United States Patent

Lyles et al.

[15] 3,638,610

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[54] DEVELOPMENT APPARATUS

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[52] **U.S. Cl.** **118/636,** 118/637, 117/17.5

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

[58] **Field of Search** 118/636, 637; 117/17.5

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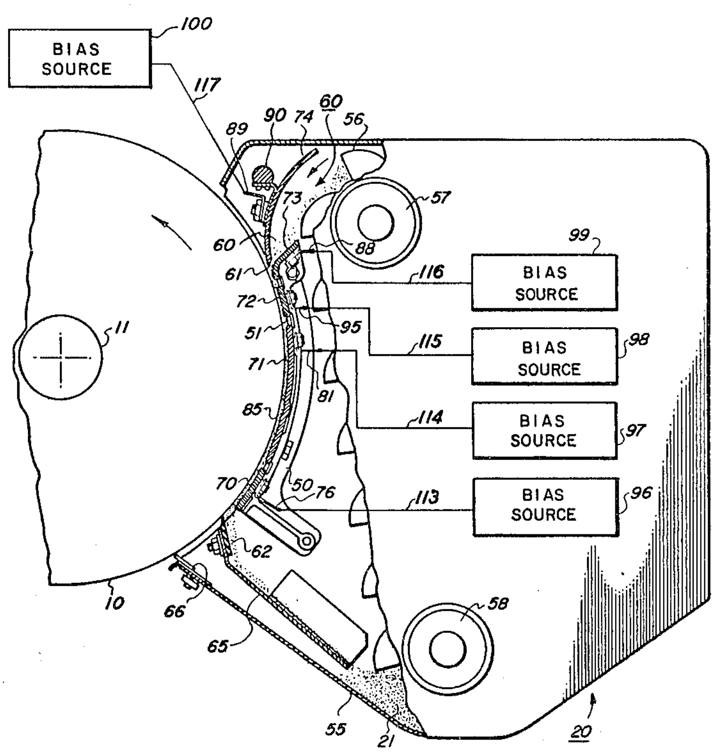
[57] **ABSTRACT**

Apparatus for developing a latent electrostatic image on an image support member in which a series of electrically isolated electrodes are supported in close parallel relation with the member to form a continuous, enclosed, development zone. A continuous flow of two-component developer material is passed through the development zone and the electrodes biased so that the distribution of material in the flow stream is controlled to first develop and then clean the photoconductive plate surface.

