

Sept. 10, 1963

H. BOGDONOFF ET AL
METHOD OF DEVELOPING AN ELECTROSTATIC LATENT
IMAGE ON A XEROGRAPHIC PLATE

3,103,445

Filed May 7, 1959

2 Sheets-Sheet 1

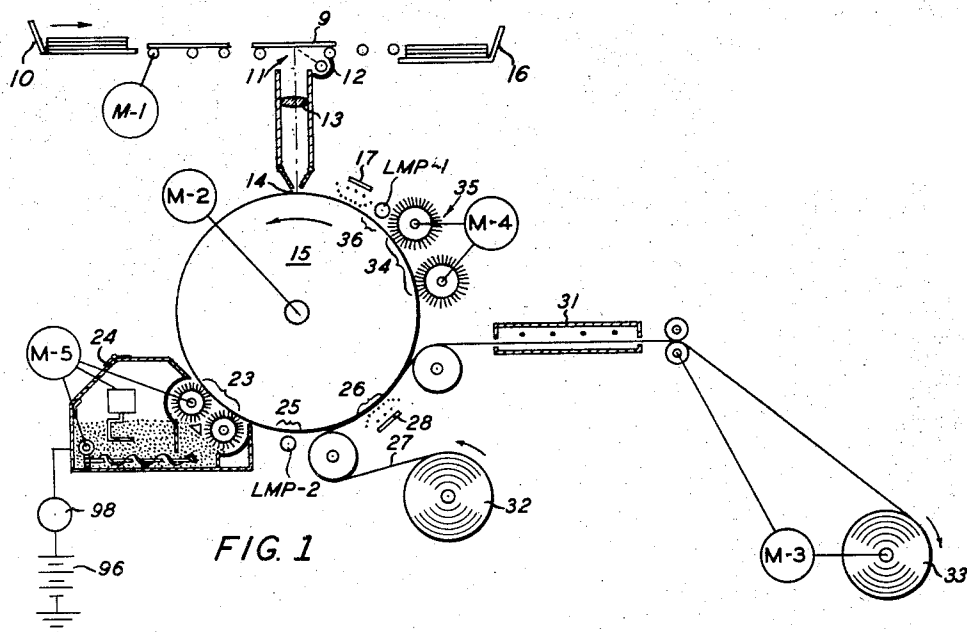


FIG. 1

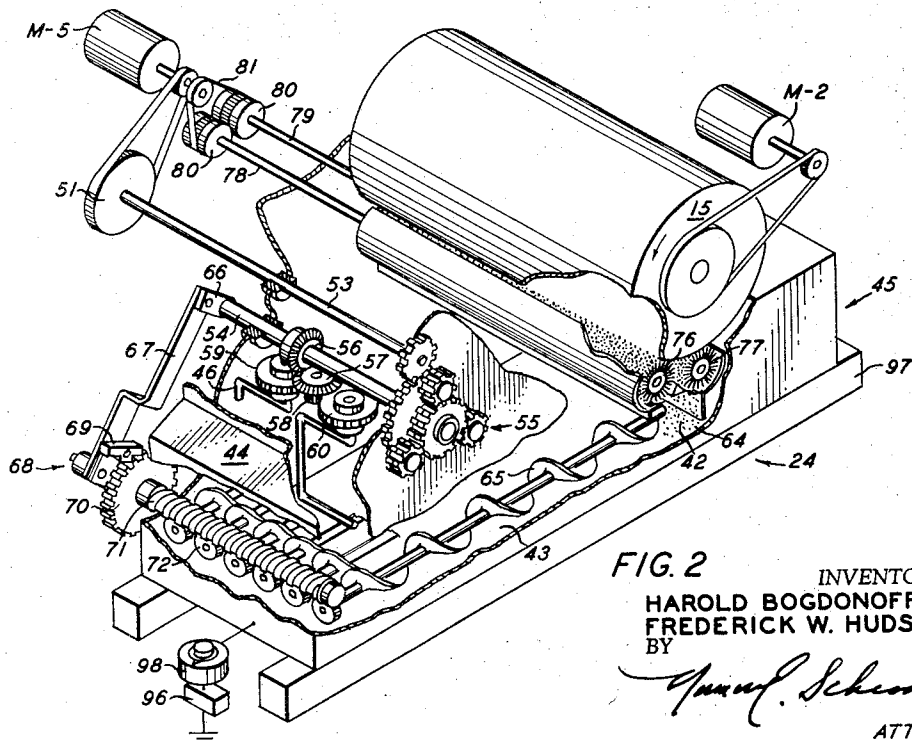


FIG. 2

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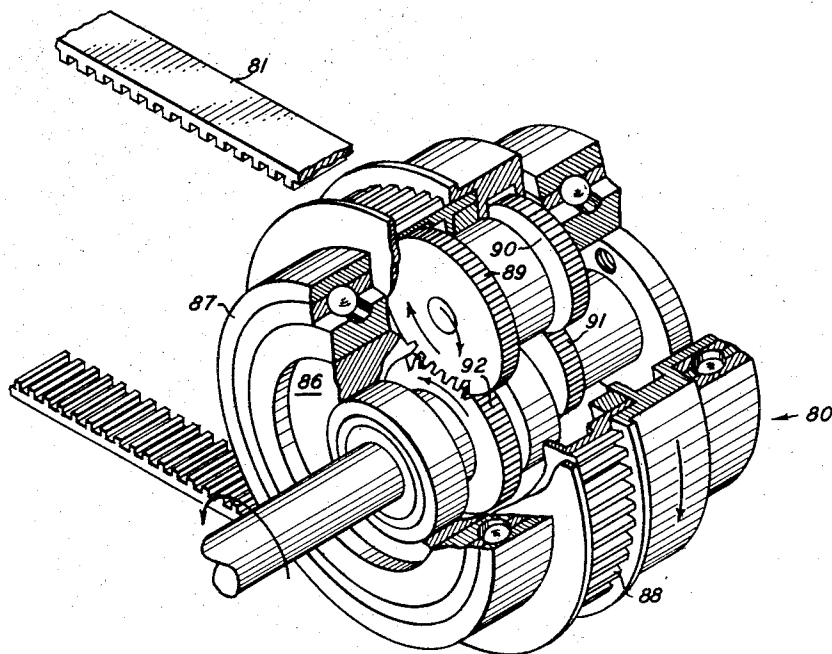


FIG. 3

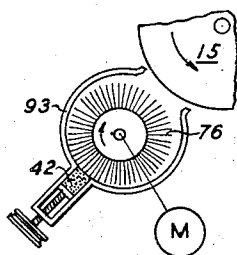


FIG. 4A

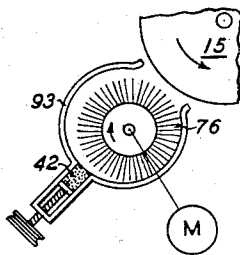


FIG. 4B

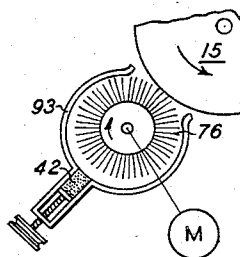


FIG. 4C

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3,103,445

METHOD OF DEVELOPING AN ELECTROSTATIC LATENT IMAGE ON A XEROGRAPHIC PLATE**Harold Bogdanoff, Rochester, and Frederick W. Hudson, West Henrietta, N.Y., assignors to Xerox Corporation, a corporation of New York**

Filed May 7, 1959, Ser. No. 811,608

7 Claims. (Cl. 117—17.5)

This invention relates to xerography and particularly to improved developing apparatus for improving the character of developed electrostatic latent images formed on a record-receiving medium. More specifically, this invention relates to improved developing apparatus whereby electrostatic latent images on a record receiving medium are developed with a density more uniform than heretofore and adherence of developer material to the non-image areas is prevented to a greater extent when developing by means of a member which presents developing material held on its surface into contact with a latent image on a record-receiving medium.

