March 31, 1970 R. W. GUNDLACH 3,503,776

XEROGRAPHIC DEVELOPMENT

Filed Feb. 21, 1966

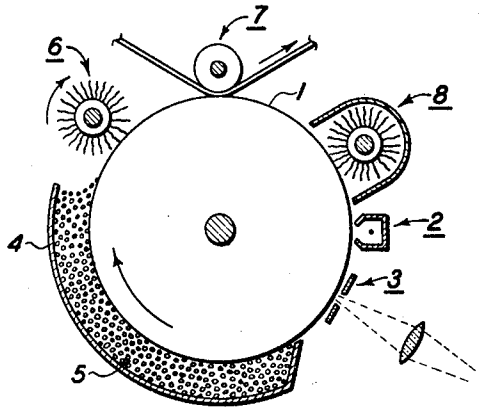


FIG. 1

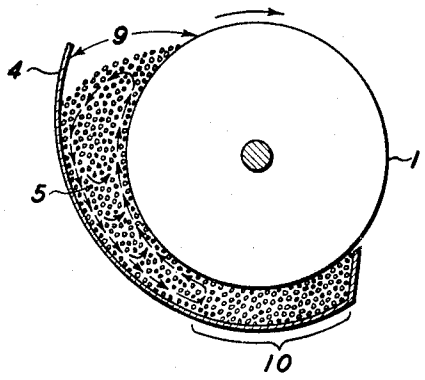


FIG. 2a

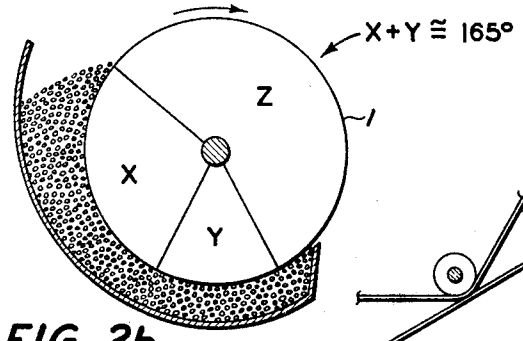


FIG. 2b

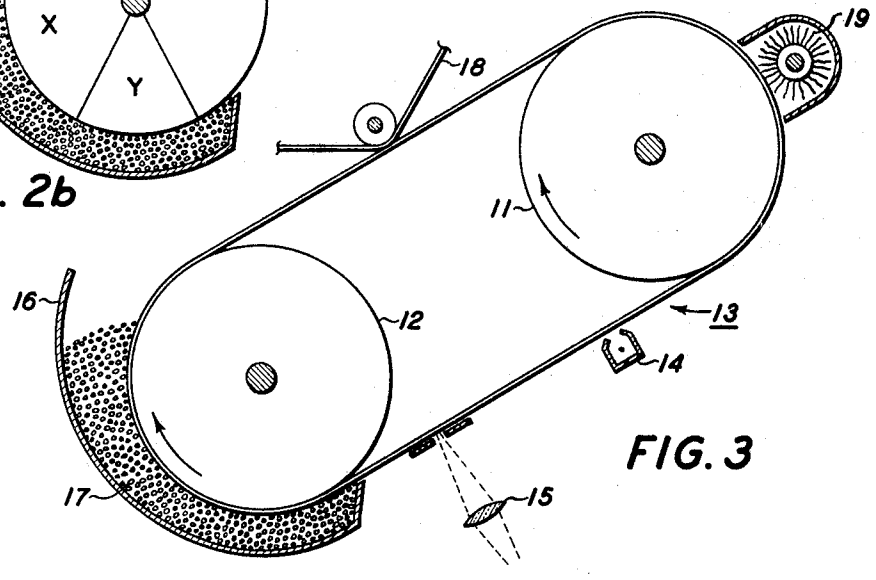


FIG. 3

INVENTOR.
ROBERT W. GUNDLACH

BY James J. Calabrese
Stanley Z. Cole

ATTORNEYS

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XEROGRAPHIC DEVELOPMENT

Robert W. Gundlach, Victor, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York

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ABSTRACT OF THE DISCLOSURE

Images are formed by transporting an electrostatic latent image bearing surface in a generally ascending arcuate path, and contacting only the imaging surface in a contact zone with a bath of developer material supported in a concave chamber adjacent the lower face of the imaging surface as the imaging surface is transported in the arcuate path, the contact zone extending from about the lowermost point of the arcuate path and terminating below the uppermost point of the arcuate path whereby frictional contact between the developer and the imaging surface along the contact zone circulates the developer in the bath.

