Oct. 17, 1967 J. M. LYLES 3,347,691

XEROGRAPHIC DEVELOPMENT

Filed Oct. 21, 1965 4 Sheets-Sheet 1

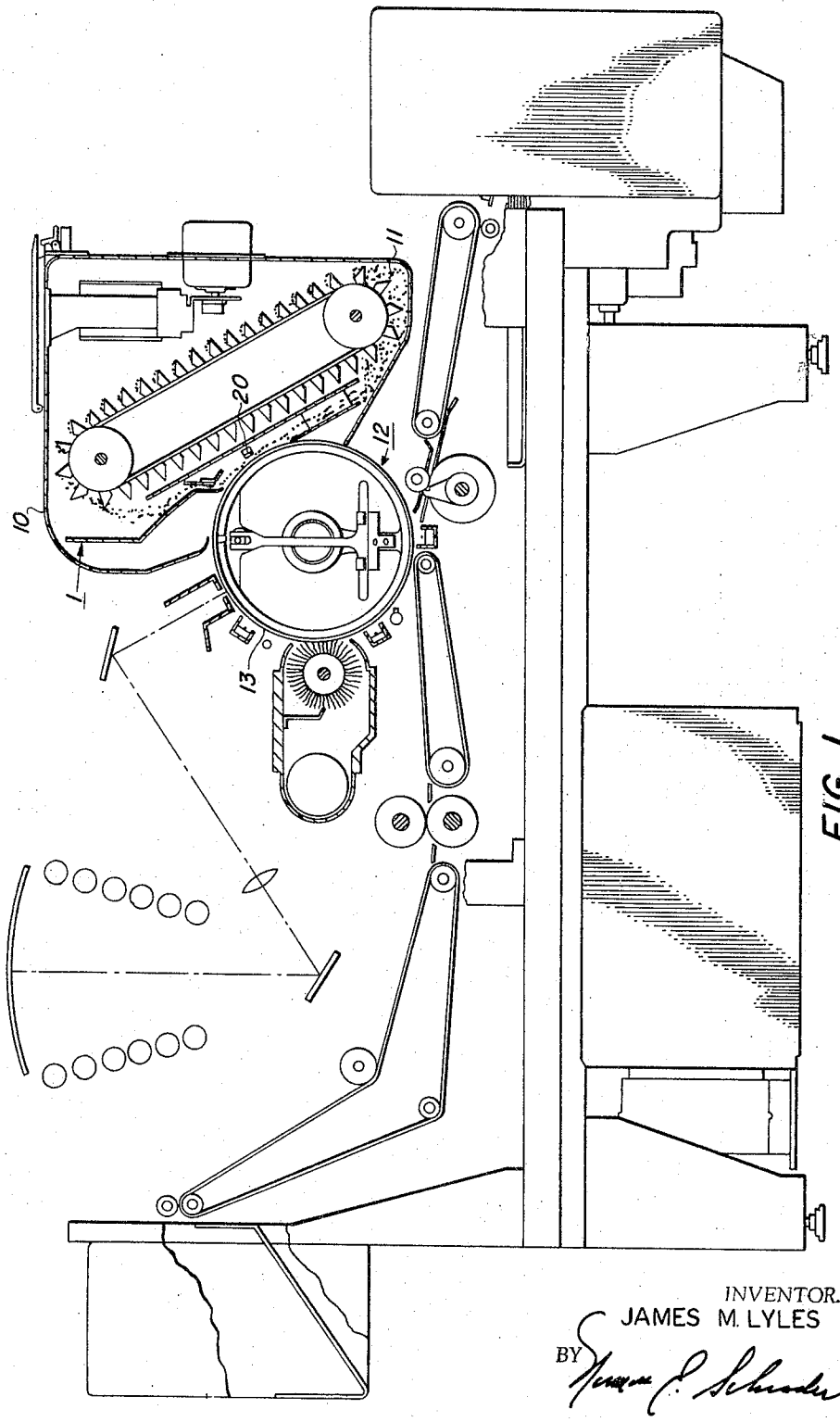


FIG. 1

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Oct. 17, 1967 J. M. LYLES 3,347,691

