations are not overcome since relatively small voltage variations in the power supply can produce relatively large changes in corona current with correspondingly large variations in charging rate. Variations in atmospheric pressure also affect the corona current and charging rate. Different electrophotographic plates will also have different capacity due to different thicknesses of insulating layer or of dielectric constant and consequently will require different quantities of charge to bring them to the same potential.

If electrophotographic plates are not charged to a sufficient potential the electrostatic latent image obtained upon exposure will be relatively weak and the resulting deposition of electrostatically-attractable material, such as a powder or a liquid mist, during development of the image, will be small. If the plates are overcharged other difficulties are encountered. One serious result of overcharging is the permanent damage to the photoconductive layer by the creation of small spots or areas on the plate which are so altered that they are not thereafter capable of holding a charge even after recharging the plate.

It has been further found that different areas on the same plate often become charged to different potentials. This latter irregularity of charge is due perhaps to variations in the photoconductive layer, or perhaps to irregularities in the ion spraying capacity of different portions of the corona discharge device; and the result of this irregularity is a streaky effect when the photoconductive layer is dusted with an electroscopic powder to produce an image.

It has now been found that by the introduction of an electrode, such as a conductive grille between the source of ions, e. g. the corona discharge electrode, and the in-

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insulating layer, such as a photoconductive insulating layer, to which the ions are flowing that the flow of ions can be regulated and the insulating layer can be charged to a potential below the maximum electrostatic potential that the insulating layer will hold. The potential assumed by the insulating layer is also made relatively independent of the charging potential, the time of charging, and other characteristics of the charging unit, thus giving a sufficiently uniform charge to the insulating layer regardless of line voltage variations, preventing damage to the layer from overcharging, and also giving a uniform charge to the insulating layer over different portions of that layer and preventing streaky effects when the layer is charged and developed. The charging device is, moreover, capable of operating in air at atmospheric pressure.

It can now be seen that one object of this invention is to afford an electric charging device so that the insulating layer may be charged to a uniform potential substantially independent of line voltage variations or variations in the structure of the layer and which will obtain the best result with the electroscopic developing material, but will enable the sensitization of the layer to a potential below the maximum which the layer will sustain, thus avoiding breakdown of the layer from overcharging, and streakiness from variations in composition of the layer or in structure of the ion source.

Another object of this invention is to deliver the necessary charge to the insulating layer in a predetermined period of time.

Still a further object of this invention is to permit the use of a relatively high potential on the corona charging device regardless of the maximum electrostatic charge that an insulating layer can hold and regardless of the time of charging the layer.

An yet another object of this invention is to permit charging of a photoconductive insulating layer to a potential below the maximum potential that the layer will hold but still to permit the layer to be charged to a potential high enough to produce an image when dusted with the electrostatic developing powder that is as sharp and clear-cut as if the layer were charged to its maximum potential.

For a better understanding of this invention, together with other and further objects thereof, reference is now directed to the following description taken in connection with the accompanying drawing, and the scope of my invention will be pointed out in the appended claims.

In the drawings:

Figure 1 is a perspective view of a corona charging device having a control electrode in accordance with a preferred form of my invention and the figure includes a diagram of a circuit which may be used with the device;

Figure 2 is a section of a portion of the device of Figure 1 taken on the line 2—2 of Figure 3;

Figure 3 is a side elevation of a portion of the device of Figure 1;

Figure 4 is a graph illustrating the contrast between measured results obtained in charging a group of insulating layers with and without the control electrode of the present invention;

Figure 5 is a graph of the results obtained in successively charging the same insulating layer with the device of the present invention and with a device not embodying features of the invention;

Figures 6 and 7 are diagrams illustrating electric field conditions at two different stages in a charging process;

Figures 8, 9 and 10 illustrate modified forms of corona charging devices;

Figures 11 and 12 show a still further modification in which the ion source comprises a series of pointed corona electrodes;

Figure 13 is a circuit diagram illustrating an A. C. corona circuit; and

Figure 14 shows another modified corona circuit.

