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XEROGRAPHIC DEVELOPING APPARATUS

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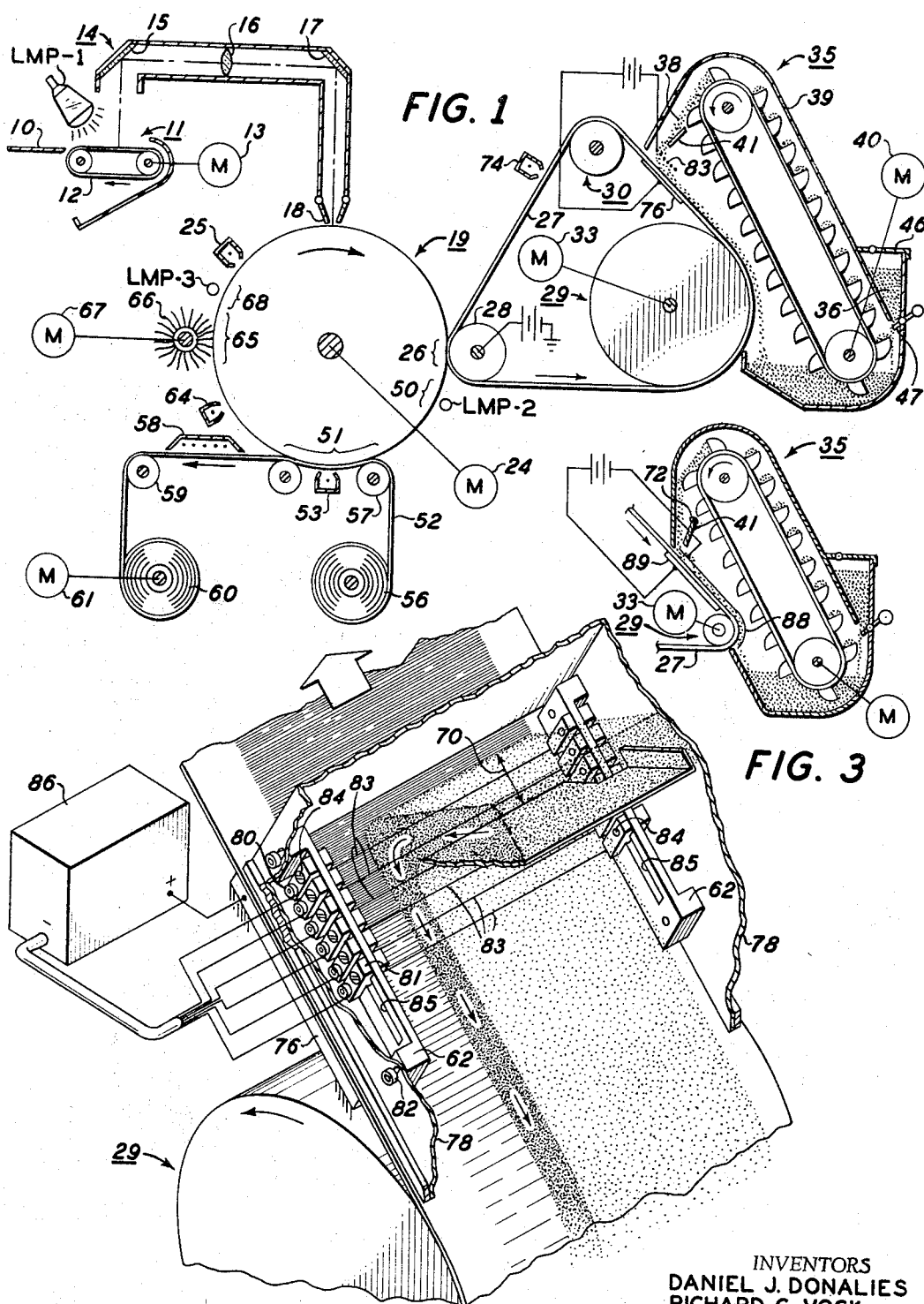


FIG. 2

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XEROGRAPHIC DEVELOPING APPARATUS
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ABSTRACT OF THE DISCLOSURE

Apparatus for developing latent electrostatic images in which a donor member having a uniformly distributed quantity of electroscopic developer powder thereon is advanced into and out of contact with electrostatic images on a xerographic plate. A high uniformity of density and distribution of the powder on the donor member is obtained by discharging the powder from a source of supply above the donor member into a field resulting from an electrode array between the source of supply and the donor.

