United States Patent

Donalies

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[54] **FLUIDIZED DEVELOPMENT APPARATUS**

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[73] Assignee: **Xerox Corporation,** Rochester, N.Y.

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[51] **Int. Cl.** **G03g 13/00**

[58] **Field of Search** 118/602, 637; 117/17, 17.5

[56] **References Cited**

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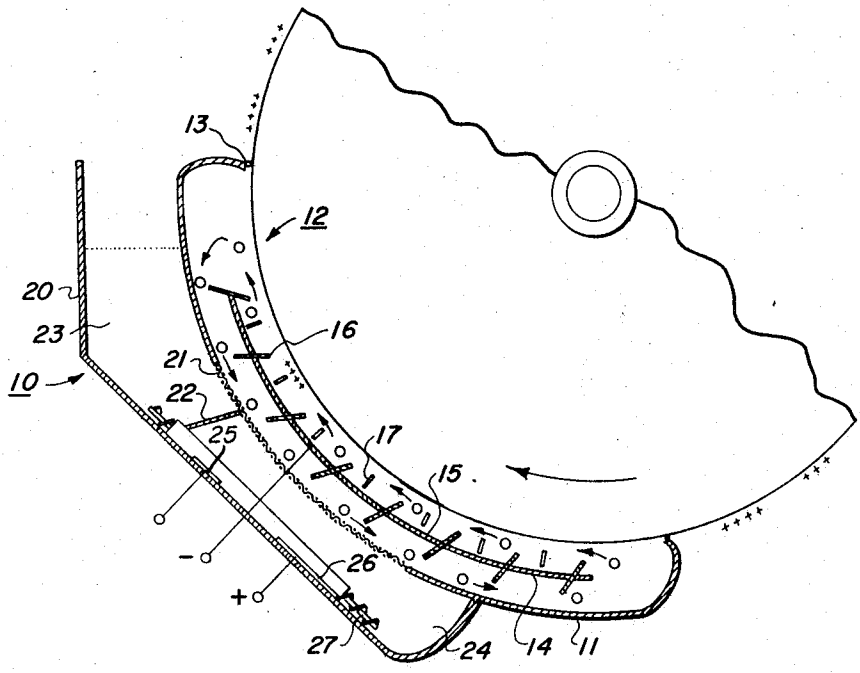
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[57] **ABSTRACT**

An apparatus for developing a latent electrostatic image wherein the developer material is circulated in a fluidized state past the image. The developer is fluidized by an orbiting member which further acts as a biased development electrode to better develop the electrostatic image. The fluidized developer flow moves in the direction of movement of the surface bearing the electrostatic image to be developed whereby the combined motion of the orbiting electrode and the movement of the image bearing surface results in the developer being propelled at an average velocity equal to the velocity of movement of the image for effective development of the leading edge thereof. Further, means are included to optimally tonerize the carrier particles in the developer while being circulated for development.

