United States Patent

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[72] Inventor **Ernest A. Weiler**
Rochester, N.Y.

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[73] Assignee **Xerox Corporation**
Stamford, Conn.
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[54] **MULTIPLE BRUSH DEVELOPMENT**
4 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **117/17.5,** 118/637
[51] **Int. Cl.** **G03g 13/08,** G03g 15/08
[50] **Field of Search** 117/17.5; 118/637

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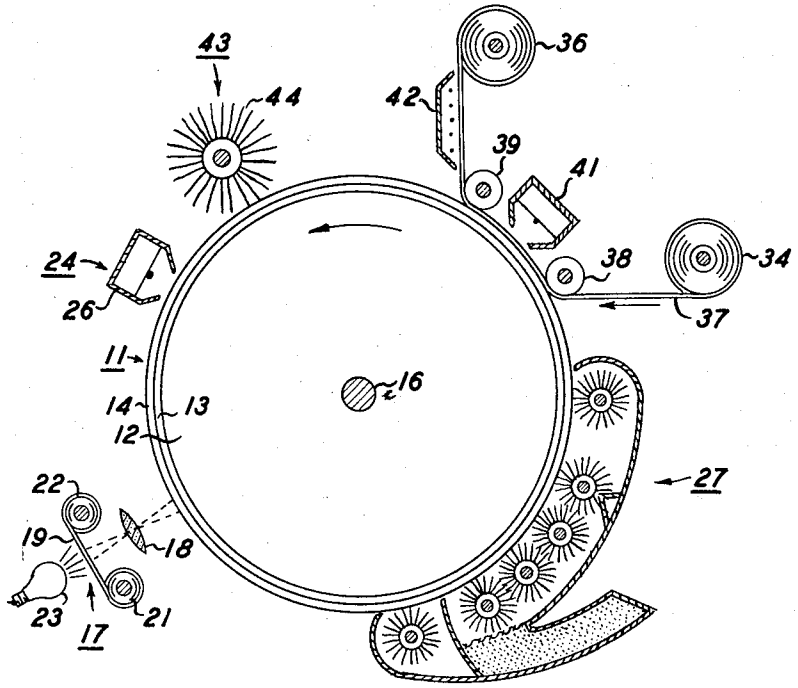
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Primary Examiner—William D. Martin
Assistant Examiner—M. Sofocleous
Attorneys—Stanley Z. Cole and Norman E. Schrader

ABSTRACT: Two or more brushes are placed adjacent to and in mesh with each other and a surface bearing a latent electrostatic image to form a high-speed development system. Adjacent development brushes in the system are rotated at different speeds relative to one another to create a swirling motion during development. The primary brush in the system is the brush which initially contacts the latent image as it passes the development area and is, preferably, the only brush in the system which is loaded with toner by external means, the other brushes in the system receiving toner as a result of their meshing one with another.