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

In xerography, the image to be developed is formed on an insulating support surface referred to throughout this specification as a "record-receiving medium" which may be a conventional xerographic plate possibly in drum form or may be such other surface on which an electrostatic charge pattern may have been transferred by means known to those skilled in the art.

Development is attained by presenting a developing material into contact with the electrostatic latent image on the record-receiving medium. One of the more common methods of presenting developing material is by cascading the material over the image with apparatus such as disclosed in copending application S.N. 393,058, filed November 19, 1953, in the name of Mayo et al., and now abandoned. Another common method, to which the apparatus of this invention relates, employs a member such as disclosed in copending application S.N. 401,811, filed January 4, 1954, in the name of Lewis E. Walkup. The member disclosed in the copending Walkup application may conveniently be a fur, brush, cylinder or the like which frictionally electrifies the developing material with which it contacts, charging it to a polarity opposite to the polarity of the electrostatic latent image to be developed and then with a stippling motion presents the material to the image. Developing material is retained on the surface of the member by the action of electrostatic forces wherefrom on contact with the electrostatic latent image on the record-receiving medium it is attracted thereto by the polarity forces of the image. This method of developing has proven to be fast, economical and successful and is commonly referred to in the art as "brush developing."

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As the name implies, in brush development it is common to use brushes which can be of a variety of types as for example those consisting of synthetic or vegetable fibers or animal fur. In general, however, a brush is selected on the basis of its triboelectric properties, electrical conductivity, density of bristle, length of bristle, etc. and for which beaver fur has proven most satisfactory.

The developing material employed is selected on the basis of its characteristics for the application, as for example it is usual for line copy reproduction such as black lettering on a white background, wherein the material is cascaded over the image to be developed, to employ a two-component developer consisting of toner and electroscopic carrier beads which may be of a type disclosed in Walkup Patent 2,638,416. For brush developing the developing material employed usually consists of a powdered toner of finely divided pigmented resin which may be of a type disclosed in Rheinfank Patent 2,788,288.

Whereas brush developing has proven commercially successful, it has been noted that under certain atmospheric conditions there has been a tendency to produce undesirable development characteristics. At extremely low relative humidities approaching zero, developed images of decreasing density have been noted whereas the tendency to deposit toner in the background or non-image areas of the record-receiving medium occurs particularly and increasingly with high relative humidities. It is known that non-image areas on the record medium through a normal exposure frequently retain a residual positive background potential which varies in accordance with the initial charge and on some apparatus has been found to be approximately 175–200 volts, as contrasted with approximately 800 volts in the image areas. Although it is not completely understood, it is believed that at extremely low relative humidity the fur brush is less conductive and develops a net positive bias potential to suppress the image and background charges as to limit the attraction of toner to the image and to prevent attraction of toner to the background. It is further believed that with increasing relative humidity the conductivity of the brush is increased, resulting in reduced brush bias potential approaching zero at high relative humidities which has a decreasing effect on image density but increasing tendency to produce background deposition.

As the brush becomes more conductive at least two additional phenomena are believed to occur. It is known in the art of xerography that wide solid areas of charge tend not to develop uniformly unless a conductor or semiconductor at lower or ground potential is spaced in close or touching relation to the record-receiving medium. In brush development the phenomenon is believed to occur with a more conductive brush which provides a uniform solid development field in the background areas and it is believed therefore, that brush characteristics are related to a development electrode closely spaced to the surface of a xerographic plate. Also, with a more conductive brush the triboelectrification between the brush and developing material is believed to partially break down permitting developing material to be more easily attracted to the weak background fields.

Tests conducted in a relative humidity range of approximately 27% to 80% and at an ambient temperature of about 75° F. produced background of increased prominence with increasing relative humidity to the point of almost obliterating the image. It was also noted that with increasing relative humidity the rate at which toner was fed to the brushes had to be carefully limited in order to prevent loosely adhering toner from being easily attracted to the background. However, it was discovered that by developing in accordance with apparatus of the

present invention, background deposition even at relative humidities approaching 100% could virtually be eliminated and the toner feed rate could be increased to provide greater image density.