14 Claims, 5 Drawing Figures



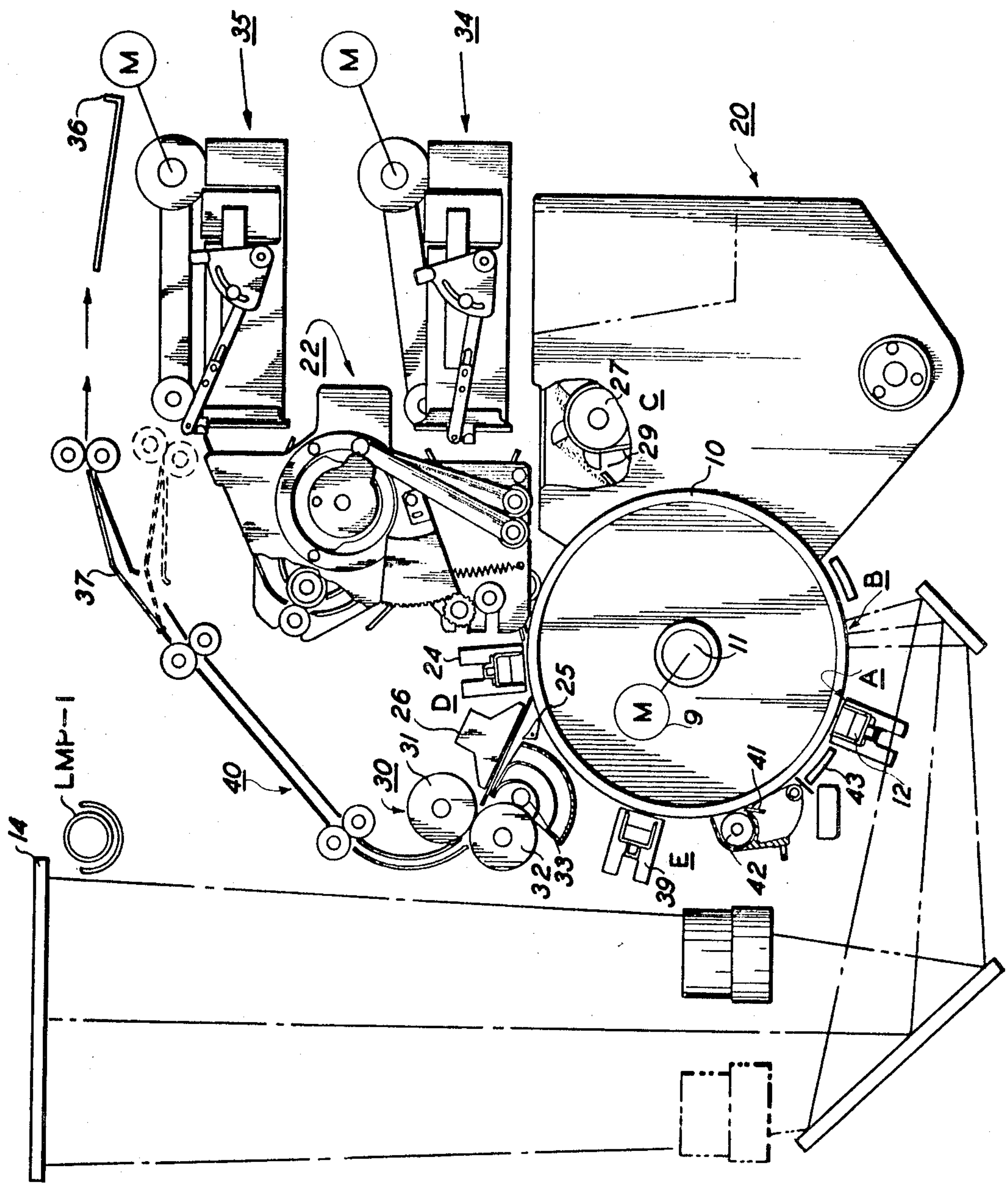


FIG. 1

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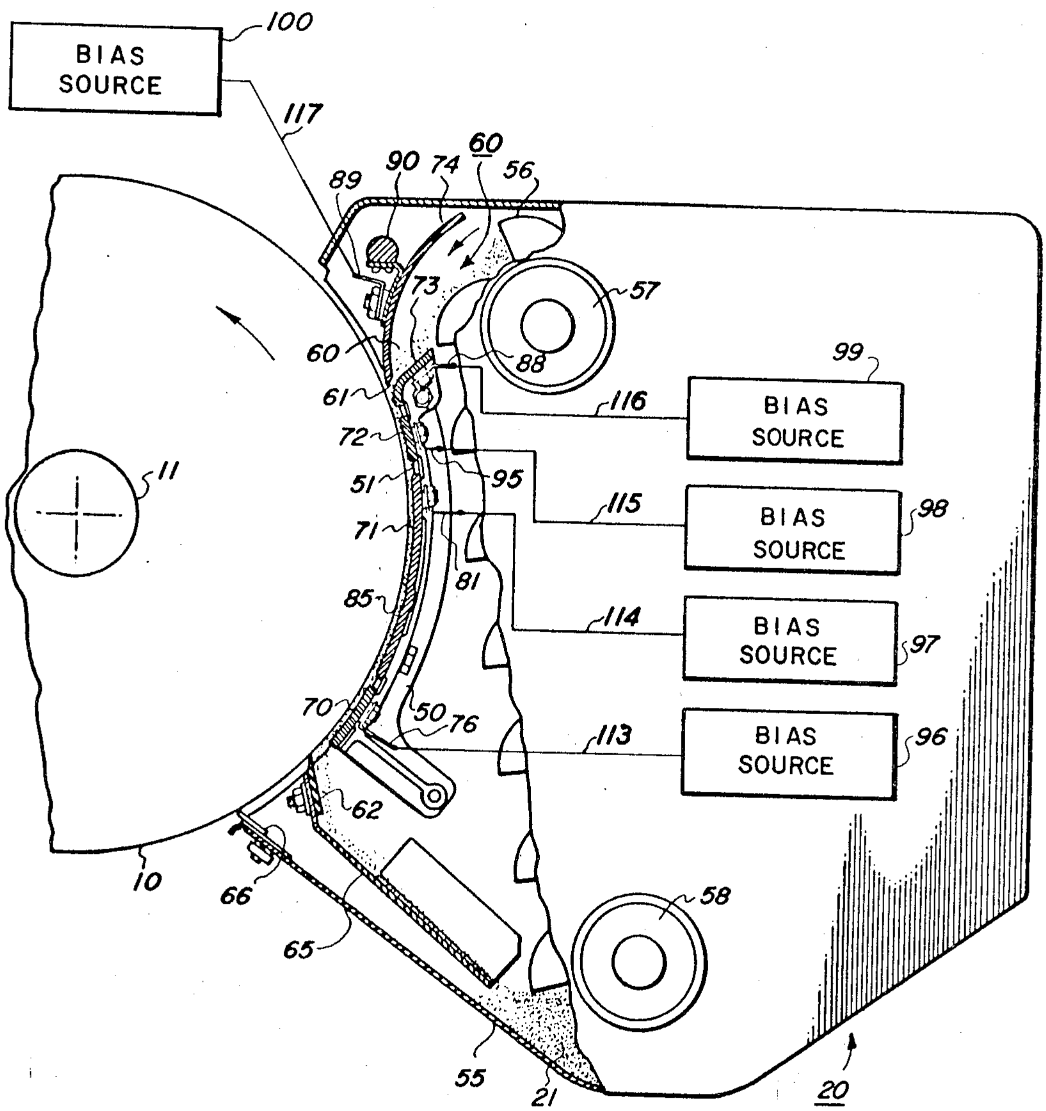
