United States Patent [19]

Hagenbach

[11] **3,793,985**

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[54] **IMAGING SYSTEM**

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Related U.S. Application Data

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[52] **U.S. Cl.** **118/637,** 117/17.5

[51] **Int. Cl.** **G03g 13/08**

[58] **Field of Search** ...... 118/637, DIG. 5; 117/17.5, 117/DIG. 6, DIG. 8; 51/163, 314

[56] **References Cited**

UNITED STATES PATENTS

2,143,610	1/1939	Muller et al.	259/2
3,263,234	7/1966	Epstein et al.	118/637 X
2,840,923	7/1958	Behrens	34/164
3,336,903	8/1967	Point	118/624
3,140,199	7/1964	York	118/637
3,306,193	2/1967	Rarey et al.	118/637
3,147,147	9/1964	Carlson	118/637
3,393,663	7/1968	Donalies	118/637
3,008,826	11/1961	Mott et al.	96/1
3,197,328	7/1965	Jung et al.	118/DIG. 5
2,932,278	4/1960	Sims, Jr.	118/637
3,331,355	7/1967	Donalies	118/637
2,910,964	11/1959	Stavrakis et al.	118/637

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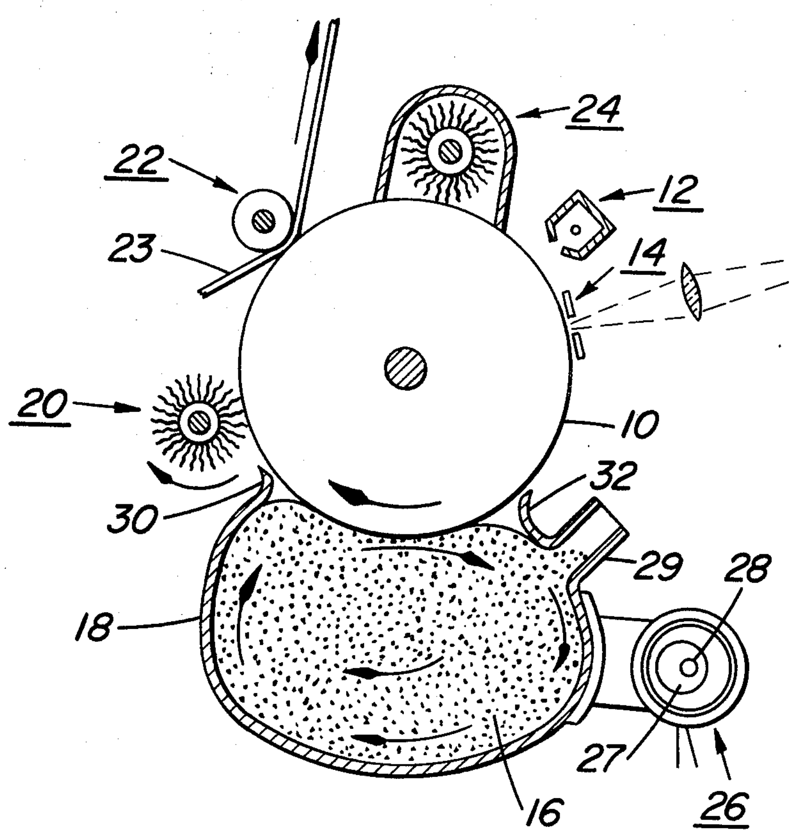
[57] **ABSTRACT**

Electrostatic latent images are developed by developer material in a chamber having a curved bottom surface by transmitting to the developer material in contact with the chamber sufficient oscillatory energy to circulate a stream of the developer material in an orbital path in a substantially vertical plane, the oscillatory energy having an axis of oscillation perpendicular to the vertical plane and contacting the upper periphery of the stream of developer material with a surface bearing an electrostatic latent image.