In cascade developing, mentioned above, there is also a tendency to deposit toner in the background but to a much lesser degree and under normal operating conditions it is hardly perceptible until operating in relative humidities on the order of 95%, which are not frequently encountered. To the extent that background deposition is less of a problem in cascade development it is believed that the carrier beads employed therewith, which triboelectrically charge the toner, are considerably less hygroscopic than the electrically conductive member of the brush developing apparatus and are therefore less conductive through a range of relative humidities approaching 95%. By further analogy, the cascade developing components loosely gravitate within a confined space having relatively little contact with apparatus electrically grounded whereas the brush has heretofore been mounted on a metallic core and caused to rub against a metallic member both of which were connected to ground and either of which or possibly some other source of connection may have been conducting the charge from the brush.

In accordance with the present invention it was discovered that throughout a complete range of relative humidities connecting a biasing potential to the developing apparatus when electrically insulated produces uniform density of image and prevents the deposition of toner on the background areas. Furthermore, it was found that because background could be controlled so well by this technique, the toner feed rate could be increased to provide increased density of developed image without background.

The principal object of the invention is to improve the character of developed electrostatic latent images by preventing deposition of toner in non-image background areas to an extent greater than heretofore.

It is a further object of the invention to improve the character of developed electrostatic latent images by reducing background deposition when developing in an atmosphere of variable relative humidity.

It is a still further object of the invention to improve the density of developed images without obtaining background deposition.

It is a still further object of the invention to improve the overall quality attainable by brush developing techniques.

These and other objects of the invention are attained by means of a bias potential connected to the developing apparatus.

A preferred form of the invention is shown in the accompanying drawings in which:

FIG. 1 is a schematic illustration of a typical xerographic reproduction apparatus including the developing apparatus of the invention;

FIG. 2 is an isometric view of a typical brush developing unit with its housing partially broken away to illustrate its operating mechanism;

FIG. 3 is an isometric view of a typical brush eccentric drive mechanism; and

FIGS. 4A, 4B and 4C schematically illustrate in sequence a brush and toner relationship for toning, triboelectric charging, and image developing, respectively.

For a general understanding of the xerographic processing system with which the invention is shown, reference is had to FIG. 1 in which the various system components are schematically illustrated. As in all xerographic systems based on the concept disclosed in the above-cited Carlson patent, a light or radiation image of copy to be reproduced is projected onto the sensitized surface of a xerographic plate to form an electrostatic latent image thereon. Thereafter, the latent image is developed with

an oppositely charged developing material to form a xerographic powder image, corresponding to the latent image, on the plate surface. The powder image is then transferred to a support surface to which it may be permanently affixed by any suitable means.

In FIG. 1 the xerographic apparatus shown may conveniently be an adaptation of a type disclosed in copending application Ser. No. 837,173, filed August 31, 1959, in the names of Cerasani and Lewis. In the adaptation illustrated, an opaque original 9 to be reproduced is fed from a support tray 10 and is transported over a system of suitable guide rollers driven by motor M-1. The original is moved past an exposure station 11 where light from a mercury arc lamp 12 is reflected from the face of the original through an objective lens 13 and an exposure slit 14 onto the surface of a record-receiving medium which in this instance is a xerographic plate in the form of a drum 15. Thereafter, the original is transported to a stacker 16.

Xerographic drum 15 includes a cylindrical member mounted in suitable bearings in the frame of the machine and is driven in a counterclockwise direction by a motor M-2 at a constant rate whereby the peripheral rate of the drum surface is identical to the rate of movement of the reflected light image. The drum surface comprises a layer of photoconductive material on a conductive backing that is sensitized prior to exposure by means of a screened corona generating device 17, which may be of the type disclosed in Walkup Patent 2,777,957, that is energized from a suitable high potential source.