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FIG. 2

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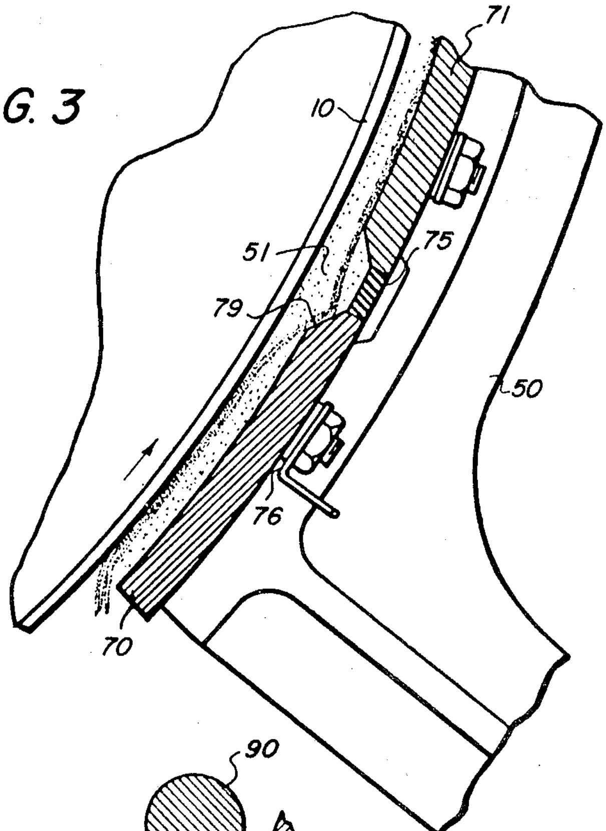
FIG. 3