This invention relates in general to xerography, and more specifically to a system of developing xerographic images.

In the art of xerography, as originally disclosed by Carlson in U.S. Patent 2,297,691, and as further described by many related patents in the field, the xerographic plate containing a photoconductive insulating layer is first given a uniform electrostatic charge in order to sensitize its entire surface. The plate is then exposed to an image of activating electromagnetic radiation such as light, X-ray or the like which selectively dissipates the charge in the illuminated areas of the photoconductive insulator while leaving behind a latent electrostatic image in the non-illuminated areas. This latent electrostatic image is then developed and made visible by depositing finely divided electroscopic marking particles on the surface of the photoconductive insulating layer. Where non-reusable photoconductive insulating material is used, the marking material or toner particles are directly fixed in place on the surface by any convenient means such as by heat fusing. Where a reusable photoconductive insulating material is used, the visible image formed by the electroscopic marking particles is transferred to a second surface, such as a sheet of paper, and fixed in place thereon to form a permanent visible reproduction of the original image.

The most widely used method of development today is cascade development. In cascade development, a finely divided pigmented electroscopic powder or toner, and a larger carrier material which acts as a vehicle for the electroscopic powder is used to develop the latent electrostatic image. The carrier material is larger in size than the electroscopic powder with said carrier being triboelectrically charged with a polarity opposite that of the electroscopic powder. The electroscopic powder is attracted to and surrounds the larger particles of carrier material and when cascaded over a xerographic plate, drum, or the like, the charge in the image area of the plate which is controlled to have a greater attraction for the electroscopic powder particles than the carrier material, attracts the electroscopic powder to said image area to form an image of toner particles. This image may be permanently fixed in place or transferred to another suitable support means such as a paper sheet. U.S. Patents to Walkup et al., 2,573,881; Eichler, 2,965,868; Walkup 2,987,660; and Carlson, 2,990278; all illustrate the well-known cascade method of development. In all of the conventional cascade systems disclosed by the above patents, it is essential that a developer bucket arrangement for carrier and toner mixing and circulation be included in the developing system. The need for a bucket conveyor adds greatly to the size and cost of a xerographic system. It is also well-known that during the cascade method of development the carrier beads and unused toner particles which drop by gravity to the bottom of the developer chamber, generate a cloud of toner particles which result in an undesirable high background deposition in non-image areas. In addition, conventional cascade systems cause high drum and carrier abrasion due to an inherent sand blast effect as the carrier and toner particles cascade against the moving drum or plate. An additional requirement in present cascade development systems concerns the need for thorough mixing of toner and carrier particles.

There is, therefore, a need for a developing system which avoids the undesirability of high background, provides for thorough toner and carrier mixing, which extends drum and carrier life, and eliminates the need for developer handling buckets.

It is, therefore, an object of this invention to provide an improved system of developing xerographic images which overcomes the above noted disadvantages.

It is another object of this invention to provide a system of xerographic development which reduces the abrasion effect presently a problem in cascade development.

It is a further object of this invention to provide a xerographic developing system which yields cleaner back ground over conventional cascade developing techniques.

It is yet a further object of this invention to provide for a developing system having greater simplicity than conventional developing techniques.

The foregoing objects and others are accomplished in accordance with this invention by providing a method of xerographic development wherein the xerographic drum, plate, or the like is merely turned or passed against a bath of developer. In this invention, as hereinafter illustrated by a xerographic drum, the drum after charging and exposing to form an electrostatic image, is pulled through a bath of developer consisting of any conventional carrier beads and toner particles.