XEROGRAPHIC DEVELOPMENT

Filed Oct. 21, 1965 4 Sheets-Sheet 2

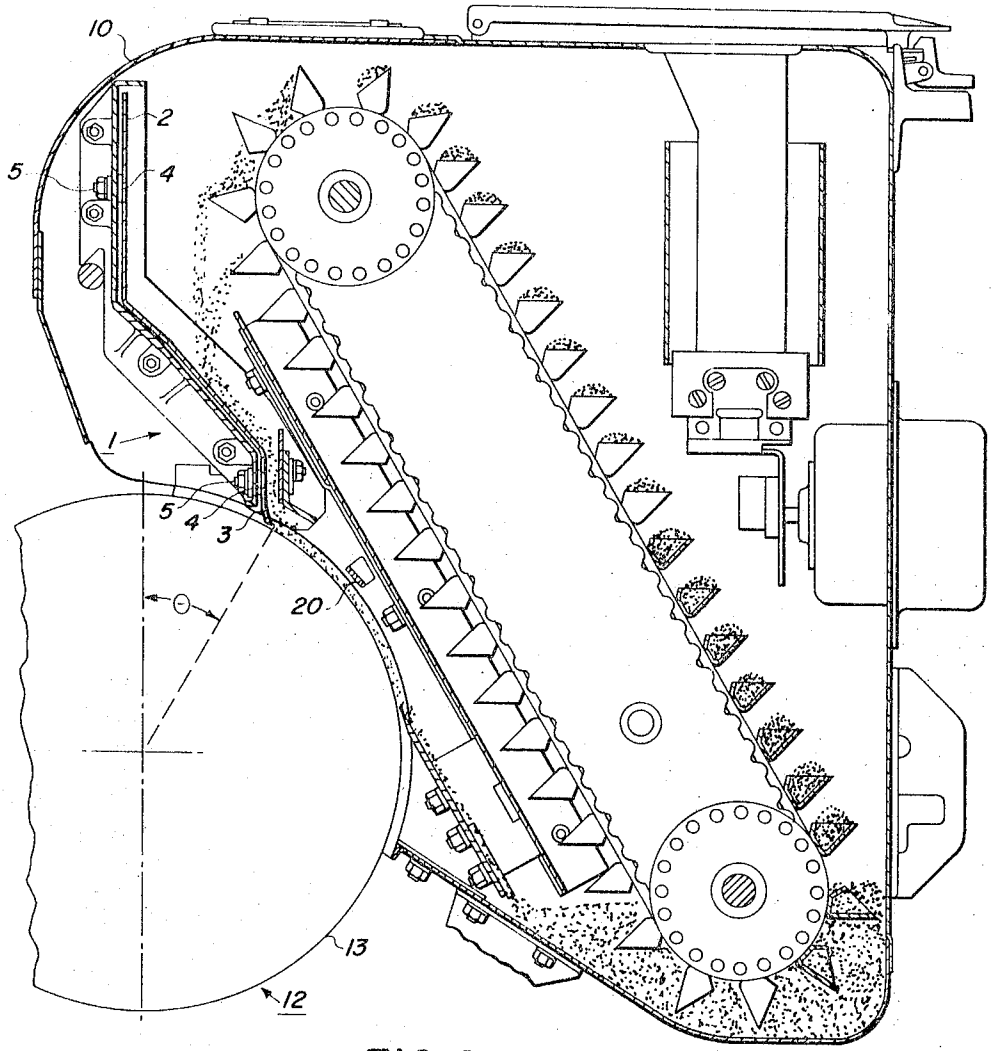


FIG. 2

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Oct. 17, 1967 J. M. LYLES 3,347,691

