Feb. 27, 1968 M. MICHALCHIK 3,370,529

ELECTROSTATIC PRINTER HAVING SELF-REGULATING CORONA DISCHARGE

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FIG. 1.

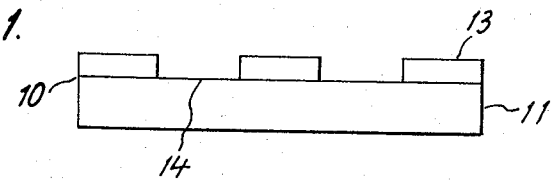


FIG. 2.

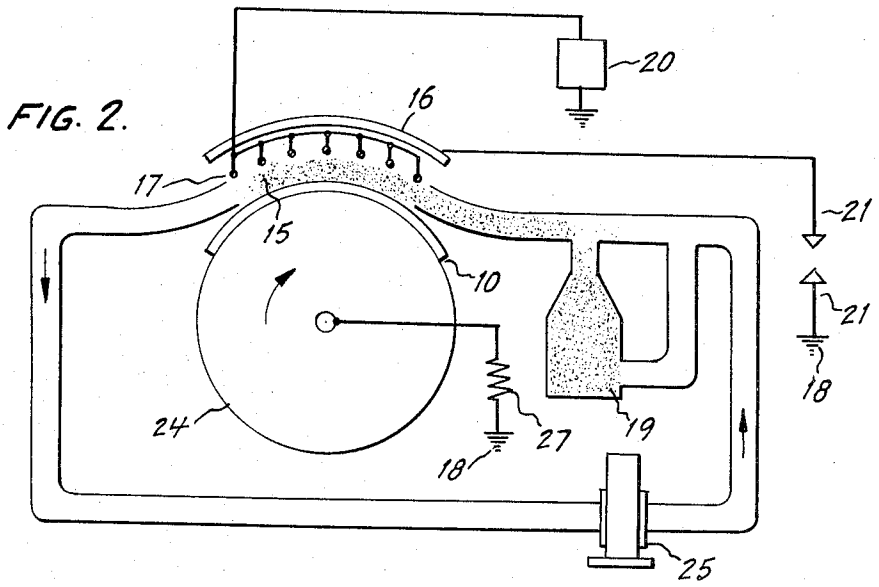


FIG. 3.

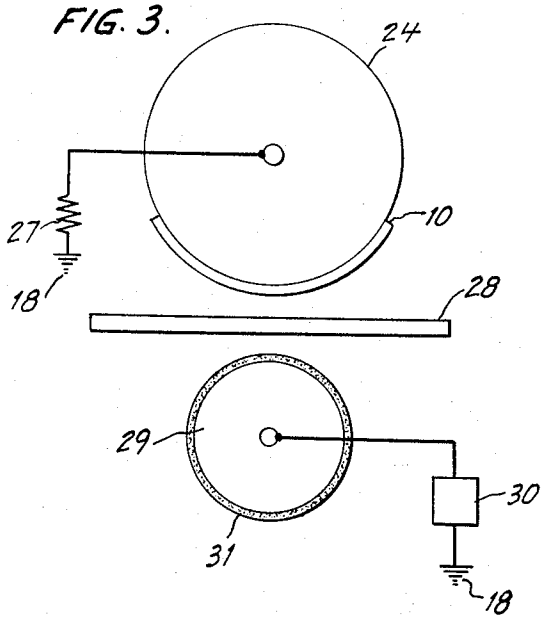
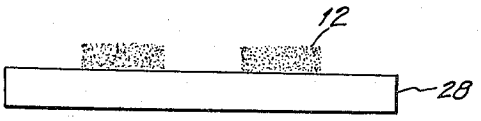


FIG. 4.



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ELECTROSTATIC PRINTER HAVING SELF-REGULATING CORONA DISCHARGE

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17 Claims. (Cl. 101—1)

ABSTRACT OF THE DISCLOSURE

Apparatus for forming a toner image on a plate having both conductive and insulative areas. The plate is subjected to a high current capability corona generator having a self-regulating feature which maintains the ionized space charge between the corona generator and the plate below the level necessary for spurious electrical discharge therebetween. In addition, there is co-action between the corona generating system and the toner which is introduced at high velocity into the ionized space. In effect, the toner becomes part of the high corona current flow and is deposited solely on the conductive areas of the plate.