7 Claims, 4 Drawing Figures



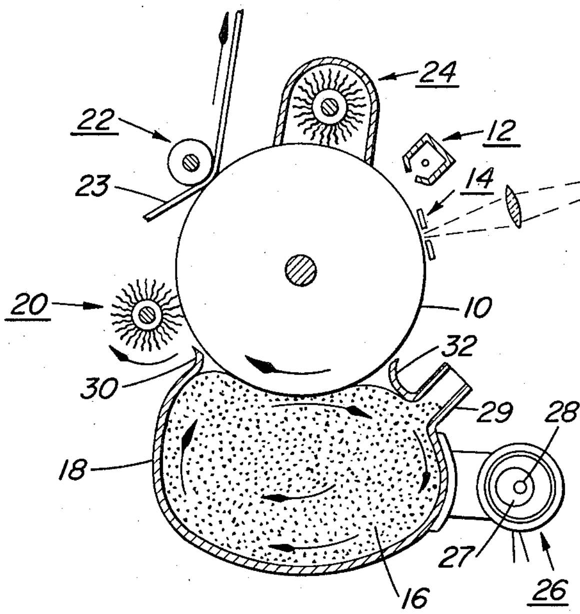


FIG. 1

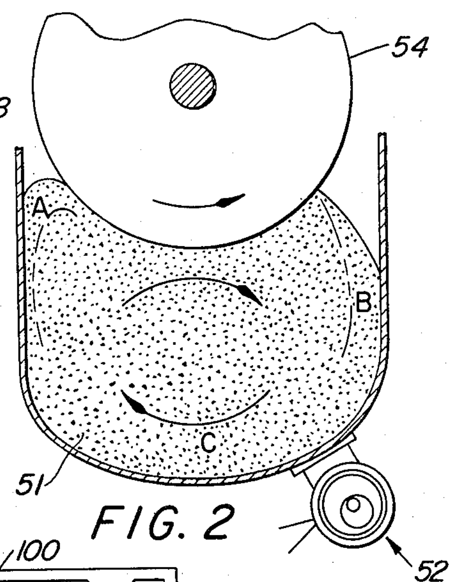


FIG. 2

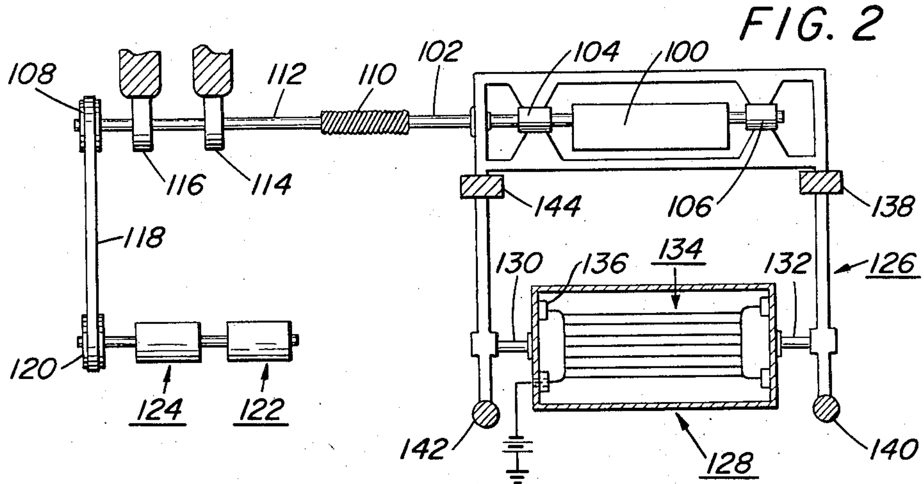


FIG. 3

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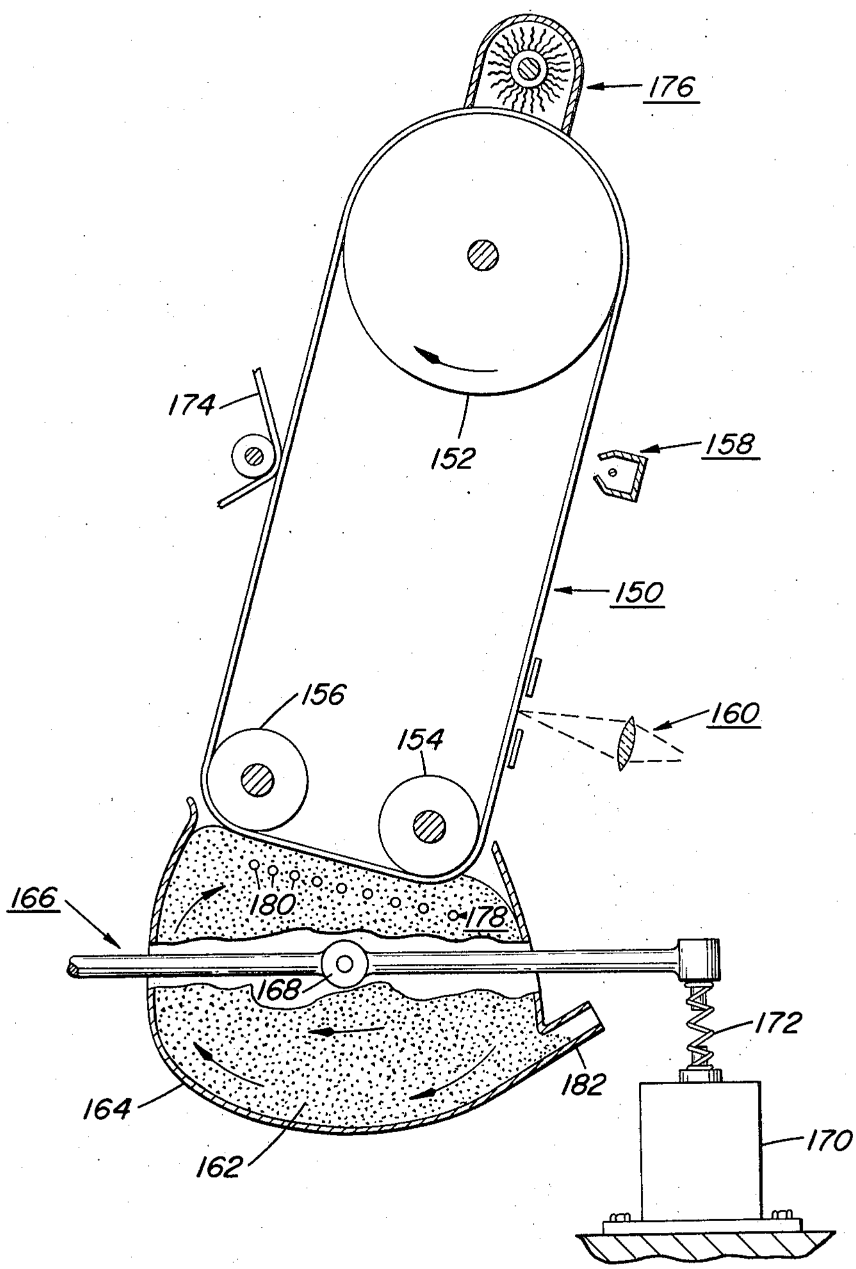
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FIG. 4