Background of the invention

This invention relates to xerography and particularly to improvements for developing latent electrostatic images by use of a donor member loaded with a developer material.

In the process of xerography, for example, as disclosed in Carlson Patent, 2,297,691, issued Oct. 6, 1942, a xerographic plate comprising a layer of photoconductive insulating material on a conductive backing is given a uniform electric charge over its surface and is then exposed to the subject matter to be reproduced usually by conventional projection techniques. This exposure discharges plate areas in accordance with the radiation intensity that reaches it and thereby creates a latent electrostatic image on or in the photoconductive layer. Development of the latent image is effected with an electrostatically charged, finely divided material such as an electroscopic powder, that is brought into surface contact with the photoconductive layer and is held thereon electrostatically in a selective pattern corresponding to the electrostatic latent image. Thereafter, the developed image may be fixed by any suitable means to the surface on which it has been developed or may be transferred to a secondary support surface to which it may be fixed or utilized by means known in the art.

Whatever method is employed for forming electrostatic images, they are usually made visible by developing. Various developing systems are well known in the art and include cascade, brush development, magnetic brush, powder cloud, and liquid development, to name a few. Still another developing method is disclosed in Mayo Patent U.S. 2,895,847 in which a support member such as a web, sheet or other member termed a "donor" is employed which carries a releasable layer of electroscopic marking particles to be presented into close contact with a latent image bearing plate for deposit in conformity with the electrostatic image to be developed.

The method of Mayo has been found generally suitable for development of electrostatic images. However, to obtain consistent high quality development with his apparatus it is necessary that the developer be supported on the donor with a high uniformity of density and distribution. This is to assure reproducible results with each successive development. Techniques for loading of the developer marking particles on the donor member to obtain uniformly satisfactory development with each successive development have heretofore not been entirely satisfactory. The powder particles on the donor must be releasable to the electrostatic image and yet be presented in uniform distribution in order to effect uniformity of

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development in the final copy. This bonding relationship has been difficult to control particularly with automatic machines in which it is desired to load the donor and mechanically move it in various directions with the developer loosely held toward a remotely supported image-bearing plate.

It has been found that techniques of the prior art in which developer particles are applied against a donor web by squeegeeing, brushing, triboelectrification, or the like result in a donor which is not entirely satisfactory being generally unsuitable for use in automatic copying apparatus. In addition, while the donor type development has been found suitable for line copy images, it has generally been regarded as limited in applications requiring development of half tone or continuous tone type image reproductions.

Summary of the invention

Now, in accordance with the instant invention, there is achieved high quality donor type development by improved apparatus for dusting or loading the developer particles onto the donor member, as to effect uniformly dense, highly charged loadings providing superior and controlled bonding properties to present powder developer to an image to be developed. Not only are the donor members more easily loaded in accordance herewith, but uniformity in loading bond is maintained through presentation to an image bearing surface. At the same time, it had been found that donor members loaded in accordance with the invention hereof respond with greater fidelity to gradations of field strength of the electrostatic image to provide pleasing renditions as associated with half tone, continuous tones or the like.

The problems inherent in the prior art devices and processes are, therefore, overcome in accordance with the invention in which donor loading is effected by directing developer into direct and electrical contact with a biased electrode, as by dropping or cascading a two-component developer mix through an electrode comprising an array of biased wires on a grid supported over the donor member. The developer is charged by the electrode and then cascades over the donor member to load the powder particles thereon in a dense, uniform and highly charged condition.

Accordingly, is it an object of the invention to provide novel apparatus to effect improved development of electrostatic images.