6 Claims, 3 Drawing Figures



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SHEET 1 OF 2

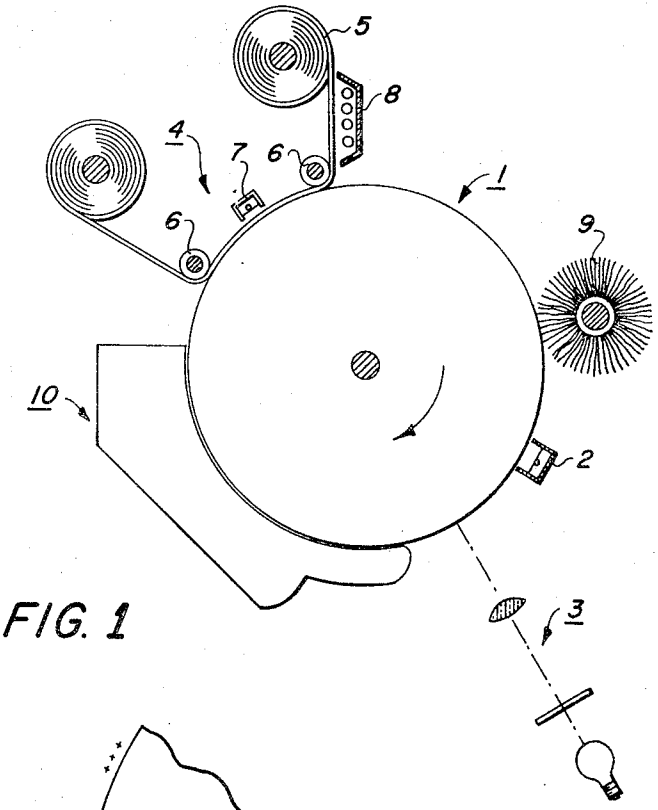


FIG. 1

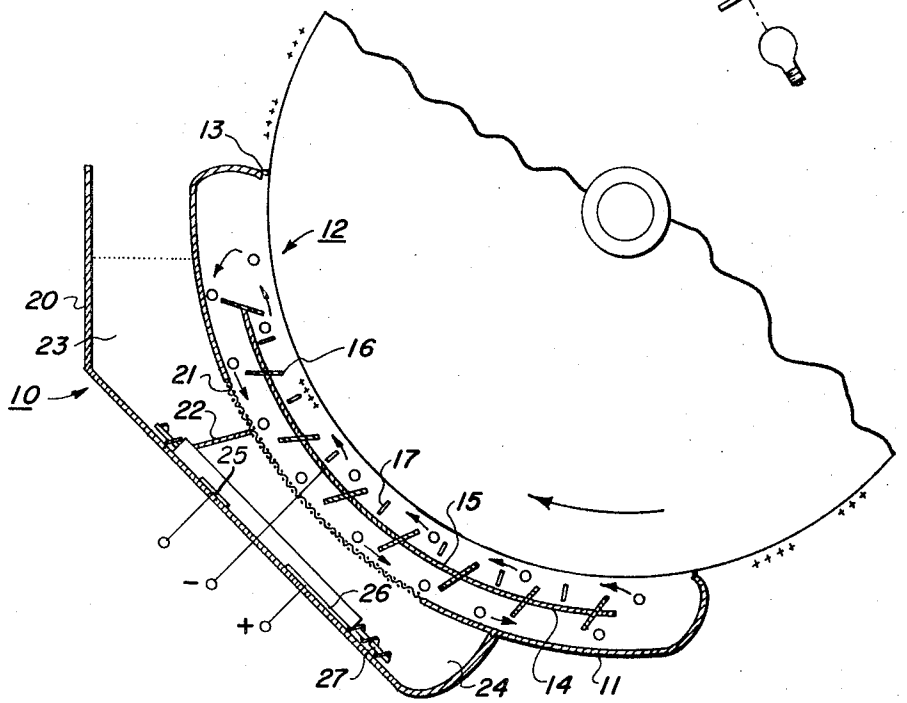


FIG. 2

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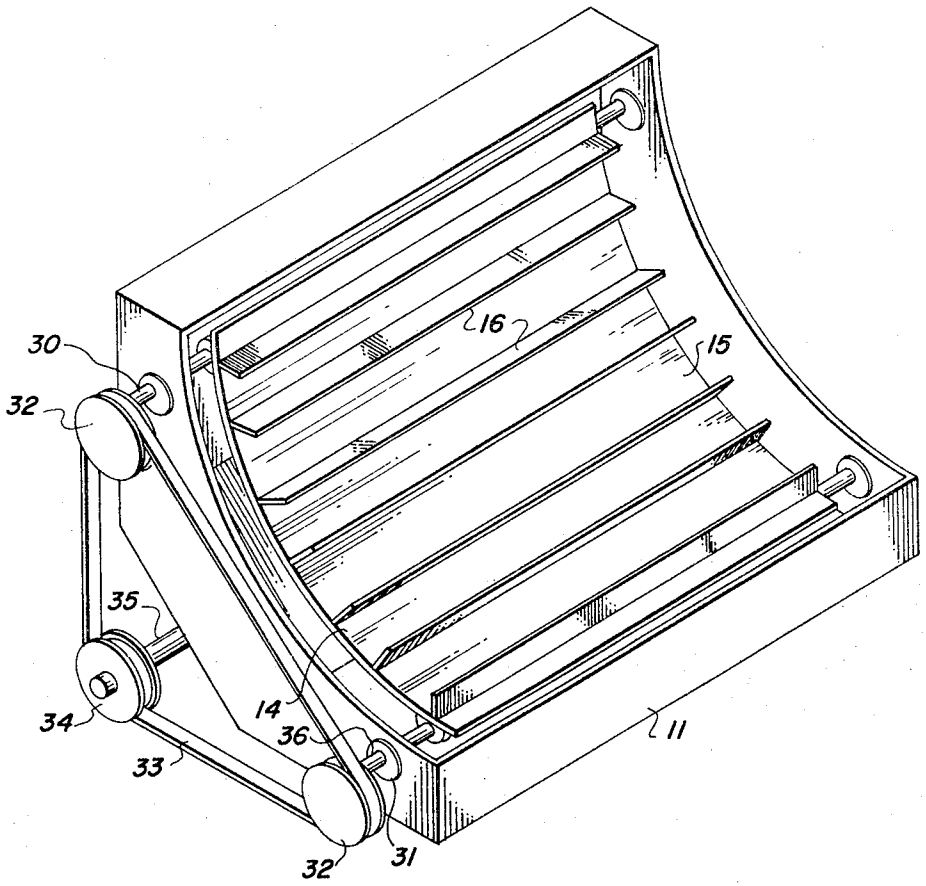