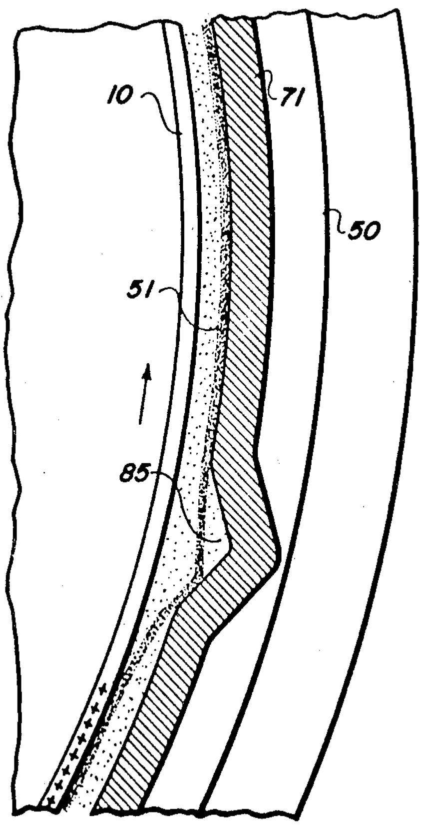


FIG. 4

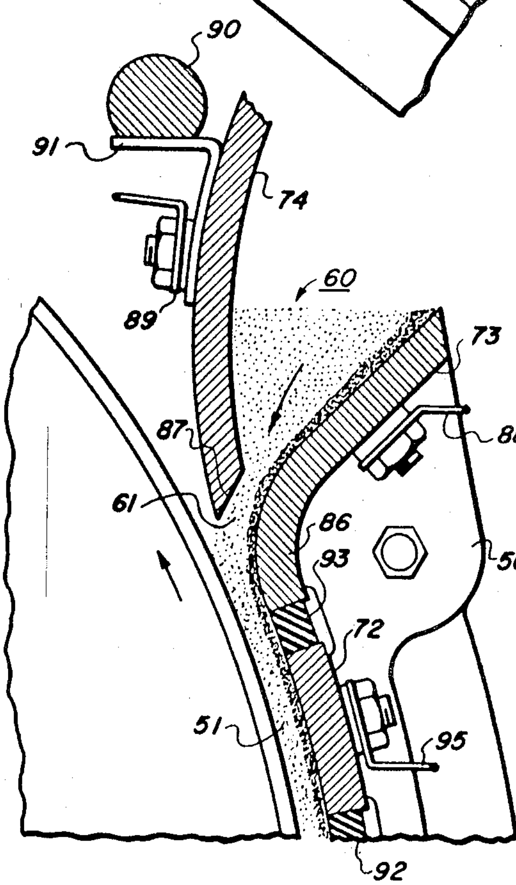


FIG. 5

DEVELOPMENT APPARATUS

This invention relates to xerographic development apparatus and, in particular, to a development system in which the distribution of materials in a flow of two-component developer material is controlled.

In xerographic development, it is the conventional practice to cascade a flow of two-component developer material over an image bearing photoconductive plate such as a drum or belt which is being transported in the direction of developer flow. The toner ladened carrier beads coming in contact with the moving surface give up charged toner particles to the more highly charged images thereon thus making the images visible. The now toner deplete carrier beads coming with the plate surface, being electrostatically unbalanced, act both to mechanically and electrostatically remove randomly dispersed toner particles unavoidably deposited in the background or nonimaged areas on the plate. This classical cascade development and cleaning sequence is best carried out when the contact time between developer and plate is relatively long, that is, long enough to allow this natural two step chain of events to produce optimum image development on the plate. However, when the contact time between the plate and materials is short, as in an opposed flow system where the developer moves in opposition to the plate surface, or when contact cannot be sufficiently maintained throughout the development zone, as for example, when the plate or a portion thereof is in an inverted or vertical position, the many advantages associated with two-component development cannot be thoroughly utilized. Two-component development has therefore been restricted generally to use in a cascade system in which developer material is poured over a photoconductive surface and the surface moved in the direction of developer flow.

It is therefore an object of this invention to improve xerographic development and, in particular, development apparatus utilizing two-component developer material.

Another object of this invention is to improve xerographic development apparatus to provide broader utilization of two-component developable material.

A still further object of this invention is to improve two-component development apparatus wherein a latent electrostatic image can be developed on an image support member moving in opposition to the flow of developer material.