IMAGING SYSTEM

This is a division of application Ser. No. 567,475, filed in the United States on July 25, 1966, now U.S. Pat. No. 3,574,660 issued Apr. 13, 1971.

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

In the art of xerography, as originally disclosed by Carlson in U.S. Pat. No. 2,297,691 and as further described in many related patents in the field, a xerographic plate containing a photoconductive insulating layer is first given a uniform electrostatic charge in order to sensitize its entire surface. The plate is then exposed to an image of activating electro-magnetic radiation such as light X-ray or the like which selectively dissipates the charge in the illuminated areas of the photoconductive insulating layer while leaving behind a latent electrostatic image in the non-illuminated areas. This latent electrostatic image is then developed by depositing finely divided electroscopic marking particles, often referred to in the art as "toner," on the surface of the photoconductive insulating layer. Where nonreusable photoconductive insulating material is employed, the electroscopic marking material is fixed in place on the surface of the insulating material by any convenient means such as by heat fusing. Where a reusable photoconductive insulating material is used, the visible image formed by the toner particles is transferred to a second surface, such as a sheet of paper, and fixed thereon to form a permanent visible reproduction of the original image.

The most widely employed method of electrostatographic development today is cascade development. In cascade development, relatively large carrier particles are employed to transport finely divided pigmented electroscopic marking powder or toner to a latent electrostatic image. The carrier particles are triboelectrically charged with a polarity opposite that of the electroscopic powder. The electroscopic powder electrostatically adheres to the larger particles of carrier material and when cascaded over an electrostatic latent image-bearing plate, drum, belt or the like, the powder deposits in the image areas of the plate by a charge which is controlled so as to have a greater attraction for the electroscopic powder particles than the carrier material. The deposited particles form a powder image which may be permanently fixed in place or transferred to another suitable support such as a paper sheet. Illustrative patents describing the widely used cascade method of development include U.S. Pat. No. 2,573,881 to Walkup et al; U.S. Pat. No. 2,965,868 to Eichler; U.S. Pat. No. 2,937,660 to Walkup; and U.S. Pat. No. 2,990,278 to Carlson. In all of the conventional cascade systems disclosed by the foregoing patents, it is essential that a developer bucket arrangement for carrier and toner mixing and recycling be included in the development system. The presence of a bucket conveyor contributes greatly to the size and cost of an electrostatographic imaging system. Further, passage of the bucket conveyor system through the developer supply during the mixing and recycling operations promotes the formation of grit and rapidly reduces developer lift. An additional problem encountered in the conventional cascade process is the occurrence of developer starvation. Starvation occurs in the downstream region of the development zone after

much of the electroscopic marking particles carried by the carrier particles have been removed by the latent electrostatic image. The depleted or starved developer contributes to the formation of low density images. It is also well known that during the cascade process, a powder cloud is generated as the carrier beads and unused toner particles drop by gravity to the bottom of the development chamber. This powder cloud often causes the formation of an undesirably high background deposit in non-image areas. In addition, drum and carrier abrasion is promoted by the constant impact of carrier and toner particles cascading across the surface of the drum or plate. A further requirement in existing cascade development systems is the need for thorough and uniform mixing of toner and carrier particles during the recycling and replenishing cycles.