Electroscopic toner and carrier compositions are well-known to those skilled in the art. Among the patents describing such compositions are U.S. Patents 2,618,551 to Walkup, 2,618,552 to Wise, 2,638,415 to Walkup and Wise, 2,659,670 to Copley, and 2,788,288 to Rheinfrank and Jones. Toners generally have an average particle diameter between 1 and 30 microns while the carrier beads are larger and may range from about 250 to 700 microns in diameter. The carrier and developer particles may for example, be contained, in a C-shaped developing chamber and developing carried out merely by pulling or rotating the xerographic drum, while in direct contact with the developer, through the developer chamber. It has been

discovered that the developer bath becomes self-circulating as the xerographic drum is rotated in contact with the developer particles. It should be noted that no external agitation means such as mechanical or fluidizing means are necessary for circulation or mixing of the developer.

While the developer chamber is generally parallel to the moving xerographic drum, and therefore roughly C shaped, it should be understood that the outer shell of the developer chamber may be of any suitable shape which allows for the conditions necessary for development as set forth in the specification. A typical shape includes an L shaped developer chamber formed by a vertical side section and a horizontal bottom or base. Similarly, even when in the C shape, the developer chamber may be modified, such as by making the top or upstream end of the chamber wider than the bottom or downstream end to allow for a more efficient circulation of the developer bath.

In general, the carrier beads may be of any suitable size. Typical ranges are from 250 to 700 microns in diameter. Similarly, any suitable toner concentration may be employed, with concentrations ranging approximately from ½ to 2 percent by weight being suitable. The toner particles may be replenished by adding toner to the top of the developer chamber with the self-circulating developer bath automatically mixing the added toner.

The advantages of this improved xerographic development method will become apparent upon consideration of the following disclosure of the invention; especially when taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a schematic sectional view of one form of apparatus for carrying out the novel method set forth in the specification.

FIG. 2*a* is an enlarged schematic view of the developer chamber of FIG. 1.

FIG. 2*b* is a schematic view of the xerographic drum illustrating the areas of the drum surface which relate to the developer chamber of FIG. 1.

FIG. 3 is a schematic view of a second form of apparatus for carrying out the method set forth in the specification.

Referring to FIG. 1, reference character **1** designates a rotatable xerographic drum having an outer layer of photoconductive insulating material such as as vitreous selenium. The surface of the drum is uniformly charged by conventional corona charging device **2**, and exposed to a pattern of activating electromagnetic radiation at **3**. The latent electrostatic image formed by **3** is developed by rotating drum **1** through a self-circulating developer chamber **4** containing a cascade developer **5** consisting of substantially spherical carrier beads and a suitable marking toner. As the drum **1** rotates in direct contact with the developer bath, the carrier beads and attached toner particles flow in chamber **4** in a counterclockwise motion thus rendering the developing chamber self-circulating. Upon leaving the developer chamber, the latent electrostatic image is coated with toner particles. Fur brush **6** may be employed to dislodge unwanted carrier beads at the fringes of the image areas without adversely effecting the developed image. This is unnecessary for beads greater than about 500 microns diameter and density of 5 or more. The developed image is transferred at transfer station **7** to a moving paper web. The transferred image may be permanently fixed to the paper by any convenient means such as heat fusing. The drum is then cleaned of any excess toner particles at cleaning station **8** at which time it has completed the entire developing and image transfer cycle.

FIG. 2*a* is an enlarged view of the self-circulating developer chamber wherein the rotation of xerographic drum **1** of FIG. 1 through chamber **4**, containing developer **5**, causes a counterclockwise self-circulation of the developer bath due to a combination of the chamber shape, and the friction between the rotating xerographic drum and the carrier particles. The small arrows in the developer bath indicate the direction of flow of the developer material. It can be seen that when additional toner is added to the developer bath, uniform mixing of the toner and carrier particles is easily attained due to the self-circulating action of the developer bath.

As further illustrated in FIG. 2*a*, the developer chamber need not be uniformly spaced from the xerographic drum, but in fact optimum results are attained when the distance between the outside of the developer chamber and the drum is wider near the top where circulation of the developer bath is greatest. This is illustrated by distance **9** in FIG. 2. The arc of the drum covered by the developer bath of the developer chamber need only be about 165° of the total drum surface in order to operate satisfactorily. A segment of the chamber beginning substantially vertically below the drum does not appear to undergo any developer flow and acts merely as a seal during the developing step. This is illustrated by area **10** in FIG. 2*a* which functions more or less as a seal in that no substantial developer flow or circulation is observed in this area. It can be seen from FIG. 2*b* that only about 165° or less of the surface of the drum need be encompassed by the developer bath.