FIG. 3

FLUIDIZED DEVELOPMENT APPARATUS

BACKGROUND OF THE INVENTION

This invention relates in general to developing latent electrostatic images and, in particular, to an apparatus for fluidizing developer material as it passes a photosensitive surface supporting a latent electrostatic image to be developed.

More specifically, this invention relates to a development apparatus wherein an orbiting electrode member fluidizes the developer material as it travels adjacent the image bearing surface. The frequency and amplitude of the orbital motion of the electrode member is selected so that the fluidized developer is propelled in an uphill direction approximately the same velocity as the surface of the drum whereby the average velocity of the developer and the image are substantially equal.

In the process of xerography, a xerographic plate comprising a layer of photoconductive material on a conductive backing is given a uniform electric charge on its surface and then is exposed to the subject matter to be reproduced by the various projection techniques. This exposure discharges the plate in accordance with the light intensity reaching it thereby creating a latent electrostatic image on or in the plate. Development of the image is effected by developers which may comprise in general a mixture of suitable, pigmented or dyed, resin base powder, hereinafter referred to as toner, which is brought into contact with the plate by various well-known development techniques. During such development of the image, the toner powder is brought into surface contact with a photoconductive coating and is held there electrostatically in a pattern corresponding to the latent electrostatic image. Thereafter, the developed xerographic image may be transferred to a support material to which it may be fixed by any suitable means such as heat fusing.

Various development devices have been utilized in xerography to develop a latent electrostatic image formed on a photosensitive surface. One well-known technique of development is disclosed in U.S. Pat. No. 2,573,881 to Walkup et al., wherein toner carried by carrier particles is rolled or cascaded over the latent electrostatic image bearing surface. The carrier and toner materials are selected so that a triboelectric attraction exists between them causing the two particles to cling together and acquire an opposite charge. In practice, each carrier has numerous toner particles attracted thereon allowing them to be transferred into contact with the photoconductive surface where the greater electrostatic attraction of the latent image will overcome the triboelectric attraction between the two developer components causing toner to be stripped off the carrier and electrostatically bonded to the charged image to effect development thereof.

Several difficulties are associated with the aforementioned cascade method of development. Cascade development, for example, presents a problem in developing large image areas, since the electrostatic field of the image is stronger at the edges than in the central portion. Therefore, the lines of force at the edges are sufficient to attract toner from the carrier, but in the central portion of the image toner is not attracted to the image since the field is not strong enough to overcome the triboelectric attraction between the two components of the developer. Such a phenomenon

will result in incomplete development of the central portion of an image while the edges are comparatively better developed.

Cascade development also requires a thorough inter-mixing of developer after repeated development of an image. If inter-mixing does not occur, a defect in development referred to as image striations results because of localized carrier material becoming depleted of toner powder. Normally, toner depletion occurs in cascade development when the carrier and toner materials move past the image in one direction across the photosensitive surface. Since images normally have varying size latent charge patterns to be developed along the direction of flow, repeated development causes the developer flow moving past the more massive image areas to be depleted of toner in a greater amount than the less massive areas thereby causing certain areas of the developer flow to be depleted of toner more than others. Therefore, elaborate inter-mixing systems are required to overcome this toner depletion problem.

Further, since in cascade development the developer only passes the image in a linear direction, directional effects can occur which appear in the developed areas as streaking. Also, the carrier particles in the cascaded developer flow often stick or "bead" to the image bearing surface whereupon the beading carriers become depleted of toner material while the underneath levels of developer not in direct contact with the image retain sufficient toner to produce effective development. Such beading of the carrier to the surface is caused partly by the fact that the developer flow is not sufficiently turbulent in cascade development to create an inter-mixing between the carrier beads in contact with the image and the carriers in the underneath levels of the flow.