Although the cascade process has proved to be a most effective process for producing excellent high quality reproductions of line patterns, faithful reproductions of original images comprising solid areas, halftones, continuous tones or the like, cannot be produced with the conventional cascade development system. It has been found that cascade process reproductions of large back or dark areas are not developed uniformly throughout their entire area but are developed more heavily around the edges than in the central portions of the area. Apparently, in order for the electroscopic marking powder to deposit on the electrostatic latent image and adhere thereto, it is necessary that it be brought within the influence of electrostatic lines of force emanating from the image pattern. These lines of force extend between points of different potential and commonly extend between points on the image-bearing surface that have a potential gradient between them. When the area of an image pattern has very low contrast from one point to a nearby point, the potential gradients are small and the lines of force set up are consequently less effective during development. This is particularly true in large solid image areas where there are no nearby potential gradients on the image surface. The net effect is that frequently no development takes place in the center portion of such areas of uniform potential. It has been found that positioning a development electrode in close proximity to the image-bearing surface during development improves the continuity of the development in low contrast image areas. The use of such electrodes in electrostatographic development processes is well known and disclosed, for example, in U.S. Pat. Nos. 2,573,881 and 2,777,418. The improved continuity of development apparently is due to the presence of the electrode which supplies a nearby potential gradient for setting up the electrostatic lines of force. However, systems in which development electrodes are employed suffer serious deficiencies in certain areas. Because the development electrode must be spaced as closely as possible to the image-bearing surface for most effective use, the developing material employed in cascade processes tends to bunch-up or jam between the image-bearing surface and the development electrode with consequent smudging of the image as well as scratching and abrasive deterioration of the image bearing surface. Further, the flow of developing material over the image-bearing surface is often impeded by the presence of development electrodes thereby limiting the speed of the development process. Thus, there is a continuing need for a better system for developing latent electrostatic images.

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

It is another object of this invention to provide asystem of electrostatographic development which reduces the effects of abrasion presently encountered in cascade development.

It is a further object of this invention to provide an electrostatographic developing system which produces images having less background than images produced by conventional cascade development techniques.

It is yet a further object of this invention to provide a developing system which is simpler and more compact than conventional developing systems.

It is another object of this invention to provide an improved development system which prevents developer starvation.

It is another object of this invention to provide a high speed solid area development system.

It is still another object of this invention to provide a developer circulating system which promotes more rapid and uniform mixing of toner and carrier particles.

The foregoing objects and others are accomplished, generally speaking, by providing an electrostatographic development system wherein a latent image-bearing surface is brought into contact with a stream of individually vibrating developer particles moving in a generally cyclical path. Movement of both the individual developer particles and the stream is effected by a device which imparts regular oscillatory motion to an arcuate developer chamber within which the developer particles are contained. In this invention, as hereinafter illustrated by a xerographic drum, a drum carrying a latent electrostatic image is at least partially immersed in a flowing stream of developer material comprising conventional electroscopic marking particles with or without carrier material.

Electroscopic marking particle and carrier compositions are well known to those skilled in the art. Representative patents in which these developer compositions are disclosed include U.S. Pat. No. 2,618,551 to Walkup, U.S. Pat. No. 2,618,552 to Wise, U.S. Pat. No. 2,633,415 to Walkup and Wise, U.S. Pat. No. 2,659,670 to Copley, U.S. Pat. No. 2,788,288 to Rheinfrank and Jones, and U.S. Reissue Pat. No. 25,136 to Carlson. Generally, the toners have an average particle diameter between about 1 and about 30 microns whereas the relatively larger carrier beads have an average particle diameter from about 50 to about 700 microns in diameter. However, if toner particles are employed without a carrier, larger toner particles are preferred for optimum flow characteristics.