While a preferred embodiment of the invention is described herein, it is contemplated that considerable variation may be made in the method of procedure and the construction of parts without departing from the spirit of the invention. In the following description, and in the claims, parts will be identified by specific names, for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring more particularly to the drawings in which specific embodiments of the invention are illustrated, Figures 1, 2 and 3 illustrate a charging apparatus mounted on a support or baseboard 1 so that an insulating layer 2 may be moved along a path over horizontal guide plate 3 at a predetermined distance beneath a charging device 4 comprising corona discharge wires 5 mounted on the spaced insulating support blocks 6 with a control electrode in the form of a wire grille 7 positioned between the discharge wires 5 and the insulating layer 2.

The insulating layer 2 may be a photoconductive insulating layer which is adhered to an electrically conductive backing plate 8 so that the layer 2 on the conductive backing 8 forms an electrophotographic plate 9, which plate is passed beneath the charging device 4 by the endless belts 10, 11 driven at a substantially constant speed by a gear motor 12 which turns belt pulley shaft 13, the other shaft 14 being an idler. The shafts 13 and 14 are journaled in bearings in the uprights 15, 16 and 17, 18 respectively, secured to the baseboard in spaced pairs on either side of the charging device 4 so that the shafts 13, 14 are substantially parallel to the corona discharge wires 5. The belts run on pulleys 19 affixed to shafts 13 and 14, the shafts and pulleys being placed with their axes below the plane of guide plate 3 so that belts 10 and 11 slide along the top face of plate 3 to carry electrophotographic plate 9 under charging device 4 in predetermined spacing from grille electrode 7. The return paths of belts 10 and 11 are underneath guide plate 3. Plate 3 is supported on legs 20 secured to the top of baseboard 1. The pulleys 19 are spaced apart to support electrophotographic plate 9 at two spaced regions across the plate. Insulating support blocks 6, formed of polystyrene or other good insulating material comprise rectangular plates having their lower corners beveled off at an angle of 45 degrees. The electrode 7 is made of conductive wire which is wound back and forth over support pins 21 mounted on the lower and beveled edges of blocks 6 so as to form a parallel wire screen or cage partially enclosing corona discharge wires 5, the electrode wires 7 being parallel to the corona wires. Preferably the plane formed by a portion of the grille 7 and the plane formed by the upper surfaces of each of the belts 10, 11 are parallel and at predetermined relative positions with each other which distances will be later set out in more detail; but it is essential that the distance between the corona discharge wires 5 and the electrode grille 7 is great enough that no sparking will occur at the voltages used to establish corona.

An electrically conducting metal plate or shield 22 extends between the spaced insulating members 6 above the corona discharge wires 5. For best operating results this shield is held at a low potential, preferably ground, with respect to the discharge wires 5 and is approximately the same distance from the discharge wires 5 as the grille 7.

Since the shafts 13, 14 are mounted substantially parallel to the discharge wires 5 and on opposite sides thereof, the belts 10, 11 which extend between the shafts 12, 13 move in a direction substantially perpendicular to the discharge wires 5 and therefore the relative motion of the insulating layer 2 as it passes under the ion discharge wires 5 is in a direction perpendicular to the wires 5. The belts 10, 11 may be woven of electrically conducting wires or may contain conductive wires interwoven with fabric or may have conductors riveted therein to effect a

grounding of backing plate 8 to guide plate 3. These belts slide on the guide 3 so that the insulating layer 2 passes at a predetermined distance beneath the grille 7.

The charging device 4, comprising corona wires 5, support blocks 6, control electrode wire 7 and shield plate 22, are mounted on a cross bar 23 supported on uprights 24 secured to baseboard 1 on either side of the guide plate 3 preferably at a position substantially equispaced from the shafts 13 and 14. Shield plate 22 is mounted against the under surface of cross bar 23 and support blocks 6 have notched upper edges which receive the cross bar to which the plates are mounted in spaced parallel relation.

