

[54] XEROGRAPHIC DEVELOPING APPARATUS

3,703,157 11/1972 Maksymiak et al..... 118/637

[75] Inventor: **Lewis E. Walkup**, Honolulu, Hawaii

3,739,748	6/1972	Rittler et al.....	355/3 DD X
-----------	--------	--------------------	------------

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

3,759,222	9/1973	Maksymiak.....	118/637
-----------	--------	----------------	---------

3,850,662	11/1974	Jahn.....	118/637
-----------	---------	-----------	---------

[22] Filed: **May 24, 1974**

Primary Examiner—Ronald Feldbaum

[21] Appl. No.: 473,027

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 332,851, Feb. 15, 1973.

[52] U.S. Cl..... 118/637; 355/3 DD

[51] **Int. Cl.**..... G03g 13/06

[58] **Field of Search**..... 118/637; 117/17.5;
346/74 ES: 355/3 DD: 3 B

References Cited

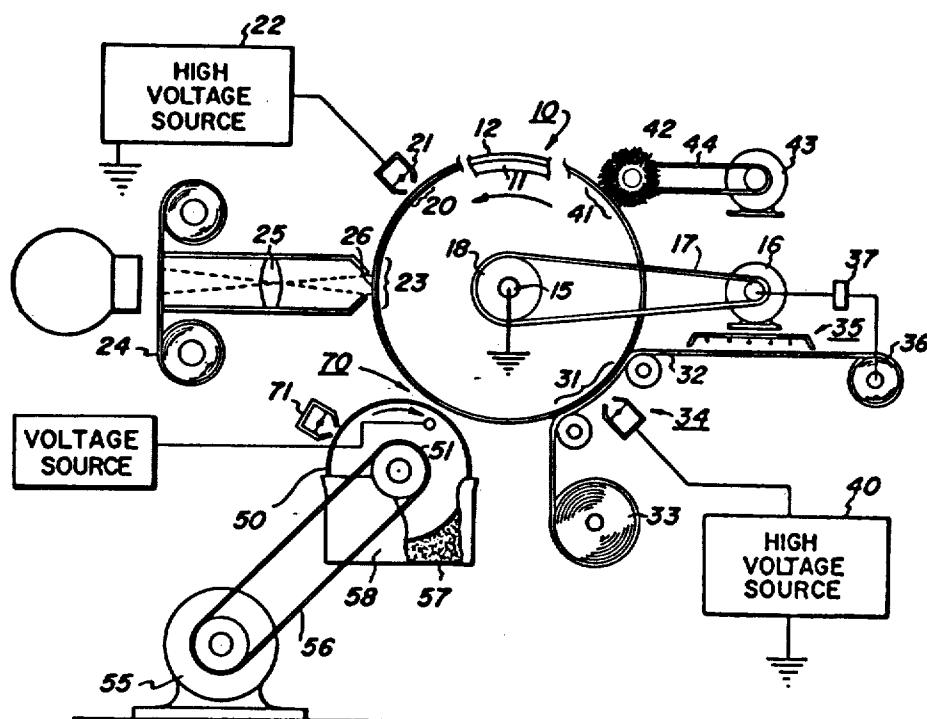
UNITED STATES PATENTS

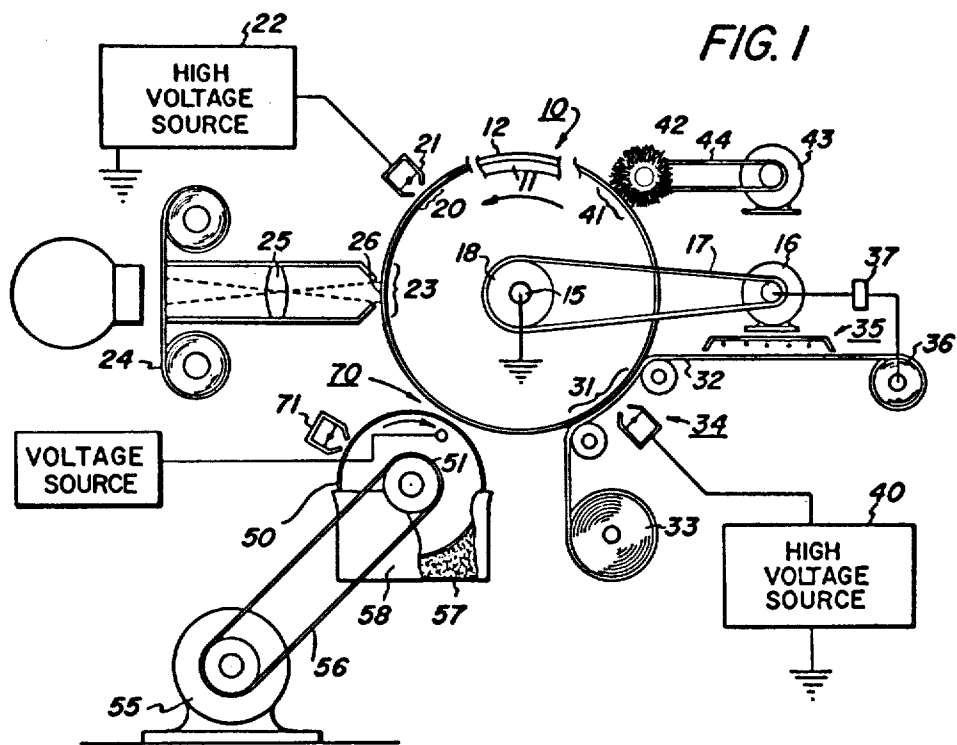
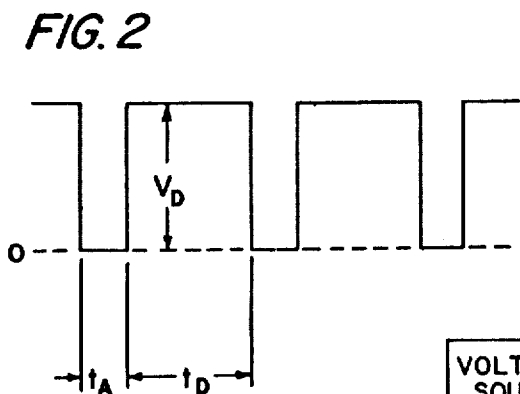
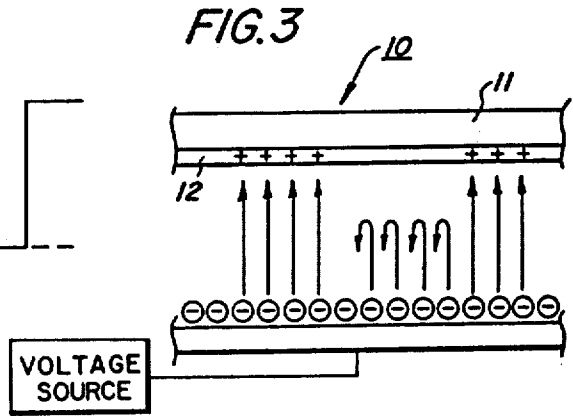
3,662,711	5/1972	Hudson.....	118/637
-----------	--------	-------------	---------

[57] **ABSTRACT**

An apparatus for developing a latent xerographic image is disclosed. The development device comprises a toner supporting donor member adjacent, and in spaced relationship to, an image retaining member. In addition, there is provided a means to introduce a pulsed electrical field across the gap between the donor and image retaining member whereby the electroscopic particles are made more readily available to the charged image thereby resulting in fine image development.

8 Claims, 3 Drawing Figures





XEROGRAPHIC DEVELOPING APPARATUS

This is a continuation-in-part of copending application Ser. No. 332,851 filed on Feb. 15, 1973.

BACKGROUND OF THE INVENTION

In the art of xerography as disclosed in U.S. Pat. No. 2,297,691 to Carlson, a xerographic plate comprising a layer of photoconducting and insulating material on a conducting backing is given a uniform electric charge over its entire surface and is then exposed to the subject matter to be reproduced usually by conventional projection techniques. This exposure results in discharge of the photoconductive plate whereby an electrostatic latent image is formed. Development of the latent charge pattern is effected with an electrostatically charged, finely divided material such as an electrosopic powder, that is brought into surface contact with the photoconductive layer and is held thereon electrostatically in a 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.