According to the present invention, developer material is brought into contact with an image-bearing surface in a manner such that the number of contacts between the developer particles and the image-bearing surface is increased over former techniques. The increase in the number of contacts is achieved by the employment of a stream of individually vibrating developer particles moving in a cylical path. Most, if not all, of the developer particles in the mass individually possess a vibratory movement not necessarily parallel to the stream path. The vibratory movement of the particles effects both fluidized suspension of the individual developer particles and cyclical movement of the total mass of developer particles. The individual developer particles appear to vibrate in tiny orbits rather than in a linear path and may be the principal reason for the improved mixing and cyclical developer stream movement achieved in this system. Due to both the constant vibratory motion of the individual developer particles and the generally cyclical movement of the developer mass, a greater number of different carrier beads and toner particles are brought into contact with each incremental area of the latent image-bearing surface during a given unit of time. The circulating developer bath is contained within a rapidly oscillating chamber having a bottom surface curved generally concentrically about the electrostatographic drum axis. Although the axial cross section of the chamber comprises a roughly arcuate configuration, it should be understood that the outer shell of the developer chamber may be of any suitable shape which allows the conditions necessary for development as set forth in the specification to occur. Typical shapes include "bowl" or "U" shaped developer chambers or variations thereof. The developer chamber may be modified by making the upstream end of the chamber wider than the downstream end or vice versa. Further, baffles may be employed in the developer housing to promote uniform flow of the developer stream. The particular modification, of course, would depend upon the direction of the circulating developer stream and the direction of electrostatographic drum rotation. The flow direction of the circulating developer stream depends upon the direction of oscillatory energy imparted to the developer chamber. The oscillatory energy imparted to the developer chamber has an axis of oscillation parallel to the axis of developer stream motion. The direction of developer stream flow may be reversed by reversing the direction of oscillation. Oscillatory motion may be imparted to the chamber by any suitable means capable of producing high frequency oscillatory energy. Typical well known sources of high frequency oscillatory energy include electric motors having fixed or adjustable eccentric weights attached to the motor armature shaft and ball type vibrators such as the Vibrolator vibrators sold by the Martin Engineering Company. The total mass of developer material in the developer housing, the developer stream velocity desired, the shape of the developer housing, the frictional characteristics of the particular developer material being employed, and the total mass of equipment actually being vibrated all affect the degree of oscillatory amplitude and frequency necessary to achieve the desired developer stream movement. Typical oscillatory frequencies include a range from about 1,000 to about 4,000 regular oscillatory vibrations per minute. Typical vibration amplitudes include from about 0.0001 to about 0.25 inches. It is apparent, however, that the energy loss during transmission of the vibratory energy from the energy source to the developer housing should be considered when determining the particular amplitude to be employed. In general, the stream velocity increase with an increase in frequency. The quality of the developed images appears to be relatively unaffected by differences between the drum surface speed and the developer stream speed. Although it is not entirely clear, the formation of high density images without an attendant smearing may be due to a combination of an absence of developer starvation and the gentle fluid-like characteristics of the developer mass.

Any suitable developer material such as those described above may be employed. Typical toner concentrations in two component developer systems include from about 0.5 to about 2 per cent by weight. The toner particles may be replenished by the addition of new toner material at either end of the developer chamber. Addition of the fresh toner material at the downstream end of the circulating developer material is preferred when a carrier material is employed because the carrier material and the fresh toner material are more thoroughly mixed prior to contact with the latent image-bearing surface. The supplementary toner material may also be added to the developer stream at any point intermediate the ends of the developer chamber; maximum mixing occuring when the new toner material is added at the downstream end of the chamber.

Any suitable photoconductive surface may be employed in the system of this invention. Well known photoconductive materials include vitreous selenium, organic or inorganic photoconductors embedded in a non-photoconductive matrix, organic or inorganic photoconductors embedded in a photoconductive matrix or the like. Representative patents in which photoconductive materials are disclosed include U.S. Pat. No. 2,803,542 to Ullrich, U.S. Pat. No. 2,970,906 to Bixby, U.S. Pat. No. 3,121,006 to Middleton, U.S. Pat. No. 3,121,007 to Middleton, and U.S. Pat. No. 3,151,982 to Corrsin.

It is obvious that any suitable electrostatographic surface may be employed for carrying out the method of the instant invention, as for example, a drum, flat plate, flexible belt and the like. The surfaces may either be movable through the development zone or fixed with respect thereto.

The advantages of this improved electrostatographic development system will become even further apparent upon consideration of the following disclosure of the invention; particularly when taken in conjunction with the accompanying drawings wherein:

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

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

FIG. 3 is a schematic plan view of a modified arrangement of apparatus for effecting cyclical movement of the developer particles.

FIG. 4 is a schematic sectional view of an alternative form of the apparatus shown in FIG. 1.

