Sept. 30, 1969 R. W. GUNDLACH 3,470,009

POWDER CLOUD DEVELOPMENT OF ELECTROSTATIC IMAGES

Filed Dec. 28, 1964

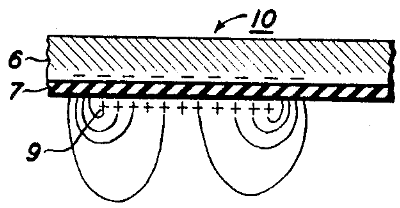

FIG. 1

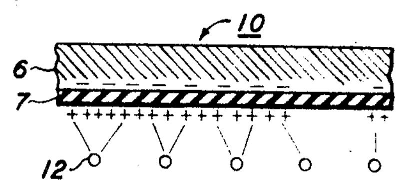

FIG. 2

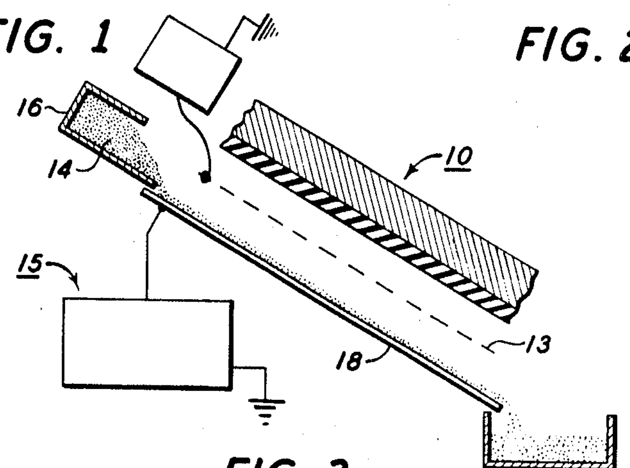

FIG. 3

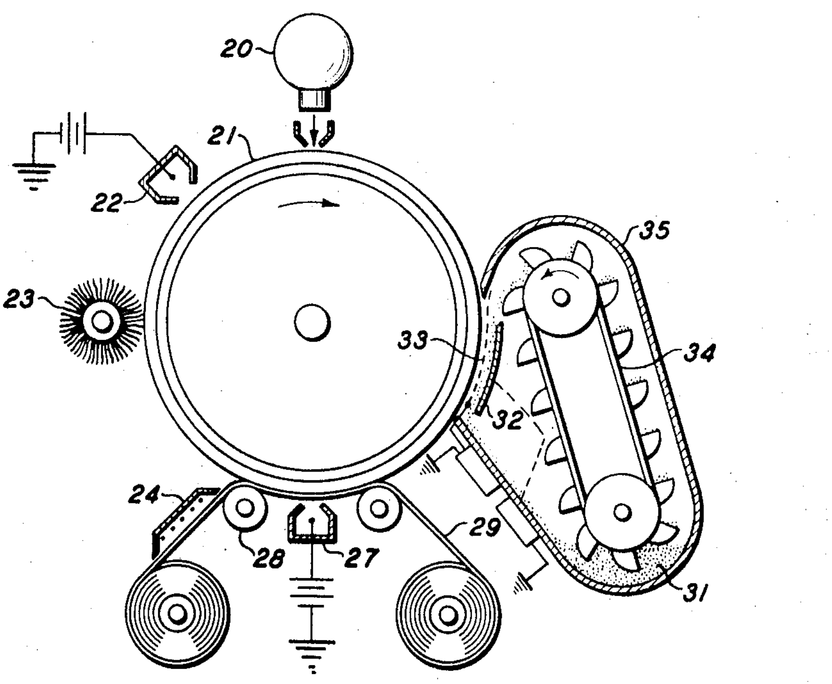

FIG. 4

INVENTOR
ROBERT W. GUNDLACH

BY Anthony J. Cennamo
Stanley Z. Cole
ATTORNEYS

United States Patent Office

3,470,009
Patented Sept. 30, 1969

1

3,470,009
POWDER CLOUD DEVELOPMENT OF ELECTROSTATIC IMAGES

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

Filed Dec. 28, 1964, Ser. No. 421,306
Int. Cl. B05b 5/00; G03g 13/08
U.S. Cl. 117—17.5 7 Claims

ABSTRACT OF THE DISCLOSURE

Method and apparatus for the development of selectively distributed latent electrostatic charges on a photoreceptive surface wherein xerographic developer material is applied to the photoreceptive surface by means of a xerographic toner powder cloud generator including an apertured screen and developer chute for generating a toner powder cloud, from the developer material, which is applied to the selectively distributive latent electrostatic charges for the development thereof.