This is a continuation-in-part of application Serial No. 427,294, filed January 22, 1965 now abandoned.

This invention relates in general to electrostatic image reproduction devices and more particularly to methods and apparatus for producing high quality high speed printing on a variety of surfaces.

The prior art methods of electrostatic printing have numerous disadvantages. Electrostatic printing press speeds in excess of 200 feet per minute have provided degraded reproductions of the image resulting from inadequate deposition of toner powder in the image areas and random deposition of toner powder in the background areas. The principal reasons for poor reproductions are lack of regulating means for securing uniform and adequate corona discharge during the deposition phase of the reproduction cycle; non-uniformity of charge imparted to the toner powder, in part due to the toner being introduced through the corona electrodes; slow transfer of toner powder from image plate to printing surface due to the relatively low conductivity of image areas on the image plate; introduction of toner, in the deposition phase of the cycle at slow speeds and; physical contact between the image plate and the image support web during the image transfer phase of the cycle. In addition, high speed transfer of electrostatic images onto a variety of uneven printing surfaces has hitherto not been practical.

Accordingly, it is the object of the present invention to provide a self-regulating corona control capable of supplying sufficient current to insure adequate deposition of toner in the desired image areas.

A further object of the present invention is to provide an improved apparatus for printing by electrostatic means that will provide increase printing speed and better quality than that attainable with existing electrostatic printing apparatus.

Another object of the present invention is to provide an improved method of electrostatic printing which permits printing by means of toner powders on a variety of printing surfaces, including uneven surfaces.

Another object of the present invention is to provide an improved method of high speed electrostatic printing which avoids direct contact between printing plate and receiving surface.

These and further objects and features of the present invention will appear from a reading of the following detailed description of one embodiment of the invention, to be read in conjunction with the accompanying drawings wherein like components in the several views are identified by the same reference numeral.

In the drawings:

FIGURE 1 illustrates a conductive image plate with an insulating photoresist suitably prepared for reproduction.

FIGURE 2 illustrates schematically one embodiment of the deposition apparatus of the present invention in which toner powder is selectively deposited on a surface which includes insulating background and conductive image areas.

FIGURE 3 is a schematic illustration of one embodiment of the transfer apparatus of the present invention in which the toner powder image is transferred to the printing surface.

FIGURE 4 illustrates the printing surface after the image has been transferred thereto.

Briefly stated high speed electrostatic printing in accordance with the present invention involves the two-phase process of deposition and transfer. The deposition phase of the invention employs a conductive plate coated with a photoresist. The plate is prepared in any conventional manner in order to form thereon an image in the photoresist leaving a surface having both conductive and insulative areas. The plate, which is connected to the power-supply-return through an impedance, is subjected to a controlled negative corona discharge which forms an ionized space between the corona discharge source and the image bearing plate. A toner powder is then introduced at high speed into this ionized space. In effect, the toner powder becomes part of the corona current flow to the conductive image areas.

It is to be noted that in the following description the conductive areas of the plate are assumed to be positive with respect to the negative potential of the corona producing electrode. Although, for ease of understanding the invention is described in this manner, it will be understood that the invention is equally applicable to positive corona discharge with a negative plate.

The transfer step of the present invention is accomplished by positioning the plate such that the powder bearing surface of the plate faces a transfer electrode. A sheet of paper or any appropriate printing surface is placed between the image plate and transfer electrode and a potential is applied between the image plate and the transfer electrode, the transfer electrode being of lower potential than image plate causing the particles of powder to be transferred from the plate to the printing surface. The powder particles may then be affixed to the paper in any conventional manner.

Referring now to FIGURE 1, there is illustrated an image plate with insulating photoresist bonded thereto in which image areas have been defined by selectively removing portions of insulating photoresist leaving exposed conductive image areas in which toner powder may be deposited. In the practice of the present invention it is necessary that an image plate be first prepared containing the image which it is desired to reproduce. In FIGURE 1 the image plate is identified in general by reference numeral **10** and includes a conductive support **11** having on one surface thereof an image to be reproduced which image is defined by an insulating photoresist **13**. Image area **14** may be formed by selectively removing insulating photoresist **13** bonded to support **11** using any conventional process. For example, support **11** can be coated with insulating photoresist **13** to a thickness of approximately 0.4 mil then the photoresist **13** is photograpically exposed to the image it is desired to reproduce. The exposed portions of photoresist **13** are then etched away leaving conductive image areas **14** which correspond to

the desired image. Support 11 should have a maximum volume resistivity of 10^3 ohm-centimeters to enable the corona current to increase to a range of 50 to 300 micro-amperes per square inch of image area as required by this invention. This will be described in greater detail below.