It is a further object of the invention to provide improved apparatus for donor type development in the process of xerography.

It is a still further object of the invention to effect improved loading techniques for loading electroscopic developer particles onto a donor member to be employed subsequently for development.

It is a still further object of the invention to effect a more uniform, dense, highly charged dusting and loading of the electroscopic developer particles onto the donor than was heretofore known in the art.

These and other objects of the invention will appear in the following specification when read in conjunction with the following drawings, the novel features being pointed out in the claims at the end of the specification.

Brief description of the drawings

FIG. 1 is a schematic illustration of a typical xerographic machine employing the donor method of imaging development in accordance with the invention hereof;

FIG. 2 is an isometric fragmentary view of a preferred apparatus embodiment for loading the electroscopic marking particles onto a donor member, and

FIG. 3 is a side view of a variation to the apparatus of FIG. 2.

Description of the preferred embodiments

For a general understanding of the xerographic processing system in which the invention is incorporated, reference is had to FIG. 1 in which the various system components are schematically illustrated. As in all xerographic systems based on the concept disclosed in the above-cited Carlson patent, a radiation image of copy to be reproduced is projected onto the sensitized surface of a xerographic plate to form an electrostatic latent image thereon. Thereafter, the latent image is developed with an oppositely charged developing material to form a xerographic powder image corresponding to the latent image on the plate surface. The powder image is then electrostatically transferred to a support surface to which it may be affixed by a fusing device whereby the powder image is caused permanently to adhere to the support surface. In the illustrated xerographic apparatus, original copy to be reproduced is placed on a support tray 10 from which it is fed onto a feed apparatus generally designated 11. On the feed apparatus, an original is moved on an endless belt 12, driven by motor 13, to pass the optical axis of projection lens system 14 that is illuminated by projection lamp LMP-1. The image of the original is reflected by a mirror 15 through an adjustable objective lens 16 and then reflected by mirror 17 downwardly through a variable slit aperture assembly 18 and onto the surface of a xerographic plate in the form of drum 19.

Xerographic drum 19 includes a cylindrical member mounted in suitable bearings in the frame of the machine and is driven in a clockwise direction by a motor 24 at a constant rate that is proportional to the transport rate of the original, whereby the peripheral rate of the drum surface is identical to the rate of movement of the projected radiation image. The drum comprises a layer of photoconductive material on a conductive backing that is sensitized prior to exposure by means of corona generating device 25, which may be an adaptation of the type disclosed in Vyverberg Patent No. 2,836,725 that is energized from a suitable high potential source.

The exposure of the drum to the radiation image discharges the photoconductive layer in the area struck by radiation whereby there remains on the drum a latent electrostatic image in image configuration corresponding to the radiation image projected from the original. As the drum surface continues its movement, the latent electrostatic image passes through a developing station 26 whereat an endless donor belt 27 loaded with developer particles passes around roller 28 into and out of contact with the surface of the drum.

Before arriving at developing station 26, the belt receives a thin uniformly distributed layer of electroscopic marking particles 36 which have been dusted or loaded on the donor belt by means of loading apparatus 35 as will be described. In the loading apparatus 35, developer material 38 is carried up by a conveyor 39, driven by suitable drive means from motor 40, and then released onto chute 41 wherefrom it cascades through an electrode array 83 and down over the belt. The developer material comprises a two-component mix of toner 36 and carrier beads of the general composition and nature described in Walkup Patents Nos. 2,618,551 and 2,638,416. As the developer material 38 is cascaded over the belt, a quantity of the toner component particles of the developer mix 38 is dusted and deposited uniformly onto the moving belt while the remainder thereof is returned to the sump of the loading apparatus 35. The toner component 36, that is consumed in dusting and subsequently in developing, is stored in dispenser 46 and is dispensed in amounts controlled by gate 47. The dusted donor belt then passes over guide roller 30. A corona charging device 74 may optionally be utilized to apply additional charge to the dusted toner in order to facilitate the selective transfer of the toner to the image pattern on the drum.