In any method employed for forming electrostatic images, they are usually made visible by a development step. Various developing systems are well known and include cascade, brush development, magnetic brush, powder cloud and liquid developments, to cite a few. In connection with these various developing systems, it is known that a conductive control electrode as, for example, disclosed in U.S. Pat. Nos. 2,808,023, 2,777,418, 2,573,881 and others, is highly effective in influencing electrostatic gradients to develop images having varying charge gradients and having relatively large solid image areas. At the same time, when developing images generally devoid of solid areas and consisting primarily of lined-copy images, superior results are generally obtainable without the electrode in place.

Another important development technique is disclosed in U.S. Pat. No. 2,895,847 issued to Mayo. This particular development process employs a support member such as a web, sheet or other member termed a "donor" which carries a releasable layer of electrosopic marking particles to be brought into close contact with an image bearing plate for deposit in conformity with the electrostatic image to be developed. In donor or transfer development of this type, the electrical properties of the donor are a factor for development in response to the area characteristics of the latent charge image. Specifically, electrically insulating donors respond best with line copy, while electrically conductive donors respond best with solid areas in a manner comparable to the control electrode. Accordingly, prior attempts to provide development flexibility on a practical basis for development of any kind of image, such as solid area versus line copy, have met with difficulty. This has resulted in limitations on the usual copying system and has necessitated selectivity with regard to particular materials to be reproduced.

As mentioned above, transfer development broadly involves bringing a layer of toner to an imaged photoconductor where toner particles will be transferred from the layer to the imaged areas. In one transfer development technique, the layer of toner particles is applied to a donor member which is capable of retaining

the particles on its surface and then the donor member is brought into close proximity to the surface of the photoconductor. In the closely spaced position, particles of toner in the toner layer on the donor member, are attracted to the photoconductor by the electrostatic charge on the photoconductor so that development takes place. In this technique the toner particles must traverse an air gap to reach the imaged regions of the photoconductor. In two other transfer techniques the toner-laden donor actually contacts the imaged photoreceptor and no air gap is involved. In one such technique, the toner-laden donor is rolled in non-slip relationship into and out of contact with the electrostatic latent image to develop the image in a single rapid step. In another such technique, the toner-laden donor is skidded across the xerographic surface. Skidding the toner by as much as the width of the thinnest line will double the amount of toner available for development of a line which is perpendicular to the skid direction and the amount of skidding can be increased to achieve greater density or greater area coverage.

It is to be noted, therefore, that the term "transfer development" is generic to development techniques where (1) the toner layer is out of contact with the imaged photoconductor and the toner particles must traverse an air gap to effect development, (2) the toner layer is brought into rolling contact with the imaged photoconductor to effect development, and (3) the toner layer is brought into contact with the imaged photoconductor and skidded across the imaged surface to effect development. Transfer development has also come to be known as "touchdown development."

In connection with transfer type development, it is known that by applying a controlled bias to a donor member characterized by appropriate electrical resistance while in contact with a plate being developed, that the donor functions to effect results similar to a control electrode described above. That is, by applying a bias potential to the rear surface of the donor member when presenting developer into contact with an electrostatic latent image, it becomes much more effective than an insulating or highly resistive unbiased donor for developing images having relatively large solid areas, as well as the various gradations of charge commonly associated with continuous tone images. At the same time, when developing images generally devoid of solid areas and gradations in tone and consisting primarily of line copy images, substantially greater image exposure latitude can still be obtained by developing with the donor in its inherently more resistive state without the benefit of the corona bias applied thereto.

A number of transfer type development systems were advanced in which background development was minimized. In U.S. Pat. No. 3,232,190 to Wilmott, a transfer type development system is disclosed in which the charged toner particles are typically stored on a donor member and development is accomplished by transferring the toner from the donor to the image regions on the photoconductive surface across a finite air gap caused by the spacial disposition of said donor and image surface. Activation of the toner particles, i.e., removal from the donor surface, and attraction onto the image regions (development) was primarily due to the influence of the electrostatic force field associated with the charged photoconductive plate surface. For this reason, the spacial positioning of the two coating

members (donors and photoconducting surface) in relation to each other was critical. Should the members be in too close proximity excessive background development occurs, while too great a distance results in inadequate development.

In the application of an electrical field to a transfer development system, a problem of background development arose. This was due to the fact that, while applying a bias across the development zone enhanced the deposition of the electroscopic particles onto the charge image pattern, the charged toner was also motivated onto the uncharged or background areas of the pattern, thereby resulting in a background development.