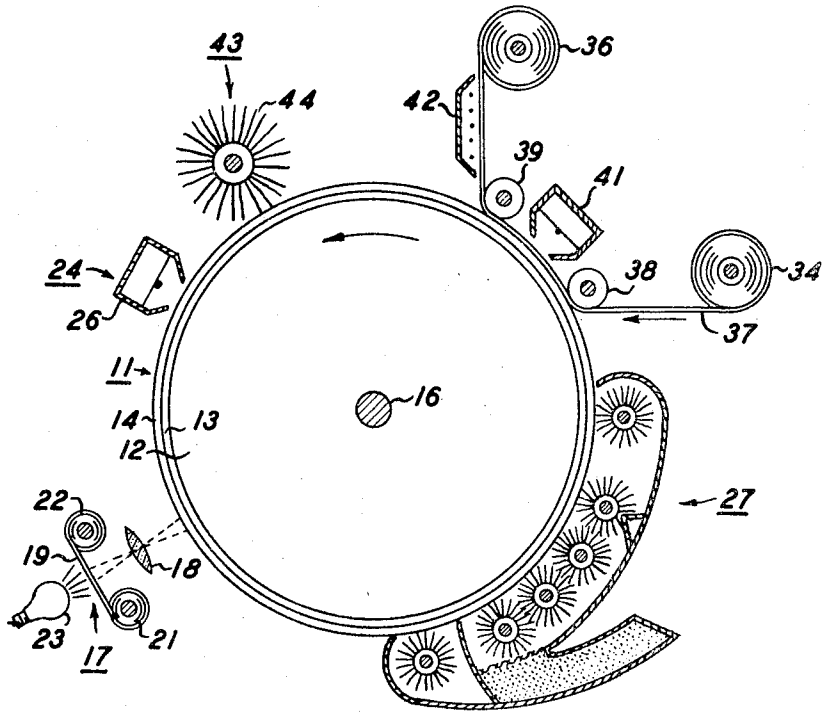


FIG. 1

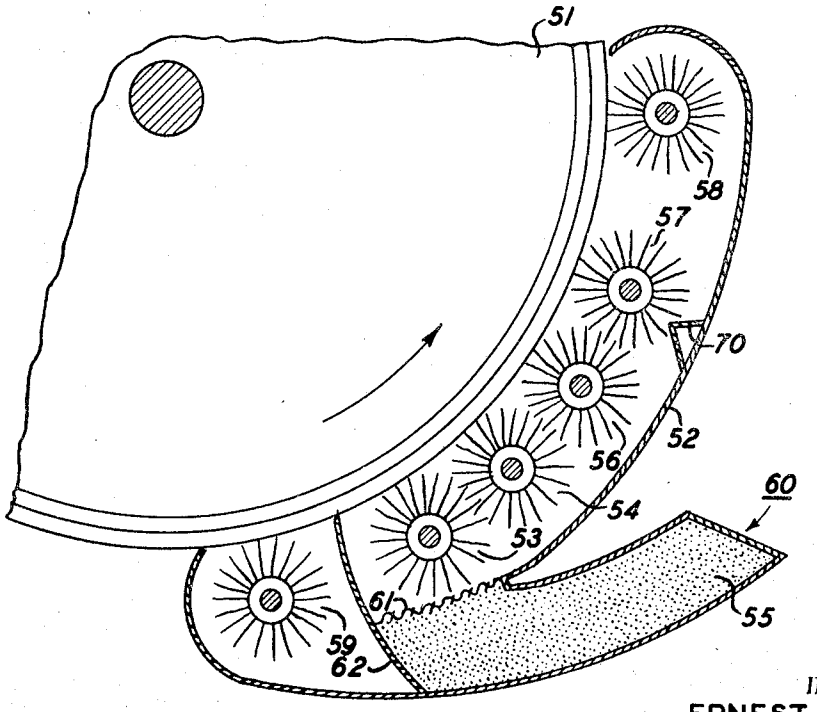


FIG. 2

INVENTOR.
ERNEST A. WEILER
BY
ATTORNEYS

MULTIPLE BRUSH DEVELOPMENT

This application is a continuation of my application, Ser. No. 659,518, filed Aug. 9, 1967, and now abandoned.

In many copying techniques, such as xerography, a latent image is first formed on a recording surface and then developed with a marking material. In the case of xerography the marking material normally used in a finely divided colored material called toner. When developing a latent image with toner a well-known technique is to pass a brush loaded with charged toner particles across the surface bearing the latent image. The charged toner particles, bearing a charge which has a different potential compared to the portions of the latent image where the toner is deposited, are removed from the brush and adhere to the recording member in imagewise configuration. The brush used may be any suitable type which can be loaded with toner particles such as a magnetic brush, fur brush, a brush made with cloth such as velvet having a fibrous surface or other similar material bearing a multiplicity of elongated carrier members on a surface.