Roller 28, is preferably of a soft resilient material, such as rubber. When electrically conductive, the roller may conveniently be biased to opposite polarity as that of the toner particles in order to suppress background charge and prevent its development.

The belt also passes over drive roller 29, being driven by motor 33, shown to be in the same direction as the surface rotation of drum 19. Belt speed can be the same as or substantially in excess of the speed of rotation of the drum, the latter maintaining a sliding or skidding contact between the belt and the drum 19 at developing station 26.

After development, the xerographic powder image passes a discharge station 50 at which the drum surface is illuminated by lamp LMP-2 whereby residual images on the non-image areas of the drum surface are completely discharged. Thereafter, the powder image passes through an image transfer station 51 at which the powder image is electrostatically transferred to a moving support surface 52 by means of second corona generating device 53 similar to corona charging device 25, mentioned above.

The moving support surface 52 to which the powder image is transferred may be of any convenient type, such as paper, and may be obtained from a supply roll 56, fed over guide roll 57 and over suitable tensioning rolls being directed into surface contact with the drum in the immediate vicinity of transfer corona generating device 53. After transfer, the support surface 52 is separated from the drum surface and guided through a fusing apparatus 58 wherein the powder image is permanently affixed thereto. Thereafter, the support surface may be fed over a further system of guide and tensioning rolls, of which roll 59 is one, and onto a take-up roll 60 that is driven through suitable drive means by motor 61.

After separation of the support surface 52 from the drum, a corona generating device 64 directs electrostatic charge to the residual powder image on the drum surface. Thereafter, the xerographic drum surface passes through a cleaning station 65 whereat its surface is brushed by a cleaning brush assembly 66, rotated by a motor 67, whereby residual developing material remaining on the drum surface is removed. The drum surface then passes through a second discharge station 68 at which it is illuminated by a fluorescent lamp LMP-3, whereby the drum surface in this region is completely flooded with light to remove any electrostatic charge that may remain thereon. Suitable light traps are provided in the system to prevent any light rays from reaching the drum surface, other than the projected image during the period of drum travel immediately prior to sensitization by corona generating device 25 until after the drum surface is completely passed through the developing station 26.

In FIG. 2 there is illustrated in accordance with the invention hereof an embodiment for loading electroscopic marking particles onto the surface of the donor member. In accordance with this embodiment a plurality of biased wire electrodes 83 are strung in substantially parallel relation to each other extending transversely beneath the chute 41 and above the moving donor belt 27. Beneath the donor belt 27 on the side opposite the electrodes and in supporting relation to the belt is a secured plate 76 grounded or oppositely biased as shown. The latter plate may optionally be used to increase the voltage difference between the donor belt and the electrode array 83 and effect enhanced loading results. By increasing the field strength between the donor and wires 83 the bond between donor and loaded toner is increased without substantially affecting the charge condition of the toner.

Electrode wires 83 span the width of the continuously advancing donor belt and are attached to opposite adjustable tension screws 80 mounted on electrically conductive slide means 81 on each side of the dielectric support frame 62. The frame, in turn, is mounted to a bracket 78 of the copying apparatus by pivotal bolt means 82 to allow the distance of the wires from the belt to be

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varied and set. The screws 80 provide a convenient means for adjusting and maintaining the tension of the individual wires which tension should be sufficient to prevent sag during loading. Slide means 81 are attached to the dielectric support frame 62 by bolts 84 and may be manually moved and set along slide 85 to vary interwire spacing. By this means the wires are supported in the developer path to contact developer in essentially normally intercepting fashion as it flows from the chute 41 onto the surface of the donor belt 27.

In FIG. 3 is illustrated a variation of the apparatus just described and wherein donor belt 27 is shown to be traveling in a direction around roller 29 opposite from that shown in FIG. 2. Chute 41 for this embodiment is pivotally supported about pin 72 whereby to direct developer discharge to the donor surface at a preselected adjustable angle. The donor travels as before between ground or biased plate 89 which need not necessarily be employed, and electrode 88 which may correspond to electrode embodiment 83 or may alternatively be of a different structural arrangement. Thus, electrode 88 may be comprised of an array of parallel wires as in FIG. 2, or may instead comprise an open mesh screen or the like formed geometrically in a pattern of intersecting and crossing wires.