XEROGRAPHIC DEVELOPMENT

Filed Oct. 21, 1965 4 Sheets-Sheet 3

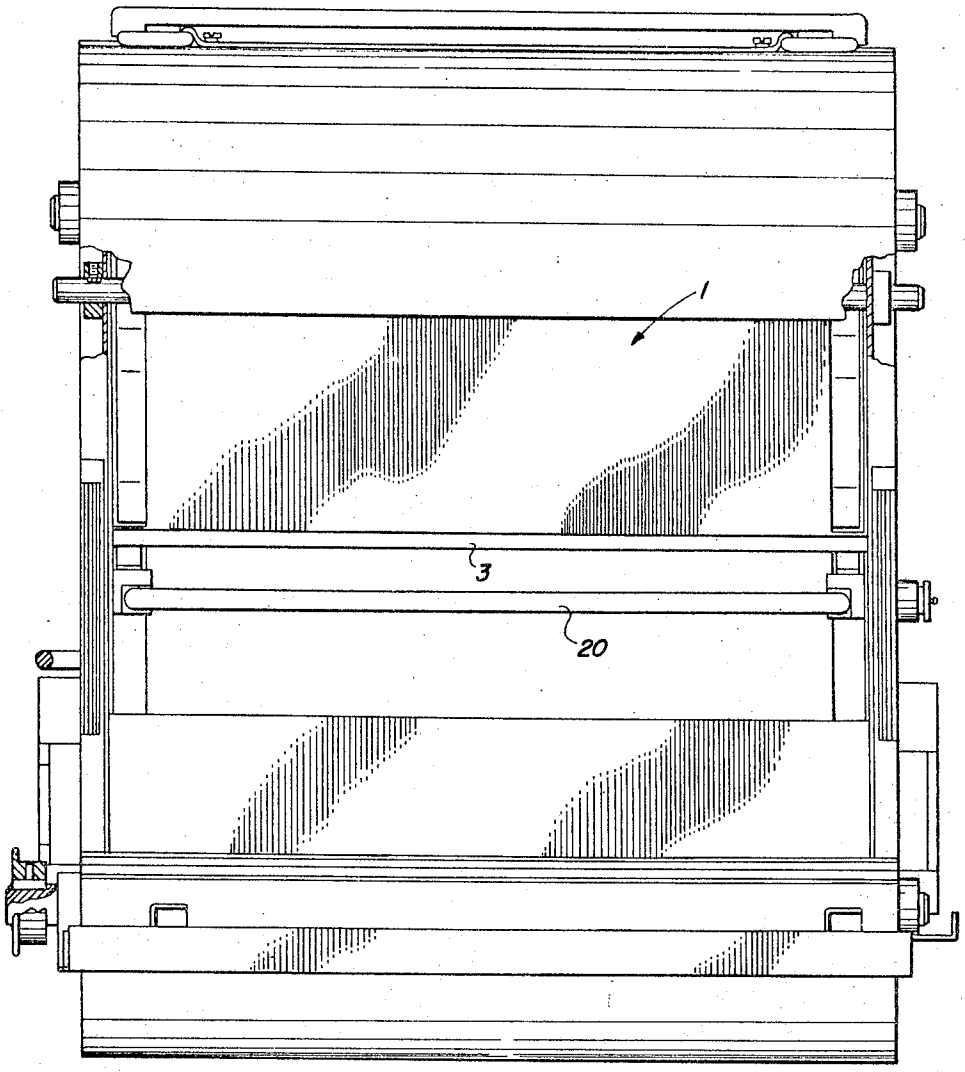


FIG. 3

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Oct. 17, 1967 J. M. LYLES 3,347,691

XEROGRAPHIC DEVELOPMENT

Filed Oct. 21, 1965 4 Sheets-Sheet 4

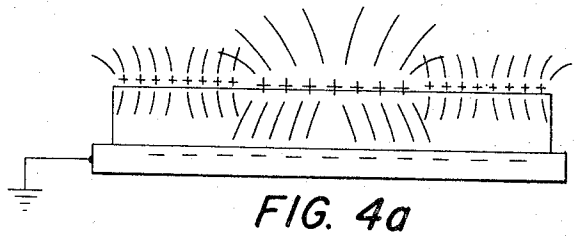


FIG. 4a

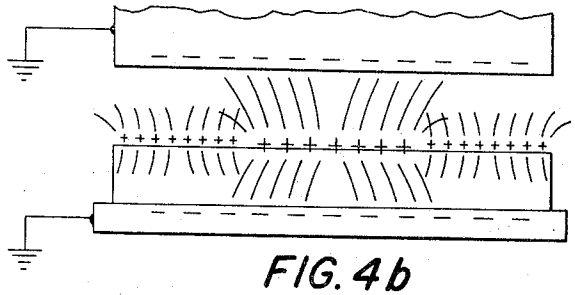


FIG. 4b

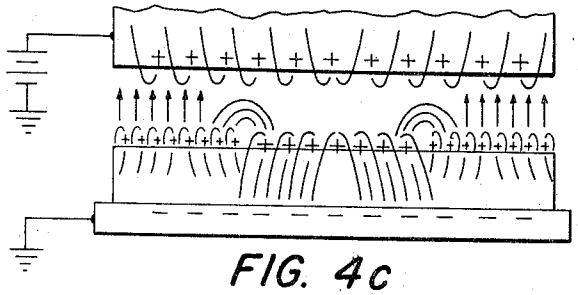


FIG. 4c

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United States Patent Office 3,347,691 Patented Oct. 17, 1967

3,347,691

XEROGRAPHIC DEVELOPMENT

James M. Lyles, Fairport, N.Y., assignor to Xerox Corporation, Rochester, N.Y., a corporation of New York

Filed Oct. 21, 1965, Ser. No. 499,291
17 Claims. (Cl. 117—17.5)

This invention relates to xerographic developing and in particular to a method and apparatus for improving the quality of electroscopic toner powder images formed on a photoconductive member.

More specifically, this invention relates to applying a positive, direct current potential to a chute used for introduction of xerographic developer material onto a photoconductive surface, sometimes referred to as a xerographic drum, to suppress the deposition of undesirable toner powder on non-latent image areas of the plate.