This invention relates to electrophotography and more particularly to a method and apparatus for development of electrostatic images such as those formed in xerography.

In xerography a photoconductive insulating layer is electrically charged and exposed to a light pattern whereupon the charge is selectively dissipated to yield an electrostatic charge pattern on a surface, this charge pattern generally being called an electrostatic latent image. In order to utilize this latent image in the production of a visible print, it is ultimately desired to deposit visible material in conformity with the image.

According to one practice in xerography, as disclosed in U.S. Patent 2,618,552, the development of the electrostatic latent image is accomplished by rolling or cascading across the image bearing surface a developer composition of relatively large carrier particles having on their surfaces electrostatically adhering fine powder particles known as toner particles. In this process the particles of granular material when brought in close contact with the powder acquire a charge having an opposite polarity to that of the powder particles adhering to and surrounding the granular carrier particles. By selecting materials in accordance with their triboelectric effects, the polarities of their charge when mixed are such that the electroscopic toner particles adhere to and are coated on the granular carrier particles. The electrostatic image on the plate retains the electroscopic toner in the charged areas that have a greater attraction for the toner than the granular carrier particles have. As a composition cascades or rolls across the image bearing surface, these toner particles are electrostatically deposited on and secured to the charged portions of the image and are not deposited on the uncharged or background portions of the image. Also, toner particles accidentally deposited on these background portions are physically removed by electrostatic action of the carrier particles passing over the surface.

Cascade development is quick and easy and is well adapted to the formation of dense black images of high contrast; however, continuous tone images such as photographs, radiographs, and the like, tend to be reproduced as somewhat contrasty prints by this technique. That is, intermediate shades of gray are not all reproduced proportionately. It has been found also that large black or dark areas do not develop uniformly throughout their whole area but tend to develop more heavily around the edges than in the middle of the charged area. The reason for this, of course, is that cascade development is effective

2

only where the electrostatic fields are sufficiently strong to compete with the granular carrier particles for toner. These image fields are much stronger at the edges where the potential gradient is greatest than near the center of large uniformly charged areas. To overcome these difficulties a developer electrode has been used in conjunction with the apparatus. Experience has shown, however, that the use of a developer electrode with a cascading developer apparatus gives rise to developer blockages in the narrow space between the image and electrode. Also, in the case of drum type apparatus, the close spacing required between the moving drum and electrode results in abrasion of the drum surface.

Another xerographic development technique first described by Carlson in U.S. Patent 2,217,776 and known as powder cloud development has been found to be an excellent developing technique for continuous tone reproduction and other work requiring solid area coverage. In powder cloud development the finely divided marking particles or toner is uniformly suspended or dispersed in a gaseous carrier in the form of an aerosol. These particles are generally given an electrostatic charge during the formation of the aerosol, and then this aerosol or powder cloud is presented to the surface of an electrostatic image bearing member such as a xerographic plate. The electric field set up by the latent electrostatic image attracts toner particles out of the aerosol and onto its own surface to thereby render the image visible.

Because of high velocity conditions necessary for cloud generation, images developed with the present apparatus are susceptible to streaking. Also collection of the particles on wall surfaces and in voids causes agglomeration of the toner. Due to the nature of the electric field of the image, no powder deposits along the dividing line between charged and uncharged areas, a defect referred to as halo. Furthermore, the eveness of development from side to side and end to end, and the speed of development leave much to be desired. Moreover, the inclusion of an electrode in this system has created a problem of high background in cases of insufficient exposure.

Although much effort has been invested in the improvement of powder cloud development, as evidenced in U.S. Patents 2,725,304 to Landrigan, 2,862,646 to Hayford, 2,918,900 to Carlson, and 2,943,950 to Ricker, which are only an exemplary sample of the patents relating to this type of development, the technique is not widely used in commercial machines because of its relative complexity and cost. Generally these devices include a source of powder or toner, and means to suspend it in a gas in the form of an aerosol which is accomplished by agitating the powder in a gaseous atmosphere and allowing the gas to expand. Depending upon the particular powder cloud generator, the creation of the aerosol may require the utilization of vanes or beaters to stir up the powder, sources of high pressure gas such as compressors, regulating valves, and the like, and means to handle and convey the aerosol after its creation while it is being transmitted for presentation to the latent electrostatic image. Furthermore, the introduction of gas from a high pressure source must be accompanied by a filtered exhaust system to carry away equal quantities of dust-laden gas.