Many electrode geometries may be utilized such as separate grids arranged obliquely intercepting. Likewise, electrodes with two or more levels of grid surface, not confined to a single plane, may be used having a substantial three dimensional configuration. Dimensional variations may exist in the different arrangements to be described without conforming to the particular description of apparatus illustrated herein and without varying from the basic donor loading concept hereof, permitting passage of developer in contact with the donor surface.

One problem to be avoided with electrode 88 is non-uniform donor loading caused by excessive shielding of the donor surface by the electrode wires which prevents uniform developer contact in the areas beneath the wires. Particularly where the wires extend co-directional with the developer flow, unless sufficient spacing is provided to permit adequate flow below the wires, there is a tendency for the flow to be generally restricted above the wires out of contact with the donor surface. If such deleted areas are not loaded to uniformity before the donor contacts the drum, the print density and contrast will be defectively non-uniform. A relatively fine grid electrode, for example, one comprised of approximate squares $\frac{3}{8}$ inch on a side or smaller, is effective to prevent the deletion effect, as would be a vibrating electrode constantly changing the projected area of the wires to a different portion of the donor.

An additional variation inherent in this embodiment is that increased turbulence of the cascading developer is effected by increased bouncing between the donor and the greater electrode surface area. By discharging the developer at an angle selectively chosen by positioning of chute 41 on its pivot, the developer bounces onto the underside of electrode 88 causing stripping of toner from carrier by mechanical means in addition to that caused by the electrical means provided by the existed field established between electrode 88 and plate 89. Thus, not only may electrodes be arranged in various grid patterns including arrays of essentially parallelly strung wires, but the angle of developer flow between the electrode and the donor can be varied to produce optimum results for varying parameters of operation. The bouncing technique or a straight fall of developer between the donor and a solid sheet electrode can also be employed wherein the electrode 88 is of sufficient length and adequate spacing is present in the flow passage between the donor and electrode surfaces. In fact, such sheet electrodes have produced good donor loadings but with less toner charge and with reduced density than for a grid electrode operating under similar conditions.

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Although it is believed that the predominance of loading and charging occurs in the donor surface in regions where developer directly contacts or comes closest to directly contacting the electrode members, as for example, immediately below and just beyond chute 41. Additional electrode area may be helpful further down the developer path to electrically contact the developer as it continues cascading over the belt surface. This enables loading additional toner not deposited in the initial contact.

Regardless of the electrode configuration used, the electrode is usually biased to the same polarity as triboelectrically acquired by the toner particles, e.g., negative, by electrical connection to power supply 86. In so-called reversal development wherein it is desired to develop uncharged rather than charged areas, positive toner and a positive bias of the electrodes would be utilized.

Ultimate development of latent electrostatic images in accordance herewith is subject to some variations other than varying electrode geometries generally attributed to the properties of the selected materials as well as the parameters of operation. As disclosed in the aforementioned Walkup patents, developer mix may be composed of electroscopic powder and granular carrier beads in varying concentrations. The type of donor surface may also be varied. The donor can be electrically conductive or insulating, within ranges to be described, and may be almost any material flexible enough to be formed into an endless belt and may comprise such materials as metal sheets, conductive rubbers, paper, Mylar or cardboard. Although a wide choice of donor materials was found to accept and retain a highly charged toner layer and thus were satisfactory in this respect, selection for continuous use in a copying apparatus is governed by other factors such as cost, availability, abrading effect on the relatively soft xerographic drum, useful life, pliability for its adaptation as a continuous belt arrangement, thickness of the material so that long lengths can be accommodated on relatively small roll diameters and other such factors. With a donor material having an electrical resistivity of from about 10^8 to 10^{12} ohm-centimeters good quality line copy reproductions but generally poor continuous tone and half-tone prints are produced. For donors with an electrical resistivity in the region above about 10^{12} ohm-centimeters, little or no continuous or half-tone development was achieved. All types of copy are satisfactorily developed with materials having an electrical resistivity generally less than about 10^8 ohm-centimeters.