One attempt in the prior art to overcome some of the aforementioned problems presented by the cascade technique of development has been by effecting turbulence of the developer flow as it passes the image bearing surface. An example of such a fluidizing of developer flow is disclosed in the U.S. Pat. No. 3,357,399 to Fisher wherein a two component developer is cascaded past the image bearing surface and the flow is agitated into a fluidized state in the development zone. The fluidizing of the developer as it passes the image results in retoning of the carriers in contact with the image by effecting transfer of toner from under layers of the flow to the toner depleted carrier in contact with the image. Also, the turbulence of the flow causes some of the carrier particles not in direct contact with the image to be interchanged with the carrier particles in contact therewith further to insure that sufficiently tonerized carrier is adjacent the image. The fluidizing of the developer flow is also found to increase developer contact with the image and alleviates streaking thereof to enhance development over the cascade method.

However, prior art fluidizing development devices and cascade devices do not adequately develop the leading edge of solid image areas on a photosensitive surface wherein leading edge refers to the first portion or edge of a solid image area that is contacted by developer flow. Such a development deficiency is related in part to the degree of inter-mixing of carrier

particles from the lower layers of the developer flow and to the insufficient retoning of carrier actually contacting the image bearing surface. However, the lack of development in the leading edges of solid areas is more related to the delay of response of the lines of electrostatic force at the image edge in attracting the toner from the developer flow.

A solution to the aforementioned solid area development problem presented by the cascade process has been by the use of a development electrode to increase and realign the lines of force emanating from the center portion of the image. However, even though the utilization of a development electrode in a cascade or fluidized bed apparatus increases the development of the central portion of the image, the leading edge response delay is not overcome by an electrode whereupon the leading edges of the solid area are not sufficiently developed. The delay of response of the developer to develop the leading edges occurs because a finite time is necessary for the field of the image to attract toner from the carrier particle, and since the developer is moving past the image, an area thereof is traversed without development. Therefore, the delay of attraction of toner from the carrier by the electric field of the charge pattern results in an insufficiently developed leading edge of the solid area image. Accordingly, it is desirable in xerography to provide a development device which overcomes the response delay of development of the leading edge of solid image areas and still creates a high degree of retoning of the carrier particles contacting the image bearing surface in the development zone and substantial inter-mixing of the carrier particles in the developer flow.

Another difficulty associated with the aforementioned prior art development devices results because developer circulating in the system becomes depleted of toner as it is utilized for an extended period of time. It is, therefore, important to provide means to add toner to the carrier while it is circulating in the system and to achieve optimum tonerizaion of each carrier particle. Such tonerization has been attempted in the prior art, but the prior technology has been deficient by either causing overtoning or not achieving sufficient toning of the circulating carrier particles. Overtoning refers to a state in which the bead carries in excess of the optimum number of toner particles that the carrier can efficiently support for effective development. Excess toner on the carrier readily attaches to the non-image or background areas of the surface because the attraction between the carrier and toner is reduced due to the excess toner thereon or the toner is easily jarred loose to develop the background areas. Inadequately tonerized carrier particles, on the other hand, do not carry a sufficient amount of toner past the image areas to effect a desirable density of particles in the developed image. Therefore, it is advantageous in xerographic development devices to provide a means to optimally tonerize the carrier particles circulating in a development apparatus.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to develop a latent electrostatic image with an improved apparatus.

Another object of this invention is to improve the development of the leading edge of a latent electrostatic image.

A further object of this invention is to eliminate sticking of the carrier particles to the image bearing surface during development.

Still another object of this invention is to increase retoning of the developer as it passes the latent electrostatic image to be developed.

A still further object of this invention is to maintain an optimum amount of toner in the developer material circulating in a development apparatus.

These and other objects are obtained in accordance with the present invention wherein there is provided an effective development device which overcomes many of the aforementioned difficulties presented by the prior art development systems. The invention comprises a fluidizing development system wherein an orbiting electrode member causes a selected degree of turbulence of the developer as it flows past the surface bearing an image to be developed. The flow of the developer is effected along the direction of the movement of the surface bearing the image to be developed and the combined motion of the photosensitive member and the orbiting electrode causing turbulence of the flow produces an average velocity of the developer material along the surface equal to approximately the velocity of the image. Accordingly, a substantial constant volume of developer is fluidized next to the image and remains in contact therewith for a sufficient length of time to overcome the aforementioned delay of development of the leading edges of the image.