In the process of xerography, for example, as disclosed in Carlson Patent 2,297,691, a xerographic plate comprising a layer of photoconductive material on a conductive backing is given a uniform electric charge over its surface and then exposed to the subject matter to be reproduced, usually by conventional projection techniques. This exposure discharges the plate in accordance with the light intensity reaching it, thereby creating an electrostatic latent image on or in the plate.

Development of a line of image is effected by developers which comprise, in general, a mixture of a suitable pigmented or dyed resin based powder, hereinafter referred to as toner, and a granular carrier material which functions to carry and to generate triboelectric charges on the toner. More specifically, the function of the carrier material is to provide mechanical control of the toner, or to carry the toner to an image surface and, simultaneously, provide almost complete homogeneity of charge polarity. In the development of the image, the toner powder is brought into surface contact with the photoconductive coating and is held thereon electrostatically in a pattern corresponding to the electrostatic latent image. Thereafter, the developed xerographic image is usually transferred to a support material to which it may be fixed by any suitable means.

In the mixture of toner particles and carrier material, the toner particles, which are many times smaller than the carrier particles, adhere to and coat the surface of the carrier particles due to the triboelectric attraction between them. During development, as the toner coated carrier particles roll or tumble over the xerographic plate carrying an electrostatic image of opposite polarity to the charge on the toner, toner particles are pulled away from the carrier by the latent electrostatic image and deposited on the plate to form a developed toner powder image.

In xerographic developing apparatus of the type utilizing cascade development, a developing method disclosed and claimed in E. N. Wise Patent No. 2,618,552, or any other method wherein the developer material flows over a photoconductive surface which has been exposed to an image forming source, creating an electrostatic latent image configuration on or in the photoconductive surface, it is desirable to develop the latent image free from any background development thus enabling an object such as a printed document to be reproduced as a sharply defined copy without objectionable variations of graying on the copy sheet due to toner particles adhering to the sheet in non-image configuration.

Background, a term used in the art to describe toner particles on the copy sheet in non-image configuration, has been a major problem in apparatus utilizing the previously described developing method. As the highly competitive electrostatic copying industry has progressed, it has become necessary to develop copying machines which are

operative over wide ranges of environmental conditions such as from approximately 15 percent to approximately 85 percent relative humidity, temperature and altitude, and capable of increased speed of reproduction in order to compete in the market. When the rate of copy reproduction is increased, larger quantities of developer material must be provided to the photoconductive surface at increased rates to supply toner particles for developing the latent image. This increased quantity of developer material contributes to the problem this invention solves. Another important factor creating this background problem is the use of these machines in conditions of high humidity. As previously stated, the toner powder is held to the carrier material by the triboelectric field generated between these two bodies. In conditions of high humidities, this triboelectric bond between the toner powder and the carrier material is weakened due to the moisture combining with impurities in the atmosphere, becoming electrolytic and thereby conducting electric charges between the carrier material and the toner powder. Basically, the generation of triboelectric forces occurs when two neutral bodies are in the same area due to electric charges tending to move from one body to the other to equalize their Fermi energy. Since this electron flow is dependent on the potential between the two bodies, the amount of charge transferred is related to their proximity. When the carrier and toner are agitated together, as in the process of cascade development, allowing substantially all of the surfaces of the two respective bodies to come into contact with each other to increase the area over which the changes are transferred, a finite amount of electric charge is transferred between the two bodies. When the contacting surfaces are separated, part of the charge transferred initially returns in its original medium depending on the speed with which the two surfaces are separated. The speed of the separation and the relaxation time (determined by the conductivity of the better conductor) determine the net charge remaining on the separated surfaces. The water vapor electrolyte, formed at high humidity, provides a transfer media for the charges between the carrier and toner powder which weakens the triboelectric field generated between the two bodies allowing the toner particles to be more easily separated from the carrier material. As a result, the toner powder becomes freely floating when the developer material contacts or impacts with an object or comes under the influence of an electric charge opposite that of the toner powder and of a greater magnitude than that of the carrier material. Since the residual charge remaining in the non-image portion of the photoconductive surface of the xerographic drum is of a small, nearly uniform magnitude, the toner particles will not be pulled from the carrier material. However, the charged toner particles which have been freed from the carrier material by impact of the developer material with the xerographic drum will adhere to the residual charged portion of the drum.

The present invention comprises a new method for suppressing undesirable background deposition, and apparatus which supresses the deposition of toner powder in non-image configuration.

It is, therefore, an object of this invention to improve xerographic developing.

Another object of this invention is to eliminate background on photoconductive surfaces by attracting freely-floating toner powder from the photoconductive surface.

A further object of this invention is to improve xerographic developing by placing an electric charge on a portion of the developer apparatus used for introduction of the developer material onto the latent image-bearing surface.