Referring now to FIG. 1, reference character **10** designates a rotatable xerographic drum having an outer layer of photoconductive insulating material such as vitreous selenium. The drum **10** is mounted to move in the direction indicated by the arrow. The surface of drum **10** is uniformly charged by a conventional corona charging device **12** and exposed to a pattern of activating electromagnetic radiation at **14.** The latent electrostatic image formed by the exposure means **14** is developed by rotating drum **10** through a stream of circulating developer material **16** comprising substantially spherical carrier beads and suitable electrostatic marking particles contained within chamber **18.** As the latent image-bearing drum surface moves through the moving stream of vibrating developer particles **16,** the latent image is subjected to contact with developer particles constantly moving into and out of contact with the latent image as well as across the image surface in a compound movement. This movement dissipates the effects of undertoned or detoned carrier particles by causing toned carriers to contact the image-bearing surface at different points along its path of movement through the development zone. This constantly occurring exposure to new carrier particles greatly reduces the possibility of forming low density images. Fur brush **20** may optionally be employed to dislodge unwanted carrier beads at the fringes of developed image areas without adversely affecting the developed image. Brush **20** may, if desired, be eliminated when carrier beads having a diameter greater than about 500 microns and a density of 5 or more are employed. The developed image may be transferred at a transfer station **22** to a moving paper web **23.** A transferred powdered image may be permanently fixed to the paper **23** by any conventional means such as heat fusing. The drum **10** may then be cleaned of any excess toner particles at a cleaning station **24** thus completing the entire charging, exposing, developing, transferring, and cleaning cycle.

Both the generally cyclical movement of the total mass of the developer particles and the vibratory movement of individual developer particles in the mass are effected by any suitable source of oscillatory energy such as the schematically illustrated means **26** fastened to the developer housing **18.** For example, a regular oscillatory movement may be imparted to the developer particles by attaching to developer housing **18** a motor having unequal eccentric weights **27** mounted on the motor drive shaft **28.** Fresh toner may be added at inlet **29** as the circulating developer material becomes depleted of toner particles. The vibratory motion of individual developer particles circulating in developer housing **18** promotes rapid and uniform mixing of carrier particles and newly added toner particles. The geometry of the developer housing **18** and the direction of orbital vibration imparted to the housing **18** may be altered to control the direction of movement of the developer stream. High speed developer machines require rapidly moving streams of developer material. In order to avoid toner starvation, stagnent areas adjacent the image-bearing surface are preferably avoided. When a uniform and rapidly moving stream is desired, curved lips **30** and **32** should the employed to impart a "bottle" configuration to the housing **18.** The curved lips **30** and **32** eliminate the formation of stagnant areas which often occur in the developer material on one or both sides of the developer housing **18.** The curved lips **30** and **32** function as guides which promote gradual rather than abrupt changes in direction of the developer mateiral **16** thereby eliminating eddy currents.

FIG. 2 is an enlarged view of a modified form of the developer housing shown in FIG. 1. The modified housing **50** has a generally U-shaped configuration wherein the sides of the U do not contain a curved lip. The small arrows in the developer bath **51** indicate the direction of flow of the developer material. Due to the configuration of housing **50,** zones of different developer velocities occur. These zones are indicated by the letters A, B and C. The velocity of the mass of developer particles in Zone B is very high as a result of the influence of gravity and the energy provided by oscillatory vibrator **52.** The rapidly moving developer stream in Zone B promotes the formation of dense toner images by providing a constant supply of fresh toner to the undeveloped image-bearing surface of drum **54.** The developer particles in Zone A move at a relatively low velocity thereby arresting powder cloud formation. Maximum utilization of apparatus employing the type of developer housing shown in FIG. 2 is achieved by rotating the xerographic drum 54 in a direction substantially opposite and parallel to the direction of the developer stream flow. However, the direction of movement of the drum and developer stream may, if desired, be nonparallel. The retardation of powder cloud formation in Zone A contributes to the establishment of an ideal environment for the developed image-bearing surface as it emerges from the developing zone.

Although a particular drum rotation direction and developer circulation direction are depicted by arrows in FIGS. 1 and 2, good quality images are obtained by reversing the direction of the drum and/or the developer stream. The direction of the developer stream may be reversed by merely reversing the orbital direction of the oscillatory energy applied to the developer housing. Where the orbital energy is applied directly to the developer housing by means of a rigidly attached electric motor having an offset weight or weights secured to the motor armature shaft, the direction of the developer stream may be reserved merely by reversing the direction of rotation of the electric motor shaft. The speed of the developer stream relative to the surface of the moving may be less than, equal to or greater than the speed of a drum surface. The speed of the drum may be regulated by any conventional speed regulator. The speed of the developer stream may be regulated by adjusting the frequency of oscillatory energy applied to the developer housing. Generally, the circulating velocity of the developer stream increases with an increase in oscillatory energy frequency. Similarly, the velocity of the developer particles circumferentially positioned in the developer housing increases with an increase in developer mass. The particular drum and developer speed to be employed depends upon the drum diameter, the direction of drum rotation, the direction of developer stream circulation and the length of the development zone (i.e., the distance a point on the surface of a drum travels while in contact with the developer stream).