Further, the turbulent motion of the developer in the development zone according to the present invention produces enhanced retoning of the carrier particles in the development zone by exchange of toner from the underneath level of carrier to the beads contacting the image surface and helps alleviate the beading or sticking of beads to the electrostatic image. Also, to insure that an optimum amount of toner is present in the circulating developer as it reaches the development zone, the present invention includes a carrier retoning feature to insure that an optimum amount of toner is added to the circulating developer. Such an addition of toner to the developer circulating in the system prevents both the aforementioned underdeveloping of the image or the undesired developing of background areas of the image bearing surface presented by the prior art development methods.

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

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of a drum type xerographic machine utilizing the development device of the present invention;

FIG. 2 is a schematic illustration of an embodiment of the development device according to the present invention;

FIG. 3 is a perspective illustration of the orbital inducing mechanism utilized in the developer device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a schematic view of a drum type xerographic machine utilizing the development device of the present invention. The central element of the machine is a drum **1** mounted by suitable means and drivable in a clockwise direction by a motor M. The drum **1** comprises an outer surface with a layer of photoconductive insulating material such as vitreous selenium or any other suitable surface. A uniform electrostatic charge is placed on the photoconductive surface of the drum **1** by means of a conventional corona charge device **2**. The uniformly charged surface is then moved to exposure means **3** which may be any well-known device which will expose the charged surface to copy to be reproduced and form a latent electrostatic image of the copy on the photosensitive drum surface.

Following the formation of a latent electrostatic image of a copy, the image on the drum will move to the development device **10** according to the present invention (to be described in detail later) to bring the latent electrostatic image in contact with developer material comprising, for example, carrier particles and electroscopic toner for development thereof. After development, the visible image moves to a transfer means **4** and is transferred from the drum to a web of paper **5** or the like which is positioned into contact with the drum by rollers **6**. A second corona charging device **7** applies a charge to the back of the web **5** to facilitate transfer of the toner powder in image form. The toner image on the web then moves past the heating element **8** which permanently affixes the toner to the paper web to form a duplicate of the original copy. A rotating brush **9** contacts the drum surface after it moves past the transfer device **4** to remove any residual image material on the surface prior to a subsequent reproduction cycle. It is clear that other modes of charging, exposing, transfer, or fusing may be utilized in connection with the present invention.

Referring now to FIG. 2, there is illustrated an embodiment of the development device **10** shown in FIG. **1** according to the present invention. In particular, in FIG. **2** there is shown a housing **11** adapted to carry and circulate developer material past the latent electrostatic image on the drum in the direction of motion of the drum surface and the housing includes an open side **12** which exposes the drum surface to the interior of the housing. The housing is mounted adjacent the drum by suitable means (not shown) and the end of walls **13** seal the housing and the drum surface to prevent loss of developer therefrom. An orbiting member **14** is mounted within the housing and defines the circulating path of the developer. The member **14** comprises a curved portion **15** conforming to the curvature of the drum and mounted thereon are a series of vanes **16** which are inclined at any suitable angle to the curved portion.

Referring to FIG. **3** there is illustrated an example of a drive means to effect orbital motion of member **14**. The drive means is attached to the orbital member by four support shafts **30** which are attached at one end by suitable means near the respective corners of the orbiting member **14**. Each of shafts **30** extend through openings **31** in the housing **11**, and the other end of the shafts **30** are attached to respective pulleys **32** rotatably mounted by suitable means (not shown) wherein two pulleys are mounted on each side of the exterior of housing **11**. The shafts **30** are rotatably attached to a respective pulley **32** at a point displaced from the center of rotation thereof and the amount of displacement from the center equals the radius of the orbit of the orbiting member. Any desired displacement may be selected to effect a predetermined orbit of the orbiting member **14**.