Still another object of this invention is to improve xerographic developing by eliminating the electric field created

between the non-latent image-bearing surface and the portion of the developing apparatus used for introduction of the developer material onto this surface.

These and other objects are attained in accordance with the present invention wherein there is provided a chute, for introducing developer material onto a latent image-bearing surface, having an electrical charge opposite to the charged toner powder of the developer material and of a magnitude sufficient to prevent the toner powder from deposition on the non-latent image-bearing surface as background. This apparatus is sometimes referred to as a biased chute.

Further objects of this invention, together with additional features contributing thereto and advantages accruing therefrom, will be apparent from the following description of an embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a front elevation schematic view of a xerographic machine utilizing this invention;

FIGS. 2 and 3 are enlarged views of the developing apparatus used in the xerographic reproducing machine shown in FIG. 1 with parts broken away to better illustrate the construction thereof;

FIG. 4 is a schematic view of a xerographic developing apparatus utilizing this invention to better illustrate the electric field principles.

Referring now to FIG. 1, there is shown an embodiment of the invention in a suitable environment such as an automatic xerographic reproducing machine wherein developer material **11** is cascaded over a photoconductive surface **13** bearing an electrostatic latent image thereby forming a corresponding toner powder image. The developer apparatus is more particularly shown enlarged in FIGS. 2 and 3.

In designing a higher speed xerographic reproducing machine, it has been discovered that a high amount of background was present on copy sheets. After extensive experimentation and analysis, it was found that this background was caused by formation of a cloud of toner powder at the lip **3** of the chute **1** of the developer apparatus whereat the developer material is introduced onto the photoconductive surface or xerographic drum **12**. This toner powder cloud was being attracted onto the drum in both image and non-image configuration. As shown in FIG. 4, when a photoconductive surface is charged with a positive charge and exposed. the charge pattern is formed on the plate as shown in FIG. 4(*a*). Upon exposure to an image, the positive charges residing on or in the photoconductive surface are theoretically dissipated to the grounded base. However, it has been found in actual practice that a small residual charge remains on or in the photoconductive surface after exposure. As the distance between oppositely charged parallel surfaces is decreased, the electric field between these two surfaces is increased; and the lines of force created by the electric field are shown as in FIG. 4(*b*). Any free particle possessing a negative charge, such as a toner particle, within the influence of the electric field existing between the positive charges on or in the photoconductive plate and the grounded plate or chute lip would be accelerated along the electrostatic lines of force toward the charged plate, where it would be deposited. Because of the higher positive charge in the image areas, preferential deposition of toner powder would occur therein; but due to the electrostatic lines of force between the residual charges and the grounded chute, toner deposition will also occur in these areas resulting in background. If, however, as shown in FIG. 4(*c*) the chute is given a positive charge, a toner particle would see no accelerating force toward a non-image area. If the positive charge placed on the chute is of the same magnitude as the residual positive charge of the non-image area, it has been found that background will still occur as a result of toner particles falling on the drum surface due to gravity and being held thereto by frictional forces. An increase of the positive charge on the chute above, that of the residual charge in the non-image areas, results in an attraction of the toner powder cloud away from the electric field of the non-image areas because of the greater magnitude of the positive charged chute accelerating the toner particles away from the drum. The electrostatic charge remaining in the image areas is of a sufficient magnitude to attract the toner particles from the developer material being cascaded over the photoconductive surface to develop the electrostatic latent image. The residual electrostatic latent charges remaining in the non-image areas are not of sufficient magnitude to break the triboelectric bond between the toner and carrier, and therefore, cannot produce background.

Heretofore, xerographic developing systems of the above-described type have utilized a chute for introducing the developer material onto the photoconductive surface which was at electric ground. Due to the relatively soft surface of the photoconductive material used on the xerographic drum, it is necessary to position this chute in close proximity with the photoconductive surface to prevent abrasion due to the impact of the developer materials onto this surface. The presence of this grounded chute in close proximity with the photoconductive surface and its residual charge in non-image areas as well as image areas resulted in a strong electric field being created between the lip of the chute and the photoconductive surface as shown schematically in FIG. 4(*b*). At high speeds necessitated by new xerographic reproducing machines and high humidity, a toner powder cloud was formed at the lip of this chute. Due to this electric field between the chute and the photoconductive surface, the toner powder cloud was being deposited on the surface as background because of the impact with the photoconductive surface freeing the loosely triboelectrically bonded toner powder. By determining the residual charge on the photoconductive surface in non-image areas, and placing an electric charge on the chute of sufficient magnitude, desirably greater than that of the residual charge on the photoconductive surface, it has been found that this toner powder cloud formed at the chute lip is actually repelled from the photoconductive surface resulting in background-free copies, as shown in relation to FIG. 4(*c*).