Referring to FIGURE 2, a suitably prepared image plate 10 is subjected to a corona discharge which as aforesaid, for ease of understanding will be described as negative. The negative charging by corona discharge is accomplished by placing support 11 with defined image areas 14 thereon under a high voltage electrode 17. The negative corona discharge forms an ionized space 15 between corona electrode 17 and support 11 which is connected to ground as for example through a mounting means shown as drum 24 on which support 11 is mounted. Ionization is actually a flow of electrons between support 11 and corona electrodes 17, which flow is substantially magnified by an increase in humidity or blowing toner powder 19 into the ionized space 15. In addition, the changes in conductivity on the surface of image plate 10, from insulating photoresist 13 to conductive support 11, in effect, reflected to corona electrodes 17, causes a non-uniform and at times inadequate ionization in ionized space 15. This non-uniformity has two main effects: first, toner powder 19 passed through ionized space 15, will not have a uniform charge and will have a greater tendency to attract to the insulating photoresist 13 on support 11 and; second, the non-uniform corona current causes uneven deposition in conductive image areas 14. These effects are especially pronounced in a high speed electrostatic printing process. If the magnitude of the voltage from the power supply 20 applied to corona electrodes 17 is increased, in order to increase the corona current, it is likely that arcing will occur between the corona electrodes 17 and support 11 when the toner powder 19 is introduced between them. Such arcing would result in poor reproductions and possible damage to support 11.

This invention provides means that not only allows increased corona current without increasing the corona supply voltage but also provides self regulation of this current to compensate for any transient effects such as increased humidity. Positioning a conductive shield 16 near the corona electrodes 17, causes an increase in corona current flow without increasing the voltage supplied to corona electrodes 17. This is desirable as a current between 50 and 300 micro-amperes per square inch of conductive image area 14 is required by this invention, the optimum value of the current being a function of and increasing with an increase in printing speed. If the current falls too low it degrades the printing quality, if too high it may result in arcing between support 11 and electrodes 17.

As noted above, the conductive shield is employed as part of a self-regulating current control system. Conductive shield 16 acquires an electrical charge induced by the corona discharge during operation. This charge accumulates until a chosen level is reached causing a spark to bridge the gap between spaced electrodes 21 connected between shield 16 and ground 18 which discharges conductive shield 16. The desired breakdown voltage can be chosen by selecting the spacing between electrodes 21.

When toner powder 19 is blown between corona electrodes 17 and image plate 10 in the presence of ionization, the quiescent ionization current is substantially increased causing the current to shield 16 to be increased to some lesser extent. However, before the ionization current between corona electrodes 17 and support 11 reaches the arcing level, shield 16 will be discharged through electrodes 21 thereby reducing the overall ionization level below that at which arcing would occur between corona electrodes 17 and support 11. Reduction of the ionization level in this manner also prevents an excessive charge from building up on insulating photoresist 13 bonded to support 11 thereby reducing the lateral surface current on insulating photoresist 13 which breaks down the insulating properties of these surfaces and causes toner powder 19 to adhere to non-image areas.

Once the ionized space is created, toner powder 19 is blown into ionized space 15 beneath corona electrodes 17, tangentially to image plate 10 mounted on drum 24, by blower means 25. In accordance with the invention blower means 25 imparts a minimum velocity of 300 feet per minute to toner particles 19. Velocities of up to 20,000 feet per minute have been used successfully. It is to be noted that the high velocity imparted to toner powder 19 is instrumental in imparting a uniform negative charge to this toner powder 19 not attainable at lower velocities. The uniform charge on toner powder 19 tends to reduce the deposition of toner powder 19 on the insulated photoresist 13. Once powder particles 19 have become negatively charged, they are drawn to image areas 14 of support 11. It is to be noted that support 11 is electrically positive with respect to electrodes 17 because corona electrodes 17 are connected to the negative side of power supply 20 and support 11 is closer to ground or reference potential.