The exposure of the drum to the light image usually discharges the photoconductive layer in the areas struck by light, whereby there remains on the drum an electrostatic latent image in image configuration corresponding to the light image projected from the opaque original. As the drum surface continues its movement, the electrostatic latent image passes through a developing station 23 in which developing material electrostatically charged by a rotating brush is applied to the drum surface by means of developing unit 24 which may conveniently be a type disclosed in the above-mentioned copending Walkup application, and a typical embodiment of which is described below in more detail.

After developing, the xerographic powder image passes a discharge station 25 at which the drum surface is illuminated by a lamp LMP-2, whereby residual charges on the non-image areas of the drum surface are discharged. Thereafter, the powder image passes through an image transfer station 26 at which the powder image is electrostatically transferred to a support surface web 27 by means of a second corona generating device 28 similar to corona generating device 17 mentioned above.

The support surface to which the powder image is transferred may be of any convenient type and is obtained from a supply roll 32 and is fed over suitable guide and tensioning rolls and directed into surface contact with the drum. After transfer, the support surface is separated from the drum surface and guided through a suitable fusing apparatus 31 which may be of a type disclosed in Crumrine Patent 2,852,651 whereby the powder image is permanently affixed to the support surface. Thereafter, the support surface is fed over a further system of guide and tensioning rolls and onto a take-up roll 33 that is driven by motor M-3.

After transfer, the xerographic drum surface passes through a cleaning station 34 at which its surface is brushed by a cleaning brush assembly 35 rotated by a motor M-4, whereby any residual developing material remaining on the drum is removed. Thereafter, the drum surface passes through a second discharge station 36 at which it is illuminated by a lamp LMP-1, whereby the drum surface in this region is completely flooded with light to remove any electrostatic charge that may remain thereon. Suitable light traps are provided in

the system to prevent any light rays from reaching the drum surface, other than the projected image, during the period of drum travel immediately prior to sensitization by corona generating device 17 until after the drum surface is completely passed through the developing station 23.

Apparatus for developing in which a stippling motion is employed is described in the first cited Walkup application. The method of presenting toner to the image with a stippling motion is considered preferred since it is believed that stippling tends to shake toner from the brush and results in a more densely developed image than, for example, when rubbing alone is employed. Another embodiment of brush developing apparatus which employs stippling is described in International Business Machine Company's "Preliminary Manual of Instruction" for use with their 939 Electrostatic Address Label Printer. It is the basic apparatus of IBM which is generally described herein.

For a better understanding of brush developing apparatus 24 to be described, reference is made to FIGS. 2, 3 and 4.

To electrically insulate the brush members 76 and 77 from ground, the entire apparatus is shown in FIG. 2 mounted on insulating rails 97. A bias potential 95 of the invention is shown connected to housing 45. The potential is of direct current and rheostat 98 is provided by which the bias supply potential can be varied.

Toner 42 is manually added into bin 43 by raising cover plate 44 which is suitably hinged to the developer housing. Stirring arms 46 maintain toner evenly distributed around the bin and are operated from motor M-5 through pulley 51 which rotates shaft 53, and through a planetary gear system generally designated as 55, shaft 54 is rotated. Secured on shaft 54 is bevel gear 56 meshing with bevel gear 57 in turn secured on a common shaft with spur gear 58 meshing with spur gears 59 and 60 secured to the stirring arms.

For placing toner into contact with the brushes, toner is fed into feed bin 64 by means of rotating augers 65. To rotate the augers, crank arm 67 is operated in a cranking motion from the rotation of drive arm 66 secured on shaft 54. A feed ratchet assembly, generally designated as 68 is operated by the cranking motion wherein a feed pawl 69, rocked thereby, systematically in its return stroke advances ratchet 70 to rotate drive-worm shaft 71 through an angle of rotation. Drive worm gears 72 mesh with the worm shaft and serve to rotate the feed-augers at approximately 1 r.p.m. Suitable means are provided for adjusting the rate of toner feed.