Electrical connecting terminals 25, 26 and 27 are provided for corona wires 5, electrode 7 and shield plate 22, respectively. Terminals 25 and 26 are mounted on one of the insulating members 6, so that the discharge wires 5 may be connected to an external high potential source, and so that the electrode 7 can be connected to a source of potential which is at lower potential than the discharge wires 5 for either polarity that is applied to the discharge wires 5. If an alternating voltage is applied to the discharge wires 5, the grille 7 is held at a potential less than the peak alternating voltage of either polarity. Terminal 27 is used to connect shield 22 to ground or a low potential.

In the circuit illustrated in Figure 1, the primary 28 of a step-up transformer 29 is connected to a source of alternating current, such as a commercial outlet of 110 volts, 60 cycle alternating current. One end of the high voltage secondary winding 30 of the transformer 29 is connected to the anode 32 of a high voltage rectifying tube 31. The other end of secondary 30 is connected through a voltage dividing resistor or potentiometer 34 to form a rectifying circuit so that pulsating direct current appears across the resistor 34. A smoothing capacitor 35 is connected across the resistor 34 to smooth out the pulsations and yield a more nearly constant direct current. The high potential end of the potentiometer 34, i. e. the end connected to the cathode 33 of the diode rectifier 31 is connected by conductor 36 to the electric connector terminal 25 of corona discharge wires 5; and the low potential end of the potentiometer is preferably grounded, as shown, and is also connected by conductors 37 or through a common ground to guide plate 3 and hence to backing 8 of the electrophotographic plate 9.

A second winding 38 forming a secondary of transformer 29 is provided to heat the cathode 33, although other energizing means could be provided.

Terminal 26 of control electrode 7 is connected by conductor 39 to a tap 38' on the potentiometer 34 to charge electrode 7 to a predetermined potential below the voltage of the corona wires 5. It is obvious that another voltage source, such as a battery, can be used, if desired, to obtain this potential.

A potential of at least about 4,000 volts between the corona electrode and the nearest conductors or electrodes is usually required in order to generate a useful corona discharge and it is preferable that the voltage be less than 10,000 volts in order to avoid sparking or excessive space charges in structures of practical dimensions. The corona electrode can be made either the positive or negative terminal of the potential source depending on the polarity of charge desired on the insulating layer. The D. C. potential can be either constant or it can be pulsating, such as that obtained by half-wave rectification of alternating current. An alternating potential can also be used since ions of both polarities are then made available in alternate half-cycles.

The voltage applied between the control electrode and the conductive backing of the insulating layer to be charged (such as backing plate 8 of the electrophotographic plate 9, or guide plate 3 if an unmounted insulating layer is to be charged) is preferably a constant D. C. voltage or a pulsating voltage which is synchronized with a pulsating corona voltage. With D. C. corona the

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potential of the control electrode can be intermediate to the potentials of the corona electrode and the conductive backing electrode or the same as the potential of the conductive backing, or in some cases the conductive backing potential can be intermediate the corona potential and the control electrode potential. In any event the voltage between the control electrode and the conductive backing is kept below the breakdown voltage of the insulating layer to be charged. With electrophotographic plates this voltage usually will not exceed 1000 volts. With D. C. corona the polarity of charge applied to the plate will be the same as the polarity of the corona electrode regardless of the polarity of the control electrode. With A. C. corona the polarity of the charge applied to the insulating layer will be the same as that of the control electrode.