The toner powder 19 may be made of a non-insulating material with a maximum volume resistivity of 10^3 ohm-centimeters or of an insulating material with a minimum volume resistivity of 10^6 ohm-centimeters. Without limiting the scope of this invention, satisfactory operating parameters for a preferred configuration has shield 16 spaced ¾-inch from corona electrodes 17 which, in turn, are arrayed in a circular segment 1 inch from the printing plate 10. This configuration is operable with 9000 volts applied to corona electrodes 17 having a diameter 3.5 mils, electrodes 21 being spaced 1¾ inches apart.

Support 11 is connected to ground 18 through an impedance shown as resistor 27. Resistor 27 performs the function of a spark suppressor, reducing the voltage difference between corona electrodes 17 and support 11 thereby reducing the likelihood of electrical discharge between corona electrodes 17 and support 11. If electrical discharge between corona electrodes 17 and support 11 does occur, resistor 27 limits the discharge current preventing damage to support 11.

One explanation of why resistor 27 acts as a spark suppressor rather than as a simple resistor is due to the fact that the current and voltage on image plate 10 are out of phase with each other. Another explanation for this spark suppression function is that prior to actual arcing between corona electrodes 17 and support 11 there is an increase in corona current. This current passes through resistor 27 causing support 11 to acquire a more negative voltage with respect to ground thereby reducing the voltage difference between corona electrodes 17 and support plate 11 below that at which arcing occurs. The optimum value of resistor 27 varies inversely with the size of support 11. A range of 10^5 to 10^6 ohms was found to be the optimum range for use with a 140 square inch support 11. Values of zero to 10^7 ohms have been used with varying degrees of success for this function, depending upon the support.

A high speed printing process requires that toner powder 19 be quickly removed from the support 11. This operation is readily accomplished by the apparatus of this invention due to the high conductivity of the image areas 14 as opposed to the relatively high insulating properties of image area surface used in the prior art. Printing speeds of up to 20,000 feet per minute can be obtained with this process.

Once toner powder 19 has been deposited in image areas 14 on support 11, the deposition phase of the present invention has been completed and the second or transfer phase can be initiated. Referring to FIGURES 3 and 4, in the transfer phase of the invention, the toner powder 19 now in the form of a powder image is to be transferred to a printing surface 28 (FIG. 4). The image plate 10 is positioned opposite the transfer electrode 29. If

desired, the transfer electrode **29** may be coated with an insulating film **31** to prevent arcing between transfer electrode **29** and support **11**. A printing surface **28** of any reasonable thickness or irregularity is placed between transfer electrode **29** and image plate **10**. When printing surface **28** is in position, a reverse polarity of approximately 1500 volts is applied between image plate **10** and transfer electrode **29**, and across printing surface **28**. Voltages as high as 8000 volts have been successfully employed when transfer electrode **29** has been coated with an insulating film **31**. In applying the reverse potential transfer electrode **29** may be positive or negative with respect to support **11** but in any event, it is of a different potential, i.e. more negative or more positive than support **11** so that an electric field is created between the two surfaces. In this manner the toner powder **19** forming the toner powder image **12** is transferred from support **11** to printing surface **28** forming transferred areas **12** corresponding to the image to be reproduced.

As indicated above for transfer of the toner powder image **12**, it is necessary that an electric field be created between support **11** and transfer electrode **29**. Thus, either one may be positive and the other negative. If toner powder **19** is deposited with a negative corona, transfer electrode **29** should be positive or at least more positive than support **11**. If toner powder **19** is deposited with a positive corona, transfer electrode **29** should be negative or at least more negative than support **11**. In any event a voltage is applied between transfer electrode **29** and support **11** so as to create an electric field between them and cause transfer of toner-powder image **12**.

Once powder image **12** has been transferred to printing surface **28**, printing surface **28** is removed from between support **11** and transfer electrode **29**. The powder image **12** is then fixed to the printing paper **28**. This final step in the practice of the invention may be accomplished in any well-known manner, as for example, by heat, resinous overlay etc.

While what has been shown and described is believed to be the best mode and a preferred embodiment of the invention, modifications and variations can be made therein as will be clear to those skilled in the art, without departing from the spirit of the invention and consequently the scope of the invention is intended to be limited solely by the appended claims.