Yet another object of this invention is to improve two-component development apparatus wherein a latent electrostatic image can be developed in the controlled conditions while being supported in an inverted position.

A further object is to control a distribution of developer material in a flow of two-component developer to either develop or clean an image support member in response to the condition of an image found thereon.

These and other objects of the present invention are attained by means of a series of conductive members electrically isolated from each other which are positioned in close parallel relation to a movable image-bearing member to form a substantially enclosed development zone, means to introduce a continuous flow of two-component developer through the development zone, and means to bias the members such that the distribution material in the developer flow is controlled so that the material first develops and then cleans the image support member surface.

For a better understanding of the present invention as well as other objects and further features thereon, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings wherein:

FIG. **1** is a schematic side elevation of an automatic xerographic machine utilizing the present invention;

FIG. **2** is an enlarged side elevation of the developing apparatus used in the xerographic reproducing machine as shown in FIG. **1** with parts broken away to better illustrate the construction thereof;

FIG. **3** is an enlarged partial side elevation illustrating the flow of developer materials through the lower part of the development apparatus as shown in FIG. **2**;

FIG. **4** is an enlarged partial sectional view of the development apparatus of FIG. **2** showing a notch in the main development electrode for redirecting the flow of two-component developer material;

FIG. **5** is an enlarged partial side elevation of the development apparatus illustrating the introductory region in which toner material is brought into contact with the image support member in the development zone and further illustrating a cleanup electrode positioned adjacent to the introductory region.

The general apparatus of the instant invention is shown herein embodied in an automatic xerographic machine employing a drum-shaped xerographic plate **10** comprising a photoconductive layer which is placed upon a conductive backing.

Drum **10** is mounted on shaft **11** journaled in the machine frame (not shown) and is rotated in the direction indicated by the arrow by means of motor **9** causing the drum surface to sequentially pass through a plurality of xerographic processing stations.

For the purposes of the present invention, the several xerographic processing stations positioned in the path of movement of drum **10** as shown in FIG. **1** may be described functionally as follows:

a charging station A, at which is positioned a corona generating device **12** for placing a uniform positive electrostatic charge on the photoconductive layer of the drum surface as the drum is driven in the direction indicated;

an exposure station B, at which a light or radiation pattern of the original document to be reproduced, which is supported on platen **14**, is projected onto the drum surface thereby dissipating the charge found thereon in the areas exposed so as to form a latent electrostatic image of the original document;

a developing station C, having a housing generally designated **20**, in which a two-component developer material utilizing, in this case, negatively charged toner particles is delivered to the entrance of the development zone from where it is caused to flow in opposition over an upwardly moving portion of the drum surface by means of bucket conveyors system **27** thus enabling the toner particles to contact and adhere to the electrostatic image on the drum surface to form a developed powder image in image configuration of the original document to be reproduced;

a transfer station D, at which the xerographic powder image is electrostatically transferred from the drum surface to a sheet of final support material by means of transfer corotron **24**; and

a drum cleaning and discharge station E, at which the drum surface is exposed to a cleaning corotron **39** and then contacted by means of a doctor blade **41** to remove residual toner particles which may remain thereon after the transfer operation and where the drum surface is exposed to the source of illumination **43** to effect substantially complete discharge of any residual electrostatic charge remaining thereon.

Transfer corotron **24** located at station D sprays the backside of the final support material with positive ions thus producing a charge of sufficient magnitude on the back of the paper to attract the toner from the drum surface to the final support material. However, the positive charge which is sprayed over the nonimaged background areas electrostatically tacks the support material to the moving drum surface. A plurality of arcuate-shaped stripper fingers positioned subsequent to the transfer station are arranged to lift the leading edge of the tacked support material from the drum and direct the material upwardly. As the drum continues to drive the support material forward, the finger strip the material from the drum and guide it into contact with vacuum transport **26**. The support material, a portion of which is still electrostatically tacked to the drum surface is caused to move along the vacuum transport towards fuser assembly **30**.