In FIG. 3, another embodiment of the invention is shown wherein an oscillatory energy source is driven by means remote from the developer housing. In this embodiment, eccentric weight 100 is mounted on a shaft 102 which in turn is journaled in support bearings 104 and 106. Shaft 102 is connected to pulley 108 by a flexible spring or cable 110 and shaft 112. Shaft 112 is supported by bearings 114 and 116. Rotation of pulley 108 is effected by belt 118 driven by pulley 120. Pulley 120 is connected to a reversible motor 122 through a variable speed drive mechanism 124. The oscillatory energy created by rotation of eccentric weight 100 is transmitted through shaft 102 to bearings 104 and 106. Since bearings 104 and 106 are rigidly secured to frame 126, the frame 126 oscillates at the same frequency as the bearings 104 and 106. Developer housing 128 is secured to frame 126 by means of shafts 130 and 132. The oscillatory energy transmitted from the eccentric weight 100 through bearings 104 and 106 to the frame 126 is further transmitted to developer housing 128 through supporting shafts 130 and 132. A development electrode 134 may optionally be attached to the developer housing 128. The development electrode 134 is supported by insulators 136. The development electrode may be electrically connected to a suitable reference potential or to ground as is well known in the art. To facilitate oscillation with minimum restraint, frame 126 is suspended from a support member (not shown) by means of rubber mounts 138, 140, 142 and 144. Spring or cable 110 also functions as a means to minimize loss of oscillatory energy.

In FIG. 4, another embodiment of the invention is shown wherein a flexible xerographic belt supported by three drums is used to permit full frame exposure. In this embodiment, flexible belt 150 supported by rotating drums 152, 154 and 156 is charged to a uniform potential by a corona charging device 158. The belt 150 is then exposed to activating electromagnetic radiation at 160. Development of the thus formed latent electrostatic latent image is effected by bringing the latent image-bearing surface into contact with a moving stream of developer particles 162 contained within arcuate chamber 164. Oscillatory energy is transmitted from a suitable source (not shown) through frame 166 and supporting shaft 168 to the developer housing 164. The frame 166 is insulated from a rigidly fixed supporting member 170 by means of helical springs 172. The toner image on the belt 150 is transferred to a transfer web 174 and the image subsequently made permanent by heat fusing. The belt 150 is then cleaned at brush 176 after the developing and image transfer cycle are completed.

A development electrode, schematically shown at 178, may be positioned in the developer stream 162 adjacent and parallel to the belt 150. The development electrode comprises a series of development electrode wires 180 which span the width of the belt 150. These electrode wires 180 may be secured to insulators as shown in FIG. 3. The electrode wires 180 may be either electrically connected to a suitable reference potential (not shown) or to ground for the establishment of an electric field adjacent the surface of belt 150. Since the development electrode 178 is secured to oscillating developer housing 164, the electrode 178 also oscillates and imparts oscillatory energy to the developer material 162. Alternatively, the electrode may be secured to a suitable stationary support (not shown). A stationary development electrode is preferred at low drum speeds and low oscillatory vibration frequencies because the formation of striated toner images corresponding to the shape of the development electrode are avoided. Although the development electrode is depicted in FIG. 4 as wires 180 extending transverse to the direction of the movement of belt 150, the wires may optionally be rotated to any position up to 90° (not shown). Further, any other suitable development electrode configuration such as a slotted plate or screen may be substituted for development electrode 178. Development electrode wires positioned substantially parallel to the direction of belt travel are preferred when the electrode is stationary because developer particle jamming between the belt surface and electrode is substantially eliminated. As the developer composition becomes depleted of toner, additional toner material may be added through inlet 182.

The following examples further specifically define and describe the system of the present invention for developing electrostatographic images in stream of vibrating developer material moving in a generally cyclical path. Parts and percentages are by weight unless otherwise indicated. The examples below are intended to illustrate the various preferred embodiments of carrying out the invention.

EXAMPLE I

A xerographic drum coated with a 50 micron layer of vitreous selenium is corona charged to a voltage of about 500 volts and exposed to activating electromagnetic radiation to form a latent electrostatic image on its surface. The selenium drum is then rotated while in contact with a stream of vibrating developer material contained in a developer chamber such as that illustrated in FIG. 2 containing 600 micron coated glass beads and 1 per cent of a pigmented toner. The drum is rotated at a linear surface speed of approximately 4 inches per second in the same direction as the developer stream flow in the development zone. An electric vibrator securely attached to an external surface of the developer housing is operated to provide an oscillatory vibration frequency of about 1,200 cycles per minute. After a single rotation through the developer stream, the image on the drum is transferred to a sheet of paper and fixed by heat fusing. An excellent image is obtained.