Developing brushes 76 and 77 are rotated in a manner whereby to dispense and charge the individual toner particles by the bristles of the brush and to contact the electrostatic latent image on the drum in a rapid stippling action with thousands of individually toned bristles.

The brushes are secured to shafts 78 and 79, respectively, which are driven from motor M-5 by a timing belt 81 connected to driving hub 80. The brush shaft is rotated and is secured off-center by which it oscillates generally in a direction opposite to the direction of rotation. Details of the driving hub are better illustrated in FIG. 3 whereat the brush shaft is shown supported in an eccentric bushing 86 secured to the inner race of bearing 87 being rotated by timing belt 81 engaging pulley 88, the outer race of said bearing being suitably held. A planetary gear 89 is secured on a common shaft with spur gear 90 both of which are supported to move with the pulley. Gear 90 meshes with stationary gear 91 such that gear 89 is rotative and transmits its rotation to spur gear 92 secured to the brush shaft. By this means the brush rotates about its own axis. By a change of gear ratios any desired rate of brush speed can be selected to effect proper toning of the brush. Obviously any desired oscillating rate and shaft speed

can be achieved and an oscillating rate of 1600 times per minute with a shaft speed of 33 r.p.m. has given satisfactory results.

As may be seen in the schematic drawing of FIG. 4A, a brush is rotated into contact with toner developing material 42 being supplied to the point of brush contact whereat the toner is triboelectrically charged to polarity opposite to the brush, causing an adherence of toner thereto. The electrification is subsequently enhanced by contact against metallic side member 93 as may be seen in FIG. 4B. Thereafter the brush presents the toner into contact with the xerographic plate, as may be seen in FIG. 4C.

In operation, an original to be reproduced is transported from support tray 10 past exposure station 11 whereat a light image is reflected onto the surface of xerographic drum which had been previously charged by corona generating device 17. Exposure of the drum to the light image discharges the non-image background areas to a potential of less magnitude than the electrostatic latent image thus formed. As the drum continues to rotate, it passes through developing station 23 whereat brushes 76 and 77 present developing material to the plate with a stipple-like motion. With the bias potential of the invention connected to the apparatus, the brush continually assumes substantially the magnitude of potential connected throughout a complete range of relative humidities, thereby suppressing background potential and preventing deposition of developing material thereon. After development, the powder image is electrostatically transferred by device 28 to support surface 27. Thereafter, the drum is cleaned and readied for the next cycle, whereas the support surface is transported through fuser 31 to permanently affix the powder image thereto.

As stated above, it is known that the non-image areas on the record receiving medium through a normal exposure frequently retain a residual positive background potential which varies in accordance with the initial charge and on some apparatus has been found to be approximately 175-200 volts, as contrasted with approximately 800 volts in the image areas.

In an analysis of the characteristics of brush development, it appears that a brush is very closely related to a development electrode closely spaced to the selenium surface of a xerographic plate. The conductivity characteristics of the various brush materials is not known, but this conductivity is known to vary in accordance with relative humidity. At low humidities, there is probably a net positive potential on the brush due to the interaction of the toner and the brush. As the humidity is increased and the conductivity of the brush is increased, this positive potential in the brush is reduced, such that at very high humidities there is probably little or no potential. It is known in the art that with a development electrode it is necessary to maintain a potential on it at least as great as the non-image or background potential on the plate's photoconductive surface to keep the background from developing. It therefore seemed that if the brush could be biased positively, the background would probably be reduced. The most practical way to apply this bias appeared to be through the entire development unit, since the brushes are mounted on metal cores, which are grounded to the development unit frame, although it is apparent that a direct connection to the brush or anywhere intermediate the unit and brush is just as feasible. Consequently, the development unit was mounted on plastic insulator rails and connected to a variable voltage direct current source. The average residual background potential on the plate tested was approximately 175 to 200 volts, and it was expected that it would be necessary to have a potential on the developing unit of at least that much to suppress background development. Tests were made at four controlled humidities: 27% RH, 40% RH,

60% RH, and 80% RH, at an ambient temperature of about 75° F. At zero bias, and low humidities there was little background, and as the humidity was increased, the background became more and more prominent, to the point where it almost obliterated the image.