Excellent results were found to occur when the chute used for introduction of the developer material onto the xerographic drum is positioned to allow the developer to cascade onto the drum at between approximately 25° and approximately 35° from the vertical centerline of the xerographic drum (shown as the angle θ in FIG. 2), the edge or lip of the chute being approximately 0.100 inch from the drum's surface and positively charged to a voltage of between approximately 500 volts and approximately 700 volts. Although the parameters of chute to drum clearance and voltage biasing may be varied, depending on the residual background electrostatic field, it has been determined that optimum results are achieved by cascading the developer material onto the drum at approximately 30° from the xerographic drum's vertical centerline, with the edge of the chute being spaced at approximately 0.080 inch or less from the drum's surface and biased with a positive charge of about 600 volts.

Apparatus for effecting this reduction in background is shown in the developer housing shown in FIGS. 2 and 3 as a plate **2** suitably insulated **4** from the developer housing **10** and connected by leads **5** to a source of electrical energy, not shown, to charge the chute. For further details of the developer mechanism shown in FIGS. 2 and 3, reference is had to copending application Serial No. 400,489 filed Sept. 30, 1964, in the name of Gilbert A. Aser et al.

This repulsion of the toner powder cloud yielded another new and unexpected result.

As the developer material flows over the photoconductive surface bearing an electrostatic latent image, the toner powder particles are pulled from the carrier beads by the electrostatic charge on the photoconductive sur-

face resulting in the carrier particles having a greater charge due to the removal of the oppositely charged toner powder particles. As a partially denuded carrier particle flows through the zone of development, the electrical field between the carrier particle and the toner powder deposited on the photoconductive surface becomes sufficient that the carrier particles remove previously deposited toner powder adhering to the photoconductive surface. When the toner powder cloud formed at the lip of the developing chute is repulsed by the action of the electric charge placed on the chute, the cloud is forced further back on the development zone and provides a source of low charged toner powder particles which are attracted to the partially denuded carrier material resulting in the decreasing of the magnitude of the electric field between the carrier particles and the toner powder on the photoconductive surface. This decrease in the electric field of the partially denuded carrier particles prevents their removal of the toner powder adhering to the photoconductive surface and thereby allows a greater amount of image density and resolution without formation of objectionable background.

As has been previously discussed, high humidity weakens the triboelectric bond between the toner powder and carrier material allowing the formation of a toner powder cloud which, if not for the subject invention, would cause background. At conditions of low humidity the triboelectric relationship between the toner and carrier is high, and the contribution to any print background caused by a powder cloud formed at the lip of the chute is believed slight since the increased triboelectric bond between the two bodies precludes the impact formation of the toner powder cloud. Any background formed at low humidity is believed to be cascade deposited and, therefore, not directly influenced by the subject invention. Low humidity background suppresion is achieved by the method and apparatus disclosed in copending application Serial No. 400,489 filed Sept. 30, 1964, in the name of Gilbert A. Aser et al., hereinafter referred to as a biased electrode, and reference is specifically made to the disclosure contained therein.

Since the subject invention provides a solution for controlling background caused by high humidity, and the above referenced copending application provides a solution for controlling background caused by low humidity, the combination of these two methods and apparatus in the developer mechanism of an automatic xerographic reproducing machine results in the preferred xerographic developer system. A combination of the biased chute **1** of this invention and a biased electrode **20** of the copending application yields excellent results for suppressing background over a wide range of environmental conditions when the chute is positioned to introduce developer material onto the xerographic drum at about 20° to about 35° from the drum's vertical center line (angle θ) with the chute to drum clearance being about 0.060 inch to about 0.100 inch and charged with a positive electrical bias of about 700 volts to about 900 volts. The center of the cooperating biased electrode is positioned about 1 inch to about 2 inches from the chute lip and spaced from the xerographic drum about 0.250 to about 0.500 inch with a positive electrical bias of about 1.0 kilovolt to about 3.0 kilovolts.

An optimum combination system has been found to be electrically biasing the chute with a positive charge of approximately 800±2 percent volts and positioned it to introduce developer material onto the xerographic drum at approximately 30°±2° from the vertical position and with a chute to drum clearance of approximately 0.080 inch±0.010 inch and electrically biasing the electrode to approximately 2.0±2 percent kilovolts with its center approximately 1.500 inches±0.010 inch from the chute lip further along the development zone and spacing the electrode approximately 0.375 inch±0.016 inch from the xerographic drum.