Under the influence of the rotating drum, the support material is moved along the stationary vacuum transport **26** into the nip between the upper fuser roller **31** and the lower fuser roll **32**. The coating fuser rolls are arranged to apply a pressure driving force to the sheet of support material positioned therebetween and to forward the sheet at a synchronous speed with the rotation drum surface. A radiant source of energy 33 extending transverse to the lower fuser roll, is capable of rapidly transferring heat energy to the lower fuser roll. The heat energy is stored on the surface of the roll and is brought into thermal contact with the image-bearing support material as the lower roll is rotated in the direction indicated by the arrow. Image fixing is accomplished in this xerographic reproducing device by means of a combination of pressure and heat energy which is transferred to the powder image as the support material moves through the fuser roll assembly.

The copy, with the fixed image thereon, is transported through a circular path of travel, generally referred to as 40, comprising a series of pinch rolls arranged to either discharge a final support material from the apparatus into catch tray 36 or to feed the support material back into a second feed tray 35. Support material stored in feed tray 35 are once again redirected through the xerographic processing stations to form a second or duplex image on the backside thereof.

It has long been known in the xerographic art that the developing characteristics of a two-component material is substantially altered when the material is caused to flow between a biased electrode and an image-bearing photoconductive surface during the developing process. Although the exact reason for this change in developability has heretofore not been clearly understood, the results achieved were nevertheless clearly evident in the quality of the copy produced.

Tests were conducted to determine what effect an electrode had on the dynamic flow characteristics of a two-component developer material during development. An extended stationary electrode was placed in the developer housing of an automatic xerographic machine and positioned in close parallel relation to a rotating drum surface. The drum was xerographically imaged by conventional xerographic techniques to produce a latent image thereon. The electrode was biased to a potential similar in polarity to the latent image and having a magnitude below the image potential but above background potential. Broad solid areas were xerographically imaged on the drum surface and then developed by passing a continuous flow of developer material between the drum surface and the electrode with the drum being moved in opposition to the developer flow. It was noted that the electrode enhanced the solid area image development. However, in all cases, the leading edge, that is, the edge of the image which first passed through the electroded region, had a washed out or underdeveloped appearance. It was theorized that in the above environment, a directional force field is established between the electrode and the background areas on the drum surface which acts to force toner particles in the developer flow towards the electroded side of the system. In other words, a toner gradient is established in the developer flow when a nonimaged area is in the electroded zone resulting in a heavy flow concentration of toner moving along the electroded side of the system. When a nonimaged area precedes a latent image into the electroded region, insufficient toner is initially available at the drum surface to fully develop the leading edge of the image. However, the image potential soon becomes the dominant force in the system and the toner is then attracted from the electrode to the drum resulting in a shifting of the toner gradient. Because the photoconductor was moving in opposition to the developer flow during these tests, the time to complete the toner gradient shift was clearly reflected by an underdevelopment along the leading edge of the images. Once the shift was completed, however, a good solid area development resulted.

To prove that a toner gradient was established in the flow of two-component developer material by a development electrode and that this gradient was responsive to changes in the electrostatic field characteristics of the system, the above experiment was repeated with two relatively broad latent images being xerographically imaged longitudinally across the drum surface. Initially, the two imaged areas were offset from each other at some distance so that a relatively long nonimaged history was experienced by the development system as the image followed each other through the electroded zone. With the relatively long nonimaged history separating the two images, the lead edge effect on both images was evident. The nonimaged history between images was progressively shortened by moving the latent electrostatic images closer together. A point finally was reached wherein the second image through the electroded region no longer had evidence of an underdeveloped lead edge thereon. The lead edge of the first image through the electroded zone, however, clearly showed signs of underdevelopment. It was evident that the nonimaged history between the images had been shortened so that insufficient time was provided to allow the gradient to shift from the drum side of the system. Sufficient toner thus was still available at the drum surface to develop the leading edge of the second image through the electroded region.

From these tests it was concluded that a toner gradient could be established in a two-component developer flow moving through an electroded development zone. Furthermore, the developability of the system could be controlled by positioning the toner gradient in or out of contact with the photosensitive plate to be developed.