In the operation of the charging device of this invention, the relative spacing of the different elements has considerable effect on the results obtained. An example of spacings found to produce good results and to achieve the objects of this invention is such that the three corona discharge wires 5 are spaced one-half inch from each other in a single plane by being threaded through aligned mounting holes in the insulating members 6. The shield 22 is spaced one-half inch above the wires 5, the wires of electrode 7 in a plane parallel to the plane of the discharge wires 5 are in a plane seven-sixteenths inch below the wires 5, and the spacing between this plane and the plane of travel of insulating layer 2 is one-quarter inch. The turns, or wires, of the electrode 7 have produced good results when they are separated from each other by approximately $\frac{5}{32}$ of an inch. A suitable wire for corona wires 5 is a smooth stainless steel wire having a diameter of 0.0035 inch and a suitable wire for the strands of electrode 7 is 0.01 inch stainless steel. Under these conditions, 6,500 volts D. C. peak voltage was applied to the discharge wires 5 and 600 volts D. C. was applied to the electrode 7, the shield 22 being at ground potential, and a current of 25 milliamperes was found to flow from the wires 5 to a metal plate passed under the charging device in the position of plate 9, the metal plate being connected through a milliammeter to ground in order that the current could be measured. It is, of course, obvious to those skilled in the art that the diameter of the corona wires 5 can be made smaller or larger provided the voltage applied to the wires is sufficient to generate a corona discharge at a potential below that at which sparking takes place. Likewise, the diameter and spacing of grille wires 7 can be varied over a rather wide range, although it is desirable to use small wires so as to leave as much open space as possible between wires while keeping the wire spacing small so that the array of wires 7 cause an electric field which resembles the field from a plate electrode positioned in the planes occupied by the wires. It is also obvious that the charging rate can be increased for any size of corona wires by increasing the voltage on the corona wires, although it is essential that the voltage between these wires and electrodes 7 and 22 be below the spark breakdown potential. The potential on wire electrode 7 can also be adjusted to any desired value to adjust the potential which is applied to the insulating layer 2.

It will also be apparent that the quantity of charge placed on insulating layer 2 will depend in part upon the speed at which plate 9 is moved under the charging device and the number of passes of the plate under the device. It has been found that if the plate is passed slowly under the device several times that the potential on insulating layer 2 increases with each pass, but that the rate of increase becomes less with successive passes until after several passes, depending on the current flowing, the coating 2 becomes charged to a stable potential which is not changed by successive passes under the charging device. It is possible to use the device in this manner to obtain an equilibrium charge on layer 2 by

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using sufficient passes for each charging operation to reach the equilibrium value. The advantages of the control electrode 7 in obtaining uniformity of charge and avoiding excessive charging of an insulating layer are, however, also obtained, but to a lesser extent, even in cases where the number of passes is insufficient to reach the equilibrium value.

Figure 4 is a graph illustrating certain advantages of the charging device of this invention when used to obtain an equilibrium charge on an insulating layer. Five different plates prepared at different times, each consisting of an aluminum sheet coated with a layer of the insulating form of selenium, which is a photoconductive insulating material, were each charged in a darkroom by passing them under the charging device eight times at a speed of 1" per second while the electrode 7 was held at a positive potential of 380 volts. Curve 40 indicates the measured plate potential after charging for the five different plates, while curve 41, which is a horizontal line, indicates the control electrode potential. The control electrode for this test comprised a wire screen such as will be described in connection with Figure 8, although the results with the parallel wire electrode of Figures 1 to 3 are similar. Curve 42 shows the potentials acquired by the same plates using a charging device which was similar in construction except for the absence of a control electrode. It will be noted that the same plates, using this prior art method of charging, received widely different potentials under similar charging conditions.

Figure 5 shows the results of another series of tests in which a single electrophotographic plate was charged for a standard charging cycle consisting of two passes under the charging device at a speed of 1" per second with 6500 volts D. C. peak voltage applied to the corona wires 5 and 600 volts D. C. applied to an electrode 7 consisting of parallel wires. Under these conditions, the plate was never charged to the equilibrium value but was charged to some value below equilibrium. After each charging cycle the plate was discharged by exposing to light to prepare it for a successive charging. Curve 43 shows the results obtained on successive chargings and indicates that, while some variation in potential was obtained on successive chargings, the variation was kept small. It will be noted that the charge in all cases was considerably below the potential of the electrode 7 as shown by horizontal line 44. Curve 45 indicates the greater variation in plate potential resulting from successive chargings of the same plate with a charging device not embodying a control electrode.