A timing belt **33** is attached to each pair of pulleys **32** on each side of the housing to rotate the pulleys. A drive pulley **34** is rotatably mounted at a convenient location in contact with each timing belt **33** to cause movement thereof and rotate each pair of pulleys **32**. The drive pulley **34** is connected by a shaft **35** to a suitable motor means (not shown) to rotate the drive pulleys and effect movement of the timing belt at a desired speed to orbit the member **14**. The openings **31** include a sealing means **36** surrounding the respective shafts **30** therein such as, for example, a foam rubber seal to prevent loss of material from the interior of the development device. Other suitable sealing means may be utilized in connection with the present invention, if desired. The drive means shown in FIG. **3** is described for convenience of illustration, but it should be apparent that other suitable drive means which will orbit the orbiting member **14** in a suitable manner may be used in conjunction with the present invention.

The motion of the orbiting member **14** agitates the developer into a fluidized state while it is in the development zone next to the image. The amplitude and frequency of the orbiting of the member is selected to be of a magnitude to move the developer upward (as indicated by the arrows) at approximately the same velocity as the image is moving on the rotating drum **1**. This selected motion of the orbiting member combines with the inherent frictional coupling of the developer in contact with the drum surface to produce the desired upward velocity of the developer in the development zone. Further, the orbiting motion of the member **14** fluidizes the developer material to an extent needed to create an exchange of toner from the carrier in the lower layers of the developer to the beads in contact with the drum surface thereby producing improved development contact. Also, the adherence of the carriers to the drum surface is alleviated by the orbital motion of the member **14** to create interchange of the carrier particles in the flow. Therefore, the turbulent flow creates better development contact and insures that an adequate supply of toner is adhering to carrier particles in contact with the drum.

The orbiting member **14** is electrically grounded or, alternatively, may be biased by a suitable potential (not shown) to act as a development electrode to alter the lines of force emanating from the image to better develop solid areas or further eliminate development of the non-image or background areas of the surface as previously described. The frequency and amplitude of the movement of the orbiting member is selected to effect a turbulent motion of developer in the direction of movement of the drum to produce an average velocity equal to the velocity of the image on the surface. Therefore, the same volume of developer is in contact with the electrostatic image for a time sufficient to increase the development of the leading edge of the solid

area portions thereof and, therefore, overcomes the response delay normally occurring in fluidizing type development devices. A series of electrically biased electrodes 17 are mounted between the drum and the orbiting member and are connected to a suitable electrical potential to alter the electric field emanating from the image for better development of solid areas or for eliminating development of non-image areas. Also, the electrodes may be vibrated by a suitable oscillating means (not shown) to increase the fluidizing of the developer if increased turbulence were desired.

When the developer material reaches the top area of the housing after passing through the developing zone, the developer falls by gravity along a path (indicated by the arrows) along the back side of the orbiting member 14. After development the carrier particles have been denuded of a quantity of toner particles and, therefore, it is desirable to retonerize the carrier for subsequent development circulation. Toner is added to the circulating developer by means of a tonerizing housing 20 suitably mounted on the back of the housing 11. A flexible screen 21, made from, for example, a plastic material, is mounted in an opening in rear wall of the housing 11. A baffle 22 divides the tonerizing housing 20 into an upper toner sump 23 to support a supply of toner and lower toner collection compartment 24. The baffle 22 further divides the screen 21 so that a portion thereof communicates with the toner sump and the lower portion of the screen communicates with the toner collection compartment 24. The developer material after passing through the development zone falls by gravity along the screen 21 and the material is agitated in its downward movement by the motion of the orbiting member 14. The upper portion of the screen is shaken or vibrated by the falling agitated carrier particles which causes an amount of toner to be sifted through the screen 21 from the toner sump and attach to the carrier particles. The number of toner particles which attach to the carrier from the sump 23 is generally greater than the optimum amount which each carrier can support for efficient development. If such excess toner were not removed from the carrier particles, the excess may readily attach to the background or non-image areas of the drum while passing in the development zone.

The excess of toner over the optimum amount that the carrier can transport is removed by the lower portion of the screen 21 through the flexing action of the excessively tonerized carriers contacting the screen, which causes toner to be sifted into the toner collection compartment 24. In order to control the sifting action of the lower screen section, an electrical field is applied to the lower portion of the screen. This field is created by applying a bias between the orbiting member 14 and an electrode 25 mounted on the inner lower wall of compartment 24. Therefore, in order to achieve the optimum degree of tonerization of the carrier without removing a too great or too small of a number of toner particles through the lower portion of the screen 21, an electric field is created on the lower portion of the screen to regulate the number of toner particles sifting therethrough.