What is claimed is:

1. Electrostatic printing apparatus capable of producing reproductions from an image plate having a conductive support and at least a portion of one surface of said support bearing non-conductive material on the non-image portions thereof, comprising a first station having first mounting means for mounting said plate, said mounting means electrically grounding said plate, a conductive shield mounted on said apparatus and insulated from ground, said shield spaced from said plate, control means connected to said shield for automatically connecting said shield to ground when the potential of said shield exceeds a predetermined level with respect to ground, a corona electrode mounted on said apparatus and insulated from ground, said corona electrode spaced between and apart from said image plate and said shield, means for connecting a high voltage power supply to said corona electrode to create a corona discharge field between said corona electrode and said plate, means for introducing toner powder into the space between said corona electrode and said plate at a high velocity, said corona discharge field causing at least a portion of said toner powder to be deposited onto the image areas of said plate, a second station having second mounting means for mounting said plate, said means electrically grounding said plate, means for moving said plate from said first station to said second station, a transfer electrode mounted on said apparatus at said second station and insulated from ground, said transfer electrode being spaced from said plate when said plate is at said second station, means for placing a printing surface between said plate and said transfer electrode, and means for connecting a high voltage power supply between said transfer electrode and said plate so that the potential applied to said transfer electrode is opposite in polarity to the potential applied to said corona electrode, whereby the toner powder deposited on the image portions of said plate at said first station are transferred from said plate to said printing surface at said second station.

2. The device as defined in claim **1**, wherein said first and second mounting means are electrically connected to ground through resistors.

3. The device as defined in claim **1**, wherein said first and said second mounting means are a single mounting means movable between said first and second stations.

4. The device as defined in claim **3**, wherein said single mounting means is electrically connected to ground through a resistor.

5. The device as defined in claim **1**, wherein said control means is an off-on device which is switched from the non-conducting state to the conducting state when the potential induced on said shield reaches a chosen level and automatically returns to the non-conducting state when the discharge current falls below the conductive state sustaining level of said off-on device.

6. The device as defined in claim **1**, wherein said control means is comprised of a pair of spaced apart electrodes.

7. The device as defined in claim **1**, wherein said means for introducing said toner powder is a blower means capable of imparting a velocity of between 300 and 20,000 feet per minute to said toner powder.

8. The device as defined in claim **1**, whereby said corona discharge field produces a corona current between said corona electrode and said conductive support of at least 50 micro-amperes per square inch of image area on said image plate when said image plate is at said first station.

9. The device as defined in claim **1**, wherein said conductive support has a maximum volume resistivity of 10^3 ohm-centimeters.

10. The device as defined in claim **1**, wherein said toner powder is made of non-insulating material with a maximum volume resistivity of 10^3 ohm-centimeters.

11. The device as defined in claim **1**, wherein said toner powder is made of an insulating material with a minimum volume resistivity of 10^6 ohm-centimeters.

12. Electrostatic printing apparatus capable of transferring an image to an image plate having a conductive support and at least a portion of one surface of said support bearing non-conductive material on the non-image portions thereof, comprising means for mounting said plate, said mounting means electrically grounding said plate, a conductive shield mounted on said apparatus and insulated from ground, said shield spaced from said plate, control means connected to said shield for automatically connecting said shield to ground when the potential of said shield exceeds a predetermined level with respect to ground, a corona electrode mounted on said apparatus and insulated from ground, said corona electrode spaced between and apart from said image plate and said shield, means for connecting a high voltage power supply to said corona electrode to create a corona discharge field between said corona electrode and said plate and means for introducing toner powder into the space between said corona electrode and said plate at a high velocity, said corona discharge field causing at least a portion of said toner powder to be deposited onto the image areas of said plate.

13. The device as defined in claim **12**, wherein said mounting means is electrically connected to ground through a resistor.

14. The device as defined in claim **12**, wherein said control means is an off-on device which is switched from the non-conducting state to the conducting state when

the potential induced on said shield reaches a chosen level and automatically returns to the non-conducting state when the discharge current falls below the conductive state sustaining level of said off-on device.

15. The device as defined in claim **12**, wherein said control means is comprised of a pair of spaced apart electrodes.

16. The device as defined in claim **12**, wherein said means for introducing said toner powder is a blower means capable of imparting a velocity of between 300 and 20,000 feet per minute to said toner powder.

17. The device as defined in claim **12**, wherein the spacing between said corona electrode and said conductive support is related to the voltage level of the power supply so as to provide a corona current of at least 50 micro-amperes per square inch of conductive image area on said image plate.

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