In order to assure good quality in this development process it is desirable to maintain a large contact area between the brush carrying the toner particles and the surface being developed, and this is especially desirable when developing an image which requires large solid area coverage. Numerous devices have been conceived to assure such quality in the xerographic process. For instance, instead of using a cylindrical brush for development, belts have been used to carry toner particles to the latent image. Such belts normally are used with a drum-shaped photosensitive surface and consist of a backing member having numerous bristles or fibers which carry toner particles to the surface being developed. The belt is supported and driven by a series of rollers, or the like, while a portion of its outer periphery maintains contact with the latent image. When the belt has tangential contact with the drum surface the resulting image quality is sufficient for relatively slow development speeds only, and as the development speed is increased, quality becomes inferior.

To increase contact area between the belt and surface bearing the latent image in high-speed systems, the belt has been wrapped around the drum so that it maintains more than tangential contact with the drum surface. However, when this is done other serious problems arise which tend to minimize the benefit of increased contact between belt and drum. One disadvantage is that it is difficult to have the belt assume the precise arc necessary in order to maintain even contact with the drum. In addition, it is a difficult task to have every portion of the belt which is adjacent the drum maintain the same degree of contact pressure on the drum which is essential to good development.

When a cylinder-shaped brush is used to develop latent images, the quality of solid area coverage is dependent upon the contact area between the brush and the surface, and their relative speeds. As the speed of the surface bearing the latent image increases, solid area coverage can be maintained by increasing the diameter of the brush so that there is a greater portion of the periphery of the brush in contact with the surface. If cylindrical brushes of a large diameter were used to assure adequate contact for high-speed drums, the development system would not be feasible because of space considerations and severe vibration and balance problems.

Another alternative in brush design when the speed of development is increased is to use a brush of relatively small diameter which rotates at a very high velocity. However, it is generally undesirable to rotate the brush at very high speeds since the brush would be difficult to load with toner particles and such high speeds would generate an excessive toner powder cloud.

It has been found that by using a multitude of brushes placed adjacent one another and rotating them at different speeds in high-speed development the increased contact area between the brushes and the latent images results in improved image quality. Accordingly, it is an object of this invention to improve apparatus for developing latent electrostatic charge patterns.

It is a further object to improve the apparatus for developing latent electrostatic images to assure good solid area coverage.

A still further object is to improve the apparatus for developing latent electrostatic images to render high-quality images in a high-speed development system.

The development apparatus in this invention requires the use of two or more brushes placed adjacent each other in contact with the surface being developed. Adjacent brushes in the system rotate at different rates of speed thereby approximating a swirling action during development. In one embodiment of the invention a series of rotating brushes are placed around a drum-shaped, photosensitive surface adjacent to and in mesh with each other. The primary brush in the group is the one located nearest the lowest point on the photosensitive surface while the remainder of the brushes in the group are stacked above the primary brush in the direction that the photosensitive surface travels during development. Since the fibers of each brush mesh with those adjacent to it, toner particles are passed from the primary brush to the next brush in the group and so forth so that all brushes become loaded with toner as they rotate. In addition, the meshing of the brushes creates a small powder cloud which enhances development of solid areas. As the photosensitive surface travels past the group of brushes, it has the opportunity to pick up toner from all the brushes. The number of brushes used in any particular system is a function of the speed that the photosensitive surface travels, more brushes being desirable as the speed of the photosensitive surface increases.

For a better understanding of the invention as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be used in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic illustration showing a typical xerographic device in which the present development apparatus is used.

FIG. 2 is a schematic view of the development apparatus showing the arrangement of the brushes relative to each other, the photosensitive surface, and the toner hopper.