Various biasing potentials were then applied to the developing unit. As the biasing potential was increased, the background was reduced, in the case of the high humidity, markedly, such that in the range of about 200 to 300 volts almost all of the background was eliminated even at the very high humidities. It was found that the potential was not very critical, and that with a potential in the above range, good quality copy could be obtained at any humidity level tested. There was some decrease in the quality of the image above 350 volts, but since the background was almost completely eliminated at approximately 250 volts, little or no improvement is gained using the higher potentials.

It was found, further, that because the background could be controlled so well by this technique, the toner feed rate could be increased beyond that normally recommended, with an increase in copy density and no increase in background.

The effect of connecting a bias potential to the developing apparatus is not fully understood nor it is understood just how the bias is conducted to the brush and distributed on the bristles to influence development. It is believed, however, that when the brush is less conductive at the lower relative humidities, the inherent tendency of the brush to develop a potential in excess of the bias supply is relieved by the excess being conducted back through the bias connection and by this means a maximum brush potential is maintained. However, as the brush becomes increasingly conductive with increasing relative humidity, it is believed that the bias potential is conducted through the conductive members of the apparatus, through the brush shaft and thence to the brush bristles.

By the above description, there is disclosed improvements in brush developing apparatus to prevent to a greater extent than heretofore the adherence of developing material to the non-image areas on a record-receiving medium and to develop denser images without background deposition.

Although the above description has particularly emphasized the use of a bias potential on the brush when reproducing positive copy from positive originals, it is considered that the principles of the invention could be just as effectively employed for reversal development, as for example, negative to positive, when using developing apparatus having the appropriate characteristics for such development.

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

What is claimed is:

1. The method of developing an electrostatic latent image of a given polarity formed on a xerographic plate by exposure of a sensitive xerographic plate to a light and shadow pattern of an original to be reproduced, said electrostatic latent image having areas of charge of a first potential of about 800 volts corresponding to areas

of shadow during exposure and having areas of charge of a second potential between about 175 volts and about 200 volts corresponding to areas of light during exposure, said method comprising

- 5 rotating a brush comprising a multiplicity of unitary fibers permanently interrelated at a base extending substantially outwardly from the base, said fibers being substantially of uniform length and being characterized as having varying electrical conductivity depending on ambient humidity,
- 10 loading said brush during rotation of said brush with xerographic developing powder by feeding said powder into contact with said brush during rotation,
- 15 the powder being of a material relative to the material comprising the fibers to cause triboelectric adherence of the powder to the fibers while electrostatically charging the powder to a polarity opposite to the polarity of the electrostatic charges which comprise the electrostatic latent image to be developed,
- 20 applying a bias potential of said given polarity to the base of said brush of a magnitude between about 200 volts and about 350 volts, and
- 25 applying xerographic developing powder to said plate from said brush during rotation of said brush and at a point following loading of said brush by making brushing contact with said brush against said plate to form a developed image substantially free of background and of a substantially uniform quality regardless of ambient relative humidity which conforms to said electrostatic latent image.
- 30 2. The method of developing an electrostatic latent image as set forth in claim 1, wherein said bias potential is between about 200 volts and about 300 volts.
- 35 3. The method of developing an electrostatic latent image as set forth in claim 1, wherein said bias potential is about 250 volts.
4. The method of developing an electrostatic latent image in accordance with claim 1 in which said brush of fibers comprises synthetic material.
- 40 5. The method of developing an electrostatic latent image in accordance with claim 1 in which said brush of fibers comprises animal fur.
- 45 6. The method of developing an electrostatic latent image in accordance with claim 1 in which said brush of fibers comprises vegetable fibers.
- 50 7. The method of developing an electrostatic latent image in accordance with claim 1 including oscillating said brush through a path of travel during rotation of said brush causing said brush to move through a cycle into and out of contact with said plate to develop said electrostatic latent image through a stippling action.

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