While for convenience purposes throughout this specification, reference has been made to positively charged carrier material, negatively charged toner particles, and positively biased developer chute and electrode, it is to be understood that this description of the specific nature of the charge on the respective items is not intended to limit this invention to this specific relationship. It would be possible to utilize a carrier material or toner material having a different relationship in regard to their triboelectric properties whereby the carrier could be charged negative and the toner positive, thereby requiring a similar change in the relationship of the charge on the background suppressing apparatus. Therefore, all references to positive or negative charges in this specification are to be considered as defining a relationship of similarly to oppositely charged bodies which may be either positive or negative as long as the relationship of like or dissimilar charge is maintained.

While the invention has been described with reference to the structure disclosed herein, it is not confined to the details set forth; and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.

What is claimed is:

1. Apparatus for suppressing background development in a xerographic developing system including

a chute of conductive material positioned to be adjacent to a latent image-bearing photoconductive member to introduce developer material onto the photoconductive member, and

means to apply an electrical charge to said chute of a similar polarity as the latent image of the photoconductive member and of a sufficient magnitude to allow development of the latent image substantially free of background.

2. Apparatus for suppressing background development resulting from the formation of a toner powder cloud in a xerographic developing system including

a chute of conductive material positioned adjacent a latent image-bearing photoconductive member to introduce developer material onto the photoconductive member, and

means to apply an electrical charge to said chute of a similar polarity as the latent image of the photoconductive member and of a sufficient magnitude to attract a toner powder cloud from non-image areas.

3. In a xerographic reproducing machine wherein there is relative movement between a photoconductive member bearing latent electrostatic charges in image and non-image configuration and a developing station, apparatus to suppress the development of the electrostatic charges in non-image configuration including

a chute of electrically conductive material for introducing developer material onto a photoconductive member,

said chute to be positioned adjacent to said photoconductive member bearing latent electrostatic charges in image and non-image configuration, and

means to apply an electrical charge to said chute of a polarity similar to the latent electrostatic charges of the photoconductive member and of a magnitude sufficient to allow development of the latent electrostatic charges in image configuration only.

4. The apparatus of claim **3** wherein said chute is positioned from the electrostatically charged latent image-bearing photoconductive member a distance of approximately 0.100 inch and charged to a voltage of between approximately 500 volts and approximately 700 volts.

5. The apparatus of claim **3** wherein said chute is positioned not more than approximately 0.080 inch from the electrostatically charged latent image-bearing photoconductive member and electrically charged to approximately 600 volts.

6. The apparatus of claim 3 wherein said photoconductive member is a xerographic drum, and

said chute is positioned to introduce developer material onto the xerographic drum at an angle between approximately 25° and approximately 35° from the vertical center line of the drum with the edge of the chute being spaced approximately 0.100 inch from the drum surface and electrically charged to between approximately 500 volts and approximately 700 volts.

7. The apparatus of claim 3 wherein said photoconductive member is a zerographic drum, and

said chute is positioned to introduce developer material onto the xerographic drum at approximately 30° from the drum's vertical center line with the edge of the chute being spaced not more than approximately 0.080 inch from the drum's surface and charged with a voltage of approximately 600 volts.

8. In a xerographic reproducing machine wherein there is relative movement between a photoconductive member bearing latent electrostatic charges in image and non-image configuration and a developing station, apparatus to suppress the development of electrostatic charges in non-image configuration including the combination of

a chute of electrically conductive material for introducing developer material onto a photoconductive member,

said chute to be positioned adjacent to said photoconductive member bearing latent electrostatic charges in image and non-image configuration,

means to apply an electrical charge to said chute of a polarity similar to the latent electrostatic charges of the photoconductive member and of a magnitude sufficient to allow development of only the latent electrostatic charges in image configuration,

an electrically conductive electrode positioned to be adjacent to the developed electrostatic image-bearing photoconductive member, and

means to apply an electrical charge to said electrode of a polarity similar to the polarity of the latent image of the photoconductive member and of a magnitude sufficient to remove development in non-image configuration from said photoconductive member.

9. The apparatus of claim 8 wherein said chute is positioned from the electrostatically charged latent image-bearing photoconductive member a distance of approximately 0.060 inch to approximately 0.100 inch and charged to a voltage of approximately 700 volts to approximately 900 volts, and

said electrode is positioned approximately 1 inch to approximately 2 inches from the chute and spaced from the photoconductive member approximately 0.250 inch to approximately 0.500 inch with an electrical charge of approximately 1.0 kilovolt to approximately 3.0 kilovolts.

10. The apparatus of claim 8 wherein said chute is positioned from the electrostatically charged latent image-bearing photoconductive member a distance of approximately 0.080 inch±0.010 inch and charged to a voltage of approximately 800±2% volts, and

said electrode is positioned approximately 1.500 inch± 0.010 inch from the chute and spaced from the photoconductive member approximately 0.375 inch± 0.016 inch with an electrical charge of approximately 2.0±2% kilovolts.