In FIG. 2*b* reference character **1** designates the xerographic drum used in FIG. 1. Section X of the drum illustrates the area of the drum, when rotating in a clockwise manner, which would be included within the developing area of the developer chamber of this invention. Area Y illustrates the area of little or no developer circulation which may optionally be included within the developer chamber area. Area Z illustrates the area of the drum surface not in contact with the developer bath.

In FIG. 3, another embodiment of the invention is shown wherein two drums employing a flexible xerographic belt are used allowing full frame exposure. In this embodiment rotating drums **11** and **12** carrying a flexible xerographic belt **13** is charged to a uniform potential by corona charging device **14**. The belt is then exposed to activating electromagnetic radiation at **15** and developed in self-circulating developer chamber **16** containing developer **17**.

The toner image on the belt **13** is transferred to a transfer web **18** and the image subsequently made permanent by heat fusing. The belt is then cleaned at brush **19** after the developing and image transfer cycle is completed.

The concept of this invention may be adapted to any type of carrier, toner, or photoconductive material. Carrier ranges in a size of from about 250 to 700 microns have been tested and found satisfactory. The carrier beads may be of any convenient material such as glass or metal, coated with plastic. Similarly, any conventional toner described above may be used in amounts ranging from about ½ to 2 percent. In addition, this process is adaptable to any photoconductive surface such as vitreous selenium, organic or inorganic photoconductors imbedded in a non-photoconductive matrix, or organic or inorganic photoconductors imbedded in a non-photoconductive matrix, etc. Such photoconductors are illustrated in U.S. Patents to Ullrich, 2,803,542; Bixby, 2,970,906; Middleton et al., 3,121,006 and 3,121,007; and Corrsin, 3,151,982.

The following examples further specifically define the present invention with respect to a method of developing xerographic images in a self-circulating developer chamber. The parts and percentages in the disclosure, examples, and claims are by weight unless otherwise indicated. The examples below are intended to illustrate the various preferred embodiments of carrying out a developing method in a self-circulating developer chamber.

EXAMPLE I

A xerographic drum coated with a 50 micron layer of vitreous selenium is corona charged to a voltage of

about 400 volts and exposed to activating electromagnetic radiation to form a latent electrostatic image on its surface. The selenium drum is then rotated through a self-circulating developer chamber such as that illustrated in FIG. 1 containing 250 micron plastic coated glass beads and 1.2 percent of a pigmented polystyrene-butyl methacrylate blend developing toner. The drum is rotated at a speed of approximately 10 inches per second. After one rotation through the developer chamber the image on the drum is transferred to a sheet of paper and fixed by heat fusing. An excellent image is obtained by this process.

EXAMPLE II

A xerographic drum coated with a 50 micron layer of vitreous selenium is charged to a voltage of approximately 500 volts and then exposed to light to form a latent electrostatic image. The drum is then rotated through a self-circulating developer chamber such as that illustrated in FIG. 1 containing plastic coated lead beads of about 700 microns diameter and 2 percent of a rosin modified phenol formaldehyde resin developing toner. The speed of rotation is approximately 15 inches per second. The developer or toner image on the drum is transferred to a sheet of paper and made permanent by vapor fixing. A high quality image is obtained from this method.

EXAMPLE III

A xerographic drum coated with a 40 micron layer of vitreous selenium is corona charged to a voltage of approximately 600 volts and exposed to form a latent electrostatic image. The selenium coated drum is then rotated through a self-circulating developer chamber containing a bath of 700 microns plastic coated lead beads of a pigmented polystyrene-butyl methacrylate blend developing toner. The drum is rotated at a speed of about 10 inches per second. The developer image is transferred to a sheet of paper and permanently fixed by heat fusing.

In a 50,000 cycle test, no evidence of abrasion of the selenium surface was seen after 50,000 revolutions through a developer chamber of the type illustrated in FIG. 1 of the drawings. During this test, the developer also showed no evidence of abrasion.