For convenience of illustration, electrode 25 is electrically biased positive with respect to the orbital member 14 although it is within the scope of the present invention to apply an opposite polarity or even an alternating polarity to the electrode members if so desired. The magnitude of the respective potentials of the electrode is experimentally selected to insure that the electric field placed on the screen results in a proper number of particles being sifted through the lower portion of the screen to produce optimumly tonerized carrier particles to be circulated in the development device. The excess toner, after falling into the toner collection compartment 24, is returned by a suitable transport means 27 to toner sump 23 at the top of the housing. Such a transport means comprises, for example, a suitable auger device driven by motor means (not shown) to carry the toner up to the sump. Alternatively, any other transport means may be utilized which will effectively carry the toner such as, for example, moving doctor blades or the like. A second electrode 26 connected to a suitable potential of opposite polarity than as applied to electrode 25 is mounted on the housing 24 to insure that all the toner is properly charged as it passes through the electric field created by electrode 25.

In the above description there has been disclosed an improved apparatus for effectively developing a latent electrostatic image supported on a xerographic photosensitive surface. The surface to be developed was described for convenience of illustration as being that of a xerographic drum but the invention may be used to develop other well known photosensitive members in the form of plates, belts, webs or coated papers. It is further within the scope of the present invention to orbit the electrode member at any selected amplitude and frequency other than disclosed herein which creates a developer velocity equal to the image velocity if a particular level of fluidizing were advantageous for selected development results.

While the invention has been described in reference to preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its essential teaching.

What is claimed is:

1. An apparatus for developing a relatively movable support surface bearing a latent electrostatic image with developer material comprising,

housing means to guide developer material into contact with a relatively movable image bearing surface to be developed,

developer agitating means operatively connected to the housing means and adapted to effect predetermined turbulence in the developer material to aid in conveying the developer material in an uphill direction along the relatively movable image bearing surface at substantially the same velocity thereof for better development contact therebetween, and

means for electrically biasing said developer agitating means to act as a development electrode.

2. An apparatus for developing a relatively movable support surface bearing a latent electrostatic image with developer material comprising,

housing means to guide developer material into contact with a relatively movable image bearing surface to be developed,

developer agitating means operatively connected to the housing means and adapted to effect predetermined turbulence in the developer material to aid in conveying the developer material in an uphill direction along the relatively movable image bearing surface at substantially the same velocity thereof for better development contact therebetween, and

electrode means for acting as a development electrode.

3. Apparatus for developing a latent electrostatic image on a support surface comprising,

housing means for guiding developer material into contact with a support surface to be developed,

agitating means operatively associated with said housing means for imparting a predetermined turbulence to the developer material to convey the developer material over the image bearing support surface,

toner supply means operatively associated with said housing means for adding toner to said developer material in said housing, and

means operatively associated with said housing means and said toner supply means for removing excess toner from said housing means to said toner supply means.

4. Apparatus for developing a latent electrostatic image on a support surface comprising,

housing means positioned proximately adjacent in communication with said support surface and containing a quantity of developer material,

agitating means operatively associated with said housing means for circulating developer material in said housing means over the image bearing support surface,

toner supply means operatively associated in communication with said housing means for adding toner to said developer material in said housing, and

means operatively associated with said housing means and said toner supply means for removing excess toner from said developer material in said housing means and depositing said removed toner into said toner supply means.

5. Apparatus for developing a latent electrostatic image on a support surface comprising,

housing means positioned proximately adjacent said support surface including a first portion containing a quantity of developer material in communication with said support surface and a second portion adapted to receive excess toner material removed from said developer material in said first portion,

agitating means operatively associated with said first portion of said housing means for effecting a circulation of said developer material over the image bearing support surface,

toner supply means operatively associated with said housing means in communication with said first portion thereof for adding toner material to the developer material in said housing means,

means operatively associated with said first portion and said second portion of said housing means for removing excess toner material from the developer material in said first portion and for depositing the removed toner material into said second portion, and

means operatively associated with said housing means and said toner supply means for returning toner material from the second portion of said housing means to said toner supply means.

6. In an apparatus for developing a latent electrostatic image on a support surface having housing means for guiding developer material into contact with the support surface to be developed and agitating means operatively associated with the housing means for circulating developer material over the image bearing support surface,

toner supply means operatively associated with said housing means for adding toner to developer material in said housing, and

means operatively associated with said housing means and said toner supply means for removing excess toner from said housing means to said toner supply means.

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