11. The apparatus of claim 8 wherein said photoconductive member is a xerographic drum,

said chute is positioned to introduce developer material onto the xerographic drum at an angle between approximately 25° and approximately 35° from the vertical center line of the drum with the edge of the chute being spaced approximately 0.060 inch to approximately 0.100 inch and charged to a voltage of approximately 700 volts to approximately 900 volts, and

said electrode is positioned approximately 1 inch to approximately 2 inches from the chute and spaced from the xerographic drum approximately 0.250 inch and electrically charged to a voltage of approximately 1.0 kilovolt to approximately 3.0 kilovolts.

12. The apparatus of claim 8 wherein said photoconductive member is a xerographic drum,

said chute is positioned to introduce developer material onto the xerographic drum at an angle of approximately 30°±2° from the vertical center line of the drum with the edge of the chute being spaced approximately 0.080 inch±0.010 inch from the drum surface and electrically charged to approximately 800±2% volts, and

said electrode is positioned approximately 1.500 inches±0.010 inch from the chute and spaced from the drum surface approximately 0.375 inch±0.016 inch and electrically charged to a voltage of approximately 2.0±2% kilovolts.

13. In a xerographic developing system wherein developer material flows onto a photoconductive member having electrostatic charges in image and non-image configuration, a method of developing only the latent electrostatic charges in image configuration comprising the steps of

placing a chute of electrically conductive material for flowing developer material onto a photoconductive member to be adjacent to a photoconductive member having latent electrostatic charges in image and non-image configuration,

applying an electrical charge to said chute of a polarity similar to the latent electrostatic charges of the photoconductive member and of a magnitude sufficient to allow development of only the latent electrostatic charges in image configuration,

flowing developer material onto said photoconductive member by means of said chute thereby developing the latent electrostatic charges in image configuration,

placing an electrically conductive electrode to be adjacent to the developed electrostatic image-bearing photoconductive member, and

applying an electrical charge to said electrode of a polarity similar to the polarity of the latent image of the photoconductive member and of a magnitude sufficient to remove development in non-image configuration from said photoconductive member.

14. The method of claim 13 wherein said chute is placed a distance of approximately 0.060 inch to approximately 0.100 inch from the photoconductive member and charged to a voltage of approximately 700 volts to approximately 900 volts, and

said electrode is placed approximately 1 inch to approximately 2 inches from said chute and spaced from the photoconductive member approximately 0.250 inch to approximately 0.500 inch and charged to a voltage of approximately 1.0 kilovolt to approximately 3.0 kilovolts.

15. The method of claim 13 wherein said chute is placed approximately 0.080 inch±0.10 inches from the photoconductive member and charged to a voltage of approximately 800±2% volts, and

said electrode is placed approximately 1.500 inches± 0.010 inch from said chute, spaced from the photoconductive member approximately 0.375 inch±0.016 inch, and electrically charged to approximately 2.0± 2% kilovolts.

16. The method of claim 13 wherein said photoconductive member is a xerographic drum,

said chute is placed to flow developer material onto the xerographic drum at an angle between approximately 25° and approximately 35° from the vertical center line of the drum being spaced approximately 0.060 inch to approximately 0.100 inch from the

drum's surface and electrically charged to a voltage of approximately 700 volts to approximately 900 volts, and

said electrode is placed approximately 1 inch to approximately 2 inches from said chute, spaced from the xerographic drum approximately 0.250 inch and electrically charged to a voltage of approximately 1.0 kilovolt to approximately 3.0 kilovolts.

17. The method of claim 13 wherein said photoconductive member is a xerographic drum,

said chute is placed to flow developer material onto the xerographic drum at an angle of approximately 30°±2° from the vertical center line of the drum with the edge of the chute being spaced approximately 0.080 inch±0.010 inch from the drum surface and electrically charged to approximately 800±2% volts, and

said electrode is placed approximately 1.500 inches± 0.010 inch from said chute, spaced from the drum surface approximately 0.375 inch±0.016 inch, and electrically charged to a voltage of approximately 2.0±2% kilovolts.

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PETER FELDMAN, *Assistant Examiner.*

Disclaimer

3,347,691.—*James M. Lyles,* Fairport, N.Y. XEROGRAPHIC DEVELOPMENT. Patent dated Oct. 17, 1967. Disclaimer filed Mar. 8, 1984, by the assignee, *Xerox Corp.*

Herby enter this disclaimer to claims 1 through 8 and 13 of said patent.
[*Official Gazette August 13, 1985.*]