Referring now to the drawings, FIG. 1 shows a typical xerographic machine in which the present development apparatus can be used. The principle element of the machine is photosensitive member 11. This member consists of drum 12 which is driven about shaft 16 by a motor (not shown). The drum is covered with layer 13 of electrically conductive material which, in turn, is covered on its outer surface with layer 14, a photoconductive insulating material such as vitreous selenium. An electrostatic latent image is formed on member 11 by passing it adjacent sensitizing station 24 and exposing station 17. The sensitizing station consists of any suitable means for placing a uniform charge on layer 14 such as corona charging device 26. The exposing station comprises light source 23 and lens 18, and transparency 19 feedably disposed between the light source and lens. The transparency is fed from reel 21 through the beam of light generated by source 23 and then rewound on reel 22 after being exposed. The light source, transparency and lens working in combination project on the photosensitive member an optical image whose movement is synchronized with that of the drum. The projected optical image causes selective charge dissipation on illuminated areas of layer 14, thus forming a latent electrostatic image. Other means of forming electrostatic latent images including means for forming images on ordinary insulating surfaces are known in the art and may be used instead of the ones shown.

After the sensitizing and exposing steps are completed, the photosensitive member passes by development station 27 which will be described more fully in conjunction with FIG. 2. Following image development, the image is transferred from photosensitive member 11 to web 37, or the like. Guide rolls 38 and 39 act to position web 37 against photosensitive member 11 while transfer is accomplished by a second corona device 41. Web 37 is fed from reel 34 before transfer and is

rewound on reel 36 after transfer and fusing. Fusing element 42 is positioned to heat the transferred image and thus fix it and permanently bond it to paper web 37. Cleaning station 43 is made up of rotating cylindrical brush 44 which contacts any residue image material from layer 14 thus readying it for reuse. The above-described process and apparatus are conventional in the art as evidenced in U.S. Pat. No. 3,117,891. Any of the many known equivalents of process or apparatus elements may be employed in connection with the present invention.

Referring now to FIG. 2, a latent electrostatic charge pattern placed on photosensitive member 51 by a technique such as that described above is developed by two or more brushes disposed side by side adjacent the path of the surface bearing the latent image. The present invention requires at least two brushes; that is, a primary brush and at least one secondary brush; however, generally speaking, as the speed of development is increased, additional secondary brushes are desirable to assure the best possible image quality. For the purpose of the embodiment shown in FIG. 2, four brushes 53, 54, 56 and 57 are used and are all contained within housing 52. These brushes can be made of any suitable material which has the ability to carry toner particles to the surface bearing the latent image; for instance, magnetic brushes or brushes made of rabbit fur. The fur brushes as shown in FIG. 2 can be grounded, or, in the alternative, biased with a polarity opposite the polarity existing on the toner particles.

Each of the brushes can be loaded individually within the development system, but it is preferable to load only one brush and have the toner particles passed along to the other brushes due to the meshing action between the brushes. If magnetic brushes were used, each brush would be loaded individually to assure toner reaches all the brushes. Brush 53 is the primary brush in the system, it being called "primary" because it is the only brush which is loaded with toner particles by external means.

Housing 52 has a loading hopper, generally designated as 60, which places toner particles 55 in the vicinity of the lowest development brush; i.e., primary brush 53. The toner can be fed to the brush in any suitable manner such as merely having the brush pass through the hopper of toner. In the alternative, the toner particles contained in the hopper can be separated from fur brush 53 by mesh material 61. This mesh material should have apertures which are large enough to permit the individual toner particles to pass through readily and can be made of any suitable material such as nonconductive brass or the like. If the screen is made of a material such as brass, after the toner is placed on the fibers of brush 53, but before they are deposited on the latent electrostatic charge pattern, the particles should be exposed to a charging means so that they possess a uniform charge. One simple apparatus to create such a charge is a triboelectric generator placed in the path of the fibers which rubs against the toner particles before they contact the surface being developed.

Another system utilized to place a uniform charge on the toner particles is shown in FIG. 2. Mesh material 61 is made of a material which is triboelectrically related to toner particle material so that as the fibers on fur brush 53 rub against the mesh material, the individual particles of toner are brought through and rub against the mesh material and receive a charge triboelectrically.

The position of the primary brush relative to the direction of travel of the surface being developed is of importance in the present invention. The primary brush; i.e., brush 53, is the brush which initially contacts the surface being developed, and, consequently, the brush which deposits the bulk of the toner on the latent image. When a rotary drum is being developed, as in FIG. 2, the primary brush is the lowest brush in the system. The significance of developing in such an "uphill" fashion will be explained hereafter.