It is, therefore, an object of this invention to provide an improved method and apparatus for generating a powder cloud;

Another object of this invention is to provide an inexpensive and convenient xerographic development system adapted for automatic operation;

Still another object of this invention is to provide for complete development of continuous tone images, such as, photographs, radiographs, and large solid dark areas;

Yet another object of this invention is to provide a cloud generating apparatus which utilizes a minimum number of parts and eliminates moving parts;

A still further object of this invention is to provide an improved development system which makes possible the complete and rapid development of any pattern by electro-photography;

An additional object of this invention is to provide a powder cloud which is formed in situ with the image to be developed.

The foregoing objects and others which will became apparent from the following description, are accomplished in accordance with this invention, generally speaking, by generating a fluid suspension of toner particles into contact with a latent image with an extremely simple improved generator. The invention is described below in connection with the drawings wherein:

FIG. 1 is an enlarged fragmentary sectional view illustrating the field lines emanating from a latent electrostatic image;

FIG. 2 is an enlarged fragmentary sectional view illustrating the effect on an electrostatic field as shown in FIG. 1 by the inclusion of an electrode;

FIG. 3 is a schematic side sectional view of apparatus according to the present invention;

FIG. 4 is a schematic sectional view of a drum type xerographic machine according to another embodiment of the invention.

Illustrated in FIGURE 1 is an exposed xerographic plate **10** having conductive backing member **6** and photoconductive insulating layer **7**. On or near the surface of insulating layer **7** is an electrostatic latent image designated by plus marks **9**. Also shown are the electrostatic lines of force characteristics of a latent electrostatic image. The plus marks on the layer indicate a charged area of the electrostatic latent image corresponding to a dark area of the original image which was used in making the exposure. It would obviously be desirable to develop this area heavily with toner powder in order that the resulting picture would have a dark area corresponding to the dark area in the original. However, it will be noted that the field lines near the center of the image which extend farthest from the image are much weaker than those near the edges which extend only a short distance. Because of this field configuration and the toner-carrier adherence which must be overcome in ordinary cascade to deposit toner in charged plate areas the edge areas, i.e., the areas that have the greatest field attraction, are developed and the relatively weaker areas in the middle of a charged area are left undeveloped by the cscade technique. On the other hand, it will be apparent that in the case of powder cloud development, where the toner is freely floating in air away from the plate surface, good development is obtained in the middle areas by the relatively weak but farther reaching field lines emanating from the center of the image while the shorter but stronger fringed field lines are not "seen" by these relatively remote particles. Therefore, if a uniform field could be obtained, it would be possible to develop the image completely.

FIGURE 2 illustrates the improvement obtained by adding a control grid **12**. Grid **12** provides a conductor spaced in front of layer **7**, thereby producing a capacitance between layer **7** and grid **12**. This tends to intensify the number of lines of force extending outwardly from the charges on layer **7** and reduce the number extending through layer **7** to its conductive backing. The grid also tends to straighten out the lines of force at the edges of the charged area so that, for example, in powder cloud development particles floating in this region will be more strongly attracted to all parts of the charged area. Grid **12** may be held at the same potential as plate **10**, or if desired, further control of development may be achieved by placing a potential on the grid which is different from the potential of the plate. For example, if a small residual potential still exists in the areas of greatest illumination (and these areas should remain white in the final developed image), biasing the screen electrode to match this residual potential will result in a minimum toner deposit in those areas.

Referring now to FIGURE 3 of the drawings, there is illustrated apparatus for developing a latent image in accordance with the present invention. As in FIGURE 2, a screen grid **13** is placed substantially coextensive with the image bearing surface of xerographic plate **10** so that the electrostatic lines of force that emanate outwardly from the different potential areas on the image tend to flow mostly to the screen. The screen should be spaced no more than .030 inch from the image for optimum field condition. On the side of screen **13** opposite that of plate **10**, is conductive chute **18** for conveying developer material **14** poured from container **16**.

Developer material **14** preferably takes the form of any suitable electroscopic toner mixed with a suitable granular carrier. Typical compositions for this mixture and for toners per se are more fully described in U.S. Patents 2,618,551 to Walkup; 2,618,552 to Wise; 2,638,416 to Walkup and Wise; 2,788,288 to Rheinfrank; 2,753,308 to Landrigan; 2,891,135 to Carlson. The size and color of the toner particles depend upon the purpose intended as, for example, the size of conventional xerographic toner in U.S. Patent 3,079,342 is about 1 to about 30 microns. These toners usually consist of an electroscopic resin and a colorant such as any suitable organic or inorganic pigment or dye. The carrier particles on the other hand generally ranged from 300–500 microns.