In U.S. Pat. No. 2,289,400 to Moncrieff-Yeates, there is disclosed an out of contact transfer development system in which a continuous and uniform force field is established within the transfer zone and assists the electrostatic force field associated with the charged imaging element during activation and development. The application of this type of electrical force field cannot, however, simply permit the toner particles to be transported over a wider gap. Because the force field is continuous and uniform, no additional control is afforded over the development process. Therefore, the electrostatic force field associated with the latent image still remains the predominant mechanism by which the toner particles are both activated and attracted to the imaged area of the photoconductive surface.

As can be ascertained from the above, the art of xerographic development, and in particular transfer development, would be significantly advanced if a pulsed bias could be used to improve both line and continuous tone quality in transfer development.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and still further features and advantages of the present invention will become apparent upon consideration of the following detailed disclosure, along with specific embodiments of the invention, especially when taken in conjunction with the accompanying drawings herein.

FIG. 1 is a cross-sectional view of a continuous automatic xerographic copying machine utilizing the developing technique of this invention.

FIG. 2 is a graphic illustration of the characteristics of the controlled pulsation technique utilized in the instant invention.

FIG. 3 is a cross-sectional view of a donor and photoconductive surface system utilized for developing a latent electrostatic image according to the method of this invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now specifically to FIG. 1, there is illustrated a continuous xerographic machine adapted to form an electrostatic reproduction of a copy onto a paper sheet, web or the like. The apparatus includes the xerographic plate 10 in the form of a cylindrical drum which comprises the photoconductive insulating peripheral surface 12 on a conductive substrate 11. The drum is mounted on an axle 15 for rotation, and driven by a motor 16 through belt 17 connected to pulley 18 secured to the shaft or axle 15.

Positioned adjacent the path of motion of the surface of the drum 10 is a charging element 21 comprising, for

example, a positive polarity corona discharge electrode consisting of fine wire suitable connected to a high-voltage source 22 or potentially high enough to cause a corona discharge from the electrode onto the surface of the drum 10. Subsequent to the charging station 20 in the direction of rotation of the drum, is an exposure station 23 generally comprising suitable means for imposing a radiation pattern reflected or projected from an original copy 24 or to the surface of the xerographic drum. To effect exposure, the exposure station is shown to include a projection lens 25 or other exposure mechanism as is conventional in the art, preferably operating with slit projection methods to focus the moving image at the exposure slit 26.

Subsequent to the exposure station is a developing station, generally designated 30, as will be further described below, for rendering the latent image visible. Beyond the developing station is a transfer station 31 adapted to transfer a developed image from the surface of the drum to a transfer web 32 that is advanced from supply roll 33 into contact with the surface of the xerographic drum at a point beneath a transfer electrode 34. After transfer, the web desirably continues through a fusing or fixing device 35 onto a take-up roll 36 being driven through a slip clutch arrangement 37 from motor 16. Desirably, electrode 34 has a corona discharge operably connected to a high-voltage source 40 whereby a powder image developed on the surface of the drum is transferred to the web surface. Fusing device 35 primarily fixes the transferred powder image onto the web to yield a xerographic print. After transfer, the xerographic drum 10 continues to rotate past a cleaning station 41 in which residual powder on the drum's surface is removed. This may include, for example, a rotating brush 42 driven by a motor 43 through a belt 44 whereby the brush bristles bear against the surface of the drum to remove residual developer therefrom. Optionally, further charging means, illumination means, or the like, may effect electrical or controlled operations.

Operative at the developing station 30 is a donor member 50 in the form of a cylindrical roll, as will be further described, which revolves about a center axis 51. Rotation of the donor is effected by means of an axle 51 being driven by a motor 55 operating through a belt 56, preferably to drive the cylinder in the same direction as the surface rotation of the drum. The speeds of the donor member and drum may be substantially the same or the donor member can travel at speeds as high as 5 to 10 times as fast as the peripheral speed of the drum to effect a greater development in imaged areas. Affixed to the donor member 50 is a high-voltage means for applying a potential between the cylindrical donor 50 and the photoconductive plate 12.