In FIG. 2, the drum is shown as rotating in the counterclockwise direction and since the primary brush is the first brush to develop, it must be the lowest brush in the system. Similarly, if a flatplate were the surface bearing the latent image, the plate should be developed while traveling on an incline to the horizontal and the primary brush would again be the lowest brush.

Toner particles that brush 53 picks up from screen 61 are brought around to the photosensitive surface where they develop the latent image. Brushes 53, 54, 56 and 57 are placed closely adjacent each other so that as they turn their fibers mesh. By this action, a portion of the toner which is picked off the screen by brush 53 and which is not deposited on surface 51 is transferred to brush 54. Likewise, a portion of the toner which is held by the fibers of brush 54 and is not deposited on the photosensitive surface by brush 54 is transferred onto brush 56. Similar transfer of toner particles occurs between brush 56 and 57 and any other brushes in the group. In this manner all the development brushes are loaded with toner particles and participate in the development process.

The reason for developing in an "uphill" fashion, as mentioned above, is to keep the toner particles circulating throughout the hopper during the development process. Flicker bar 70 removes any toner particles from brush 57 after the fibers have come into contact with the surface being developed. Therefore, brush 57 is not allowed to become saturated with toner and acts as a semidevelopment, semicleaning brush which deposits toner particles where they are needed and cleans background areas where toner particles are not desired. After removing the excess toner particles from brush 57 by a flicker bar at the position shown in FIG. 2, the toner particles roll down the housing and onto the primary brush thereby circulating the unused toner particles and keeping most of the toner on the primary development brush. The use of the flicker bar is optional.

The use of more than one brush to develop the latent image serves a twofold purpose in the present invention. The first purpose is to permit adequate toner deposit when the surface bearing the latent electrostatic charge pattern is rotating at high speeds. Good development results because of the increased contact area between the brushes and the photosensitive surface due to the increased number of brushes. In addition to the increased contact area, the meshing of fibers on adjacent brushes generates a small powder cloud in the development area which increases the efficiency of development of solid areas in the image. Further, the meshing of fibers on adjacent brushes prevents the fibers from becoming matted and, hence, they remain efficient carriers. The second purpose for using multiple development brushes is to approximate the most efficient method of development; that is, developing the latent electrostatic charge pattern by imparting a swirling motion while depositing toner particles on the latent image. The use of a multitude of fur brushes as shown in FIG. 2 approximates this motion. This motion is accomplished by two features in the movement of fur brushes. The first feature is that each brush in the group is oscillated coincident with its axis of rotation as it is rotated. In other words, each brush is oscillated side to side, or towards and away from the observer of FIG. 2. It is preferred that each brush be oscillated in a different direction compared to brushes adjacent it at any given instant for two reasons. First, such alternating motion increases the meshing and twisting of the individual toner-laden fibers which increases the swirling action. Secondly, it is easier to dynamically balance the development system in this fashion.

The second feature in the movement of the brushes is that all the development brushes in the system are not rotated at the same speed. In practice, brushes 53, 54, 56 and 57 shown in FIG. 2 may be rotated at totally different speeds from one another. However, due to pragmatic considerations, the brushes are rotated at set speeds in order to achieve optimum results in a high-speed system. The first consideration in a system using rabbit fur brushes and conventional toner; i.e., a pigment such as carbon black dispersed in thermoplastic, is the speed of the photosensitive surface being developed. For the purposes of this disclosure it will be assumed that the latent image is produced in a high-speed xerographic machine

on a drum whose surface speed is approximately 40 inches/second.

Optimum quality during the development with a fur brush ordinarily occurs when the peripheral speed of the fur brush approximates the peripheral speed of the surface being developed, the brush rotating about its axis in the opposite direction as the photosensitive member. Also, when many brushes are used in a development system, simpler and less costly brush drive systems are possible when the various speeds of the brushes are kept to a minimum number.