A potential **15** of the same polarity as the electroscopic toner particles is applied to chute **18**. Toner particles are driven from their carrier granules due to the electric field created between chute **18** and screen **13**, forming a cloud of unipolarized particles having a mutual repulsion force between them. The cloud moves through screen **13** which prevents the passage of the larger carrier into the electric image field created between plate **10** and screen **13** and deposits in conformity with the electrostatic image on plate **10**. By biasing screen **13** slightly with respect to xerographic plate **10**, to precisely match the residual surface potential of the most highly exposed areas, it is possible to help prevent any background deposits on the plate.

Screen **13** may comprise any open work conductive material including, for example, fine mesh conductive screens. The choice of mesh size or opening pattern is dependent upon such features as having sufficiently large openings to avoid plugging up by the toner particles on the one hand, and on the other hand small enough to prevent the passage of the carrier granules through the screen and also to avoid distortion of the electric field. Although FIGURE 3 shows the position of the screen to be below that of the plate, it is by no means intended that the screen could not be placed in any other suitable position such as above the plate between it and the chute.

The potential applied to the chute should be of sufficient magnitude to overcome the electrostatic attraction between the carrier granules and toner particles and to propel such particles in the direction of the screen. A potential of 4,000 volts has been found to work very well for a quarter inch spacing between chute and screen. By varying the intensity of the field, of course, it is possible to accelerate the action of the particles. The polarity of the chute should be the same as the polarity of the charged toner particles. Therefore, if negatively charged toner particles are used, a negative potential is applied to the chute.

The cloud is capable of being dispersed in any suitable fluid insulating medium. Typical examples of insulating fluids are air, carbon dioxide, nitrogen, oxygen, Sohio Odorless Solvent (a kerosene fraction available from Standard Oil of Ohio), Freon 113 (trichlorotrifluoroethane), etc.

In FIGURE 4, there is shown another embodiment of the invention adapted for automatic operation. The principal element of the machine is a xerographic drum **21** of a conductive material which is covered on its outer surface with a layer of photoconductive insulating material such as vitreous selenium. Drum **21** is rotatable about its axis in the direction indicated by conventional means, not shown. An electrostatic image is formed on drum **21** by means of a corona charging device **22** which deposits a uniform charge on the surface of photoconductive insulating layer. The drum then passes a projector **20** which exposes the charged photoconductor to a light image of the original to be reproduced thus discharging portions of the charged photoconductor which are struck by light. 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 one shown.

After image development which will be described later, the developed image is transferred from drum **21** to a web of paper or the like **29** between guide rolls **28** acting to position web **29** against drum **21** by a second corona discharging device **27**. A heating element **24** is positioned to heat the transferred image and thus fix it and permanently bond it to the paper web **29**. A rotating cylindrical cleaning brush **23** contacts drum **21** subsequent to image transfer and removes any residual image material from the drum thus readying it for reuse. Many other equivalent charging, exposure, transfer and fusing techniques known in the art may be employed in connection with the present invention.

Image development is effected by apparatus similar to that used in the embodiment of FIGURE 3. Chute **32** and screen **33** are radially spaced from the drum so that development takes place as the drum is rotated past these elements. Developer material **31** is supplied to the development apparatus by a bucket conveyor **34** in a housing **35**. Conveyor **34** moves developer material **31** to a point above chute **32** and screen **33** and drops it into the channel formed by these elements. As already mentioned, it is desirable to position the screen close enough to the drum to obtain optimum field conditions taking into account, of course, drum machine flatness tolerances. A potential is applied to chute **32** in the manner discussed above in the embodiment of FIGURE 3 resulting in a cloud development of the image surface of the drum **21** in the areas adjacent screen member **33**. Any remaining developer material falls into the bottom of housing **35** where it is available for recycling on conveyor **34**.

As can be readily appreciated, the development system of this invention is both simple and efficient. In the past, powder cloud development could be obtained only through the use of complicated and expensive machinery not to speak of the awkwardness of such a system. Also, development could normally be accomplished only by piping a high velocity cloud to a point between the image and a spaced electrode for dispersion parallel to the image. Now, in accordance with the present invention, a cloud of unipolarized particles is generated in situ, i.e., formed in the vicinity of the image to be developed, a condition never heretofore obtainable. Moreover, the cloud is dispersed in a direction normal to the image, thereby achieving complete development rapidly. Furthermore, problems normally ensuing with the use of a development electrode are obviated in the present invention, since the electrode screen functions not only as part of the generating apparatus, but also as a device for enhancing image fields over large solid areas of charge. Thus, there is achieved a unique development system of an electrostatic latent image which is both simple and inexpensive but gives complete development in all respects with a clean background.