Between the donor member 50 and the drum 10 there is maintained a spacial gap 70 which, within the purview of the present invention, can be maintained up to 6 or 7 mils (1 mil equals 1/1000 of an inch). The actual development step within the purview of the instant invention is achieved maintaining a close gap between the rotating donor and photoreceptor using a properly pulsed electrical potential between the plate and the donor to establish the proper field relationships whereby optimum line and solid development is effected with a minimum of background deposition.

Adjacent one portion of the path of motion of the developer donor member 50 is a powder loading station which may, for example, comprise a developer hopper 57 containing a quantity of developer product 58 which may be a form of a two-component developer mixer as disclosed in U.S. Pat. No. 2,638,416. The hopper opens against the donor member whereby the cylinder passes in contact with the developer's supply and is coated uniformly with the toner powder component of the mixture as the donor passes through developer. Other loading mechanisms and developer compositions may, of course, be employed including dusting brush or the like, as is known in the art.

While the donor member of FIG. 1 has been described in the terms of a cylindrical element, it is to be understood that said donor may be in the form of web, belt, or roll, or any other structure capable of operating within the purview of the instant invention. One preferred donor element of the present invention is a microfield donor consisting of a milled aluminum cylinder over which a thin layer of insulated enamel is placed, in which enamel layer there is etched a thinner layer of an electrical conductor, such as copper, in the form of a grid pattern. The enamel layer generally has a thickness of about 2×10^{-3} inches, while the copper grid layer would be in the order of 5×10^{-4} inches in thickness. The typical grid pattern on a donor member of this type generally has from about 120 to 150 lines per inch with the ratio of insulator-to-grid surface areas being about 1.25 to 1.0.

In order that a donor member function in accordance with the instant invention, it must first be characterized by sufficient strength and durability to be employed for continuous recycling, and in addition should preferably comprise an electrical insulator or at least possess sufficient high electrical insulator or at least possess sufficient high electrical resistance of approximately 10^{12} ohm-cm or greater. This is not to be considered an absolute limitation, since the resistivity requirement will become less than about 10^{11} ohm-cm and below with reduced time period of exposure between the particular incremental area of the donor and the xerographic plate. For development speeds giving shorter contact times, materials of lower resistivity may be used. Materials found suitable for this purpose include Teflon, polyethylene terephthalate (Mylar), and polyethylene.

In carrying out a preferred method of development within the purview of the present invention, a microfield donor of the type described above is used as member 50 of FIG. 1. Generally, the four basic steps in carrying out a development process are loading of the donor with toner, corona charging the toner (see corona charging element 71 of FIG. 1), passing the toner to the electrostatic latent image on the photoconductive surface, and cleaning residual toner from the donor member so as to allow repetition of the process. In the actual practice of development of most machines, there are additional steps such as agglomerate toner removal and corona discharge of the donor member, which steps are auxiliary to the development process.

In loading a microfield donor of the type described above, a bias is applied to the grid which establishes strong electrical fringe fields between the copper grid and the grounded aluminum substrate. As the donor is rotated through a bed of vibrating toner containing both negative and positively charged toner, these fields collect toner on the donor in both grid and the enamel

insulator areas. In the next process step the entire layer of toner is then charged negatively using a negative corona (see 71 of FIG. 1). As the toner passes peripherally adjacent the spacially disposed photoconductive layer having the electrostatic image disposed thereon, an electrical pulse is applied to the donor 50 thereby creating an oscillating electrical field between the donor 10 so as to create a bias on the negatively charged toner particles. As the donor approaches the plate, the applied field between the donor and the plate induces the toner into the spaced gap. Upon the momentary cessation of the bias, those particles caught up in the field of the charged image areas of the plate will proceed to deposition, while those in the non-image areas will return to the donor.

Referring now to FIG. 2, a typical pulse cycle is demonstrated. Basically, the single pulse cycle is considered in two components, namely, a non-activating zero potential part which operates for a time T_a and a positive part described as development transfer, defined by a potential V_d which operated for a time T_d . The number of times per second a pulse cycle is repeated is defined as the repetition rate. The zero volt reference is used for the V_d voltage level. In reality, the pulse is not perfectly rectangular in shape; however, rise times are small enough so that they can be neglected. In utilizing the particular development system described above, the potential is usually applied to the donor thereby creating a field between the donor 50 and the photoconductive plate, the latter being considered the ground for the applied voltage. However, it is to be understood that under certain conditions a potential may be applied to the drum element 10 to effect a bias on the toner to accomplish the same development results. In other words, the drum could be the source and the donor the ground for the application of a field to effect removal of the toner and its deposition onto the imaged areas of the plate.