Taking these two considerations into account in the apparatus shown in FIG. **2**, the preferred speed of brushes **53** and **56** is 42–46 inches per second in the clockwise direction while brushes **54** and **57** rotate 34–38 inches per second in the clockwise direction. These speeds are preferred since experiments indicate that a variance of from 4–12 inches per second between adjacent brushes result in superior images. Therefore, primary brush **53** and brush **56** have a peripheral speed slightly faster than the peripheral speed of surface **51** and tend to brush the surface whereas brushes **54** and **56** have a speed slightly slower than the surface being developed and tend to drag on the surface.

It should be reiterated at this point that the above brush speeds and directions of rotation are merely sample speeds and are not critical to the operation of the invention. For instance, brushes **54** and **57** could be rotated in the counterclockwise direction while brushes **53** and **56** rotate in the clockwise direction and the system would still be operative. The major consideration in the invention is that adjacent brushes mesh with each other and rotate at different speeds relative to each other.

Cleaning brush **58** bears against photosensitive surface **51** at a point removed from development brushes **53**, **54**, **56** and **57**. This cleaning brush does not mesh with any of the other brushes in the system and interferes with the photosensitive surface only after it has passed through the development area. The purpose of this brush is to remove background toner from the developed image. Brush **59** acts as a sealing brush catching any toner that leaks from the development area in the direction opposite the direction of rotation of the photosensitive surface and is most desirable in high speed systems. Toner particles caught by this brush are placed on the photosensitive surface in imagewise configuration by brush **59**. Both cleaning brush **58** and sealing brush **59** are optional in the apparatus shown.

In addition to the method outlined above many other modifications and/or additions to this invention will be readily apparent to those skilled in the art upon reading this disclosure, and these are intended to be encompassed within the scope of the invention.

What is claimed is:

1. In a development apparatus for applying electrically charged toner particles to a moving surface bearing a latent electrostatic image comprising a primary rotatable brush adapted to initially contact the image and at least one secondary rotatable brush wherein the brushes contact the surface for applying toner particles thereon, and wherein the bristles of the secondary brush are in interference with the bristles of the primary brush, means for imparting rotative peripheral movement to the primary brush and means for loading the outer periphery of the primary brush with toner particles, the improvement comprising,

means for imparting rotative peripheral movement to the secondary brush and at a speed different than the speed of the rotative movement of the first brush.

2. In a development apparatus for applying electrically charged toner particles to a moving surface bearing a latent electrostatic image comprising a primary rotatable brush adapted to initially contact the image and at least one secondary rotatable brush wherein the brushes contact the surface for applying toner particles thereon, and wherein the bristles of the secondary brush are in interference with the bristles of the primary brush, means for imparting rotative peripheral movement to the primary brush and means for loading the outer periphery of the primary brush with toner particles, the improvement comprising,

means for imparting rotative peripheral movement to the secondary brush and at a speed different than the speed of the rotative movement of the first brush, said rotative movement of the secondary brush being in a direction opposite that of the rotative movement of the primary brush.

3. The apparatus of claim 1 wherein the speed of said rotative movement of the primary brush is greater than the speed of movement of the surface and the speed of rotative movement of the secondary brush is less than the speed of movement of the surface.

4. In a method of developing a surface bearing a latent electrostatic charge pattern with charged toner particles which comprises the steps of contacting at least two brushes having their bristles in interferring relationship, one being a primary brush arranged to initially contact the pattern and the other being a secondary brush, loading the primary brush with toner particles, moving the surface relative to and in interference with the brushes whereby the first brush to contact the pattern is the primary brush, simultaneously oscillating the brushes in a plane parallel to the plane of the surface and perpendicular to the movement of the surface, the improvement comprising:

imparting rotative peripheral movement to each of said brushes and at speeds wherein the rotative movement of said primary brush is different than the speed of rotative movement for the secondary brush.

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