In certain instances, the development mechanism of this invention may be particularly desirable for use together with and/or in combination with other developing systems, techniques and devices. The two developing systems may, for example, be used either sequentially or in combination at one spot on the surface of the electrostatic image to be developed. Accordingly, it is contemplated that the cloud generator of this invention may be used, if desirable, in combination with any other suitable developing techniques. Other typical developing techniques include brush development, as described in U.S. Patents 2,975,758 and 3,015,305; touchdown development, as described in U.S. Patent 2,895,847; loop development, as described in U.S. Patent 2,761,416 to Carlson. These combinations will be found to be particularly desirable where the developing systems complement, enhance, or otherwise effect each other in their developing capabilities.

What is claimed is:

1. The method of developing an image on a latent electrostatic image bearing member comprising feeding a mixture of toner particles and grossly larger carrier beads along a feed path adjacent the surface of said image bearing member with conductive foraminous screen between said mixture and said image-bearing member, said toner particles and carrier beads being of materials which are separate from each other in the triboelectric series so that they will charge each other to opposite polarities in said mixture, said screen having openings of a size which will pass said toner particles but not said carrier beads, applying an electric field behind said mixture as it passes over said screen, said field being of the same polarity as said charged toner particles and of a magnitude sufficient to drive at least a portion of said toner particles from said mixture and through said openings to form a toner cloud adjacent said image bearing surface for developing the latent electrostatic image thereon.

2. A method according to claim **1** including electrically biasing said screen with respect to said image bearing member to prevent excess background deposits.

3. A method according to claim **1** including imparting relative movement between said image bearing member and said cloud.

4. Apparatus for developing a latent image on an electrostatic image bearing member comprising a screen spaced from and coextensive with said image bearing member, said screen being conductive and having a mesh size larger than toner particles but smaller than granular carrier, means for supporting a mixture of granular carrier beads and toner particles on the side of said screen opposite that of said image bearing member, and means to apply a potential of the same polarity as said toner particles to said supporting means, said potential being of sufficient magnitude so that said toner particles are repelled in a cloud moving toward said image bearing member for deposit in conformity with said latent image.

5. Apparatus for developing a latent image on an electrostatic image bearing member comprising a screen spaced from and coextensive with said image bearing member, said spacing between said screen and said image bearing member being less than .30 of an inch, means for supporting a mixture of granular carrier beads and toner particles on the side of said screen opposite that of said image bearing member, and means to apply a potential of the same polarity as said toner particles to said supporting means, said potential being of sufficient magnitude so that said toner particles are repelled in a cloud moving toward said image bearing member for deposit in conformity with said latent image.

6. Apparatus for developing an image on a latent electrostatic image bearing member comprising an electrode chute adjacent the surface of said image bearing member, a conductive screen intermediate said chute and said image bearing member, means to feed a mixture of charged toner particles and grossly larger carrier beads between said screen and said chute, said screen having openings of a size which will pass said toner particles but not said carrier beads, means to apply a potential to said chute of the same polarity as the charge on said toner particles and of a magnitude sufficient to repel at least a portion of said toner particles from said carrier beads through said screen towards said image and means to move said image bearing member past said chute.

7. Apparatus according to claim 6 further including means to apply a low biasing voltage of from about 10 to about 130 volts to said screen to prevent toner deposition in background areas of said image bearing member, said biasing voltage being of the same polarity as the polarity of charge on said image bearing member.

References Cited

UNITED STATES PATENTS

2,784,109	3/1957	Walkup	117—17.5
2,808,023	10/1957	Hayford	117—17.5 X
2,808,328	10/1957	Jacob	117—17.5
2,862,472	12/1958	Carlson	117—17.5 X
3,008,826	11/1961	Mott et al.	117—17.5 X
3,011,473	12/1961	Gundlach	117—17.5 X
3,011,474	12/1961	Ulrich	117—17.5 X
3,140,175	7/1964	Kaprelian	117—17.5 X
3,241,483	3/1966	Duff	117—17.5 X
3,257,223	6/1966	King	117—17.5
3,294,017	12/1966	St. John	117—17.5 X
3,306,193	2/1967	Rarey et al.	
2,618,551	11/1952	Walkup	117—17.5
3,081,698	3/1963	Childress et al.	117—17.5 X
3,202,093	8/1965	Childress	101—114

WILLIAM D. MARTIN, Primary Examiner

E. J. CABIC, Assistant Examiner

U.S. Cl. X.R.

96—1.4; 117—37; 118—637