EXAMPLE II

A xerographic drum coated with a 50 micron layer of vitreous selenium is corona charged to a voltage of about 400 volts and exposed to a light and shadow image to form a latent electrostatic image. The selenium drum is then rotated while in contact with a stream of vibrating developer material contained in a developer chamber such as that illustrated in FIG. 2 containing 250 micron coated steel beads and 1 per cent of a pigmented toner. The drum is rotated at a linear surface speed of approximately 7 inches per second. A regular oscillatory motion was imparted to the developer chamber by an electric motor having unequal eccentric weights on the armature shaft. The motor was securely attached to an external surface of the developer chamber and operated at about 1,750 revolutions per minute to provide an oscillatory vibration frequency of about 1,750 cycles per minute. After a single rotation through the developer stream, the image on the drum is transferred to a sheet of paper and fixed by heat fusing. A dense unsmeared image is obtained.

EXAMPLE III

A xerographic flexible belt coated with 30 micron layer of selenium is corona charged to a voltage of about 700 volts and exposed to a light and shadow pattern to form a latent electro-static image on its surface. The portion of the xerographic belt bearing the electrostatic latent image is brought into contact with a stream of vibrating developer material within witin an electroded developer chamber such as that illustrated in FIG. 4 containing 500 micron coated glass beads and 2 per cent of a pigmented toner. The electrode comprises wires, each 10 mils in diameter, spaced at 3/16-inch intervals and spaced 1/32-inches from the surface of the xerographic belt. The electrode is rigidly secured to the ends of the developer chamber and are biased with a 350 volt bias. The surface of the belt is caused to progress over the developer material at a speed of approximately 10 inches per second in the same direction as the developer flow. An electric vibrator such as that illustrated in FIG. 3 is employed to provide an oscillatory vibration frequency of about 2,500 cycles per minute. After a single pass through the developer stream, the image on the belt is transferred to a sheet of paper and fixed by heat fusing. An image having good solid area coverage is obtained.

Although specific components, proportions and procedures have been stated in the above description of the preferred embodiments of the noval developing system, other suitable materials, as listed above, may be used with similar results. Further, other materials and procedures may be employed to synergize, enhance or otherwise modify the novel system. For example, the coefficient of friction between the developer material and the surface of the xerographic drum and/or the surface of the developer chamber may be controlled by varying the composition of the developer and/or the surface of the xerographic drum of developer chamber to yield optimum results not inconsistent with good image development.

Although corona charging is used in the examples, it should be noted that any suitable method of forming an electrostatic latent image is deemed within the scope of this invention. Additionally, any suitable source of regular oscillatory vibrational energy such as the well known roller type and turbine type vibrators may be employed to effect cyclical movement of the developer stream.

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

What is claimed is:

1. An apparatus for developing electrostatic latent images on a surface with particulate developer material, said apparatus comprises a U-shaped developer chamber having an inner surface including an inner arcuate bottom surface, said developer chamber is positioned to and below at least a portion of a latent electrostatic image-bearing member and means coupled with said developer chamber to impart oscillatory energy to said chamber, sufficient to transmit to particulate developer material in contact with said inner surface, sufficient non-linear oscillatory motion thereby defining a circuitous path to circulate developer material as a flowing stream in an orbital path in a substantially vertical plane around the central portion of said chamber, said oscillatory motion having an axis of oscillation perpendicular to said vertical plane, having an axis of oscillation parallel to said inner arcuate bottom surface, and having a frequency of from about 1,000 cycles per minute to about 4,000 cycles per minute whereby said inner arcuate bottom surface of said chamber defines the curved lowermost periphery of said orbital path, a zone of rapidly moving developer material along a portion of the upper periphery of said stream and a zone of slowly moving developer material along another portion of said upper periphery of said stream being formed by the confining of said flowing stream of developer material in said U-shaped chamber.

2. An apparatus as set forth in claim 1 wherein a development electrode constructed of conductive material is positioned beneath and sufficiently close to said surface to affect the field of said electrostatic images.

3. The apparatus as set forth in claim 2 wherein means are provided to bias said development electrode to a potential of the same polarity as that on the image areas of the latent electrostatic image-bearing member.

4. An apparatus as set forth in claim 2 wherein said development electrode is grounded.

5. An apparatus as set forth in claim 2 wherein said development electrode is apertured to permit the movement of developer material therethrough.

6. An apparatus as set forth in claim 2 wherein said

development electrode comprises a series of spaced parallel conductive wires.

7. An apparatus as set forth in claim 1 and further including developer replenishment means operatively associated with said developer chamber.

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