The size and spacing of the electrode members and their distance from the belt surface are also variables affecting the density, uniformity and the magnitude of the charge of toner on the donor surface. The uniformity and the density of the toner on the donor directly affects the density and the uniformity of the resultant print. The magnitude of the toner charge is important in achieving the selective transfer of toner from the donor to the latent electrostatic image to affect print contrast. The rate of developer flow through the electrodes and the belt speed can vary the amount of toner loaded or extracted from the quantity flowing. The speed of the developer flow determines the time of contact of developer with the electrode which directly affects the charge of the loaded toner.

Also for a constant rate of flow of developer and a constant donor belt speed, an increase in the magnitude of the electrode bias increases the amount of toner loaded. Electrode potentials in the range of about 1,000 to 2,000 volts and up to 7,000 volts produced a toner layer of sufficient depth on the donor so as to produce prints with satisfactory print contrast and density. By selectively varying the aforementioned variables, transfer of the loaded toner to the image pattern on the drum may be controlled to develop images with better contrast of greater uniformity and with greater fidelity than was possible by using the donor method of development without the improved loading apparatus of the invention.

The two-component developer mixture included toner of a general type described in Carlson Reissue 25,136, in about a 2 percent concentration of toner by weight, cascaded at a rate of between about 4 and 30 and more commonly between 9 and 15 pounds per minute per inch of donor belt width contacted at a donor belt speed up to about 50 inches per second.

The electrode in FIG. 2 was comprised of about a 0.010 inch diameter metallic wire material with an inter-wire spacing of about $\frac{1}{8}$ inch and a wire spacing from the drum of about 0.060 inch to 0.150 inch although it was found that satisfactory images were developed by using wires up to about 0.020 inch diameters with an inter-wire spacing up to about $\frac{3}{8}$ inch.

The inter-wire spacing also should generally be the smallest possible to impart maximum charge to the greatest mass of flowing developer; the lower limit of inter-wire spacing being that at which developer mix tends to back up behind the electrode instead of flowing through and cascading across the donor belt. Minimum inter-wire spacing was found to be about $\frac{1}{16}$ inch under developer flow and belt speed rates previously mentioned. Sufficient wires are used so as to at least completely contact the developer mix 38 as it cascades from chute 41 over the donor belt. For example, for a $\frac{1}{2}$ inch chute opening 70 and a $\frac{1}{8}$ inch inter-wire spacing of electrodes, at least five electrodes are employed to provide maximum charging contact of the electrodes with developer flow. Additional wires can be utilized to provide further developer contact as it cascades over the donor to enhance loading and charging of toner. Likewise, where the electrode in FIG. 3 is comprised of a grid of substantially perpendicular wires in a common plane, the wires can be less than about 0.020 inch in diameter with an inter-wire spacing of less than about $\frac{3}{8}$ inch. This arrangement forms approximate squares the maximum size of $\frac{3}{8}$ inch on a side. The optimum inter-wire spacing is that which allows for the most wires per unit area able to withstand the force of the developer flow without developer backup behind the electrode. Minimum wire spacing for this grid arrangement under developer flow and belt speed rates previously mentioned is about $\frac{1}{16}$ inch.

The potential bias supplied by roller 28 for optimum print quality was found to be a function of the voltage on the loaded toner. Optimum voltage of the donor belt V_d was found empirically to be approximately equal to the voltage at the toner surface (V_t) plus the constant 300. $V_d = (V_t) + 300$. With a V_t of 600 volts, optimum donor bias is approximately 900 volt positive. This formula was found applicable regardless of whether the print was a line copy, continuous tone or half-tone as long as the donor belt was from a material with an electrical resistivity of less than about 10^8 ohm-centimeters. The use of higher voltages than that derived give a lower density print while reduced voltages produced undesirable print background.