It is believed that the effect of the control electrode in limiting and controlling the potential applied to an insulating layer may be explained, in part at least, by a consideration of the electric fields between corona electrode 5, the control electrode 7 and the surface of insulating layer 2. Figure 6 indicates which is believed to be the condition of the electric field between the electrodes at the start of charging, and Figure 7, the field after the insulating layer has become charged to a potential slightly higher than that of the control electrode. Thus, in Figure 6, if a corona wire 5 is at a positive potential of 7,000 volts and the grille 7 at a potential of 300 volts, while the potential of the insulating layer at the start of charging is at ground or zero volts, part of the electric field radiating from corona wire 5 will extend to insulating layer 2 and part of it will terminate on electrode wires 7. Also, since electrode 7 is at a positive potential, there will be a further field between wires 7 and layer 2 as indicated. The field conditions are thus favorable to the travel of electric charges from corona wire 5 to the surface of insulating layer 2.

As charging continues the charges accumulate on the layer 2 increasing its potential until the potential reaches a value somewhat higher than the potential of electrode 7. The field conditions (neglecting ion space charges) will then be as shown in Figure 7 in which a field still

extends from corona wire 5 to electrode wires 7, but now the field between wires 7 and insulating layer 2 is reversed in direction as indicated by the arrows. Conditions are now less favorable to the travel of charges from corona wire 5 to layer 2 since these charges will encounter a field directed away from layer 2 toward the control electrode 7. When the potential of insulating layer 2 reaches a sufficiently high value above that of electrode 7, the field between them will eventually be great enough to turn all the positive charges back to electrode 7 and an equilibrium will have been reached. It is apparent that the equilibrium potential of layer 2 will be higher than the potential on electrode 7. Thus, in some cases where a rather low potential is desired on the insulating layer, the tap 38 may be moved down to the ground potential end of potentiometer 34, or the potential difference between the corona discharge electrode and the control electrode may even be made greater than that between the corona discharge electrode and the conductive backing of the insulating layer as will be described in connection with Figure 14.

It is apparent that electrode grille 7 can be formed in a variety of ways of parallel wire, punched metal sheets, wire screen and the like. Figure 8 illustrates a modification of the charging device in which a wire screen grille 46 is substituted for parallel wires 7. A woven copper screen having 16 wires to the linear inch is suitable. It is preferred that the screen be mounted on a bias as shown in Figure 8 in order that none of the wires of the screen run parallel to the direction of travel of the plate 9 as it passes under the charging device. This avoids any irregularities in the deposited charge due to the shielding action of the wires.

Figure 9 illustrates a further modification in which the control electrode comprises parallel wires 47 mounted on the bottom edge of supports 6. In this embodiment a pair of solid metal plates 48 are mounted on the beveled edges of support 6 instead of extending the electrode wires 7 up on these beveled edges. This provides a sturdier construction which is less subject to damage through accidental striking of the wires, although it reduces the charging rate slightly.

Figure 10 illustrates, in cross-section, a completely enclosed corona unit in which corona wires 5 are stretched between insulating blocks 49 mounted in a metal channel 50 which extends over the top and two sides of the corona space. The bottom face of the unit comprises parallel electrode wires 51 which are strung back and forth over pins 52 mounted in the lower edges of insulating blocks 49. This provides a sturdy compact unit in which the corona wires are well protected against injury from outside sources and extraneous air currents are excluded.