The method of the present invention is usually carried out in a xerographic system which includes at least the three basic steps of charging, exposing, and developing.

Important applications exist in which xerographic recording is desired intermittently, or on a variable speed basis. Facsimile transmission of documents and computer output recording are examples in which images are presented and must be recorded at varying rates, or even in a "start-stop" operation. The present invention has been shown to be admirably suited to such operations. Because developer circulation is caused by rotation of the xerographic drum itself, the quality of the developed image seems remarkably unaffected by changes in the drum surface speeds up to at least 40 inches/sec. That is, the total interaction of developer with the xerographic surface is evidently independent of the drum surface speed.

Although specific components, proportions and procedures have been stated in the above description of the preferred embodiments of the novel developing method, other suitable materials, as listed above, may be used with similar results. In addition, other materials and procedures may be employed to synergize, enhance or otherwise modify the novel method. For example, additional toner may be added in any convenient manner such as by hand or automatically to the top of the developer chamber. In addition, the coefficient of friction between the surface of the xerographic drum and the developer material in the developer chamber may be controlled by varying the types of developer and/or the surface of xerographic drum to yield optimum results not inconsistent with good image development. Although corona charging is used in the examples, it should be stated that any suitable method of attaining an electrostatic image by charging the drum would be included within the scope of this invention. Other typical techniques which could be employed to yield an electrostatic image include the use of a pin matrix as a print head and pin tubes. Induction charging and the use of a conductive rubber roller with a potential applied between the conductive core of the roller and the conductive backing of the photoconductor could also be used in place of corona charging.

Other modifications and ramifications of the present invention would appear to those skilled in the art upon the reading of the disclosure. These are intended to be included within the scope of this invention.

What is claimed is:

1. An imaging method comprising the steps of forming an electrostatic latent image on an imaging surface, transporting said imaging surface in a generally ascending arcuate path, said arcuate path extending upwardly from the point of tangency of a tangentially horizontal imaginary line, contacting only said imaging surface as said imaging surface is transported in said ascending arcuate path along a substantially continuous contact zone having an upper extremity and a lower extremity with a bath of substantially dry developer material comprising electroscopic marking particles and carrier beads supported in a substantially concave chamber adjacent said imaging surface, said contact zone extending upwardly from at least about said point of tangency through less than about 165° of arc along said arcuate path, said contact zone having a length along said arcuate path sufficiently long to permit said imaging surface to circulate said dry developer material in said bath by frictionally transporting at least a portion of said dry developer material along said upper extremity of said contact zone and providing sufficient substantially quiescent developer material along said lower extremity of said contact zone to form a seal for said bath of developer material.

2. An imaging method according to claim **1** wherein said concave chamber is C-shaped and has an arc length of less than about 180°.

3. An imaging method according to claim **1** including maintaining a larger spacing between said imaging surface and said concave chamber at the uppermost area of said bath of developer material than between said imaging surface and said chamber at the lowermost area of said bath.

4. An imaging method according to claim **1** including applying additional electroscopic marking particles to the uppermost portion of said bath of developer material to replenish depleted electroscopic marking particles.

5. An imaging method according to claim **1** including transferring said electroscopic marking particles deposited on said imaging surface in image configuration to a transfer sheet and fixing the transferred marking particles.

6. An imaging method according to claim **5** including cleaning said imaging surface and repeating the aforesaid steps at least one additional time to deposit electroscopic marking particles in image configuration on said imaging surface.

7. An imaging method according to claim **1** including dislodging any carrier beads adhering to said imaging surface as said imaging surface emerges from said contact zone.

8. An imaging method according to claim **1** wherein said carrier beads have an average diameter between about 250 to about 700 microns.

9. An imaging method according to claim **1** wherein said concave chamber is L-shaped.

10. An imaging method according to claim **1** wherein said imaging surface comprises an endless photoreceptor.

11. An imaging method according to claim **10** wherein said endless photoreceptor is cylindrical.

12. An imaging method according to claim **10** wherein said endless photoreceptor is a photoreceptor belt.

13. An imaging method according to claim 1 wherein said arcuate path is at least semicircular.

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WILLIAM D. MARTIN, Primary Examiner

EDWARD J. CABIC, Assistant Examiner

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