Changing variables and parameters of operation may necessitate different voltages for the electrode and the donor within the aforementioned ranges to produce satisfactory prints, but such variances may be employed without departing from the basic method, apparatus and purposes of the invention.

In operation, a biased electrode supported in the developer path attracts carrier and charges toner being discharged from chute 41 repelling it to the donor surfaces via the field set up between the backing plate and the electrode. The toner is attracted to and deposited on the donor to effect a highly charged and bonded dense loading of toner on the belt surface. The remainder of the developer cascades down over the development belt into the bottom of the loading apparatus 35. Mechanical stripping may be advantageously employed in loading toner by varying the impact angle of developer flow to the electrode and the donor belt, as by the apparatus illustrated in FIG. 3.

Electrometer readings have shown a bias on the toner surface of from about 100 volts to about 1,500 volts which when accompanied by the donor belt bias provides the magnitude of charge necessary for selective removal of toner from the donor by the latent electrostatic image at belt speeds, up to about 50 inches per second.

By the apparatus described in the present invention, uniform, highly charged toner layers of $\frac{1}{32}$ inch thickness have been loaded. This increased density of toner capacity, as well as increased toner uniformity, is evidenced by increased print density and uniformity.

The utility of the improved apparatus disclosed in this invention is that the improvement loads toner onto a donor member in a more uniform, dense, highly charged fashion and with greater bonding tenacity than was previously known in the art. Such loading is necessary for commercially acceptable print contrast and uniformity which is essential in the commercially continuous production of high quality half-tone, continuous tone and line copy prints. The invention, which is simple and adapted to automatic operation, improves the donor development method of developing images in the process of xerography.

While the invention has been described with reference to the details and constructions herein illustrated, it is not intended to be confined to the exact mechanism shown. This application is intended to cover such modifications or departures as may come within the purposes of the invention and the scope of the following claims.

What is claimed is:

1. In a xerographic reproducing apparatus wherein latent electrostatic images of copy are formed on the surface of a xerographic plate, developing means for developing the electrostatic image comprising in combination:

- (a) a web-like donor member on which to support a uniformly distributed quantity of electroscopic developer powder,
- (b) powder loading means for loading said donor with a uniformly distributed quantity of electroscopic developer powder including:

- (1) means to discharge a quantity of two-component cascade developer mix of powder and carrier from a source of supply above an advancing area of donor out of contact with the xerographic plate,
- (2) an electrode array of spaced apart members supported between said source of supply and said donor in the developer path, and
- (3) potential means connected to said electrode array whereby to maintain said array at a potential sufficient to charge the powder in said mix, and

(c) drive means to advance said donor member from said loading means into and out of contact with the electrostatic image on the xerographic plate whereby the powder on said donor is selectively removed to the electrostatic image on the xerographic plate.

2. Apparatus according to claim 1 in which said donor member has an electrical resistivity at least less than about 10^{12} ohm-centimeters.

3. Apparatus according to claim 1 including: an electrode plate supported adjacent the donor on the side opposite said electrode array and substantially co-extensive therewith.

4. Apparatus according to claim 1 in which said continuous flow of developer mix from said discharge means is at the rate of about from 4 to 30 pounds per minute per inch of donor width.

5. Apparatus according to claim 1 in which said electrode array includes in combination:

- (a) a support frame secured about the path of the moving donor member, and
- (b) a plurality of spaced apart wire-like members supported by said frame spanning the donor path in interfering contact with the developer flow about the dis-

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charge position of said developer and extending therefrom in the direction of cascade.

6. Apparatus according to claim 5 in which said electrode members are comprised of:

a screen-like substantially planar grid, forming an open mesh of about 1/16 inch to 3/8 inch spaced generally uniformly anywhere from 0.060 inch to 0.150 inch from said donor.

7. Apparatus according to claim 5 in which said potential means bias said wires to a voltage of from about at least 1,000 volts.

8. Apparatus according to claim 7 in which said electrode members are arranged with an inter-member spacing of from about 1/16 inch to about 3/8 inch, spaced gener-

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ally uniformly from said donor, about 1/16 inch to about 5/32 inch.

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