For some applications it is possible to use pointed conductors as the corona electrodes. Figures 11 and 12 illustrate one embodiment in which a row of conductively-connected pointed needles 53 comprise the corona electrode. The needles pass through an insulating support bar 54 formed of polystyrene, or other good insulating material, and are electrically connected together by welding or soldering them to a metal strip 55 clamped to the top of insulating bar 54 and provided with a terminal 56 for connection to a high voltage source. Control electrode 57 comprises parallel wires strung from pins 58 in the lower and beveled edges of insulating support blocks 59 in a manner similar to that used in the device of Figures 1 to 2.

Figure 13 is a circuit diagram of a modified power supply for the charging device. In this circuit the rectifier tube is eliminated and secondary winding 61 of transformer 60 supplies high voltage alternating current directly to corona wires 5, the winding 61 being connected directly between the wires and ground. A D. C. control voltage is applied to control electrode 7 by a separate D. C. source such as battery 62. The polarity of electrode 7 determines the polarity of charge placed on an insulating layer or coating of an electrophotographic plate passed

over grounded guideplate 3. Thus, as illustrated, a positive potential of 400 volts on electrode 7 will result in the deposition of a positive charge on an insulating layer to raise it to a potential determined by the 400 volt potential on the electrode.

Figure 14 shows a still further modified circuit in which the secondary 64 of high voltage transformer 63 supplies a high voltage D. C. potential to corona wires 5 through rectifier tube 65. In this circuit the potential difference between control electrode 7 and the corona wires 5 is greater than that between the conductive support for the insulating layer and the corona wires. This is accomplished by grounding tap 66 on a potentiometer 67 bridged across the D. C. output of the transformer-rectifier combination 64, 65 and connecting electrode 7 to the opposite end of potentiometer 67 from the corona wires 5. This circuit is particularly suitable for applying relatively low potentials to an insulating layer. It is believed that in this case equilibrium is not reached until the insulating layer becomes charged to a positive potential, even though the control electrode 7 is at a negative potential of 100 volts or more.

It will be apparent from the foregoing that a charging device has been described and illustrated which enables the control of the potential of charge applied to an insulating layer in a predetermined manner.

In the claims the term "charging surface" or "charging plane" refers to the surface or position in space which is occupied by the surface of the insulating layer while it is being charged. It is obvious that, while the surface is a plane in the examples illustrated, it can take other forms such as cylindrical, for example, in which event the insulating layer may be the coating of a rotating belt or drum. It is also obvious that the insulating layer can be held stationary in the apparatus during charging and the ion source and control electrode can either be extensive enough to cover the entire surface or they can be advanced over the stationary insulating surface.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. A device for uniformly charging the photoconductive insulating coating layer supported on a conductive backing of an electrophotographic plate, comprising a movable support for advancing said plate at constant speed in a plane parallel to its surface, an elongated corona discharge electrode comprising at least one fine conductive strand in spaced parallel relation to said plane extending across the path of travel of said plate, a conductive shield partially surrounding said corona discharge electrode and shielding said electrode on the side away from the plate, a conductive grille disposed in a plane parallel to said plate between said corona discharge electrode and said plane of plate advance, a corona-generating potential source connected to said corona discharge electrode to apply a corona-generating potential between said corona electrode and said grille and between said corona electrode and said shield to generate a corona discharge from said corona electrode, contact means for making contact with said conductive backing of said electrophotographic plate, and a lower potential source connected between said grille and said contact means to apply a charging field through the photoconductive insulating layer of the plate and to limit the potential applied to said photoconductive insulating coating by said corona discharge.

2. A corona discharge voltage regulator for the control of the potential of a high voltage electrode comprising a perforated grid structure disposed adjacent said high voltage electrode, a plurality of corona discharge needles directed toward said high voltage electrode and separated therefrom by said grid, said needles and said grid being separated and maintained at different potentials with said

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grid being at a potential intermediate said needles and said electrode whereby corona discharge occurs between said needles and said grid and a known fraction thereof reaches said electrode, and means to vary the potential difference between said needles and said grid whereby the magnitude of the corona discharge therebetween is controlled to vary the discharge reaching said high voltage electrode.

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