While not to be construed as limiting, a general description of possible mechanisms occurring at the development interface, i.e., the space gap between the donor and photoconductive surface, is shown in FIG. 3. As shown, the bias level during the inactive or zero potential, portion of the pulse is such that the negative toner particles experience only a field force engendered by the charged areas of the photoreceptor 10 and comprised of a substrate 11 and photoconductive layer 12. When the potential is applied to the toner particles experience a greater field force which is sufficient to loosen and motivate them from donor element 50 into the space gap. When the potential is reduced to zero by pulsing those loosened electroscopic particles in the field of the charge image continue towards deposition while those in the non-imaged areas are drawn back to the donor. The overall effect of the pulsing is enhanced development in image areas and nondevelopment in background areas. As can be ascertained from the description of the mechanism, the duration of the potential as well as the magnitude of the space gap have to be spacially considered in optimizing all the parameters of the development system.

Through experimentation on the present development system utilizing a space-gap donor system in combination with a pulse bias, parameters of spacing and voltage have been ascertained. It has been found that a bias applied to the plate may range up to a value of about +750 volts. Further, it has been found that opti-

mum pulse frequencies occur in the radio frequency range of **10 to 3,000 kilocycles/sec.** Utilizing these voltages and frequencies space gaps of up to **7 mils (1 mil equals 1/1000 of an inch)** may be attained.

The experimental work carried out in developing the instant invention utilized simple bench-type apparatus. A Xerox **813** size cylindrical donor containing a grid of **120 lines per inch** was loaded by rotating through a vibrating tray of toner and then charged negatively. The actual transfer development step was completed by rolling the donor over a halogen doped selenium plate. The donor-to-photoreceptive spacing was maintained by plastic shim stock placed on the edges of the plate. Nominal spacings of up to **178 microns** were used on all tests. Since the primary objective of the experimentation was to investigate development variables, the charging and loading functions were kept reasonably constant. Typical toner layers were **2 to 2½ mils thick** and were checked optically. The charge on the toner layer was monitored by reading the potential above the toner layer after charging. Then the measurements were made on semimicro densitometer systems and pulse variables were set and monitored on an oscilloscope at all phases of experimentation.

Since many changes could be made, the above invention and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intent that all matter contained in the drawings and specifications should be interpreted as illustrative and not, in any sense, limiting.

What is claimed is:

1. An apparatus for developing a latent electrostatic image recorded on an image retaining member comprising:

- a. a donor member for supporting a uniform layer of electroscopic developing material adjacent the image retaining member, said donor member and image retaining member being spacially disposed

as to create a space gap between both members; and

- b. means to introduce a pulse electrical bias across said gap, said pulse being of a strength and a duration sufficient to enable the deposition of the electroscopic material onto the charged image areas and prevent the development of non-image areas.

2. The apparatus of claim **1** wherein said pulse has a frequency of from about **10 to 3000 kilocycles/sec.**

3. The apparatus of claim **1** wherein the spacial gap between the donor and the photoreceptor measures up to **7 mils.**

4. The apparatus of claim **1** wherein the voltage range of the pulse bias is up to about **+750 volts.**

5. The apparatus of claim **1** wherein the donor member is in the form of a rotatable cylinder.

6. The apparatus of claim **5** wherein the cylindrical donor comprises an aluminum substrate and an enamel surface layer supporting an etched layer of copper in the form of a grid pattern.

7. The apparatus of claim **6** wherein the grid contains **120 to 150 lines per inch.**

8. An apparatus for developing a latent electrostatic image recorded on an image retaining member comprising:

- a. a cylindrical donor member being adapted to support a uniform layer of finely divided toner on the surface thereof, said donor being spacially positioned adjacent said image retaining member by means of a small space gap;
- b. means to apply bias potential across the space gap to effect removal of the toner particles from the donor and onto the charged areas of the photoconductive plate; and
- c. means to periodically pulse said bias potential to a zero potential whereby toner not in the field of the charged image areas returns to the donor member.

* * * * *