Apparatus is herein disclosed in which the above findings are utilized to produce a development system in which complete control is afforded over a two-component developer material as the material moves through a xerographic development zone. Although the present apparatus is illustrated in an opposed flow system, it should be clear, because of the complete control afforded over the developer material, that the present apparatus is equally well adapted for use in a wide variety of machine environment and is in no way restricted to use in the particular embodiment. It should be further evident, that the present apparatus can be utilized in any number of two-component development systems to develop image upon xerographic plates which are supported in any number of positions inverted or otherwise.

Referring now specifically to FIG. 2 through 5, the apparatus of the present development system basically comprises a series of conductive control members separated by insulating blocks which are supported in close parallel relation to a moving xerographic drum surface so as to form a continuous enclosed flow path therebetween. This flow path is herein referred to as the development zone and is numerically designated 51. Positioned at the upper entrance to the enclosed development zone is an entrance chute, generally referenced 60, through which a continuous flow of two-component developer material is introduced into the development zone. A series of conductive control members form the backwall of the development zone 51 and, as will be explained in greater detail below, function to control the distribution of developer material in the flow stream during development. The front wall of the development zone is described by the upwardly moving drum surface. It should be noted that in this particular development apparatus, the drum surface is moving upwardly in opposition to the downwardly moving developer flow stream. This particular flow relationship between developer and plate is directly opposite that utilized in most conventional cascade development as disclosed by Walkup in U.S. Pat. No. 2,618,551 in that therefore, the carrier beads do not operate in the classical sense to first give up toner during the development process and then, when partial denuded, scavange the weakly held background development from the nonimaged areas.

The conductive control members, and the insulating blocks separating these members, are mounted on a nonconductive rigid support frame 50 and the frame affixed to the sidewalls of the developer housing 20. An opening is provided in one end wall of the housing through which the rotating drum surface is allowed to pass in close proximity to the conductive control members supported therein. The control members and the insulating blocks both extend horizontally across the drum surface and have end seals (not shown) provided which ride in contact with the extreme ends of the drum surface to enclose the development zone **51**.

Two-component developer material is transported from a storage and mixing area in the sump **55** of the developer housing into an entrance chute **61** by means of a conveyor **27** (FIG. 1). The conveyor is madeup of a series of horizontally extended elongated buckets **56** affixed to an endless belt which passes over pulley assemblies **57** and **58**. As the buckets are transported in the direction indicated through the developer sump area, the buckets become loaded with developer material. The continuous movement of the buckets through the developer mix sufficiently agitates the developer mix to produce triboelectric charging of the materials. The loaded bucket, upon leaving the sump area, are raised to the top of the developer housing where they are discharged into entrance chute **60** thus supplying a continuous flow of material to the development zone.

The developer material delivered into the entrance chute is introduced into the development zone **51** where it is allowed to flow downwardly under the influence of gravity in opposition to the upwardly moving photoconductive plate surface. The behavior of the developer material, as it passes through the development zone, is closely and automatically controlled by the control member to development the plate surface and clean unwanted background which results in the development of extremely clear, clean, xerographic images. Because of the unique sensitivity of the present system, a wide variety of images such as line copy, solid area, half-toned images or any combination thereof can be processed without changing the electrical or mechanical parameters of the present system. As the developer material leaves the development zone, it is intercepted by a pickoff baffle **62** which is mounted in close proximity to the drum surface in the lower portion of the developer housing. The intercepted developer material is redirected down an incline chute **65** back into sump area **55** where it is stored and recharged preparatory to being reused in the xerographic developing process. Also positioned immediately below the pickoff baffle is a developer housing seal **66** adapted to coact with the moving drum surface to prevent any developer material which might migrate into this area from escaping from the developer housing.

After the plate is charged and exposed, the latent image is transported upwardly on the drum surface through the bottom opening provided into development zone **51**. It should be noted that in this embodiment, the point of entry of the latent electrostatic image is also the point at which developer material is leaving the development zone. However, as will become apparent from the discussion below, the developer material in this start of developing region is, because of the systems unique characteristics properly charged and in condition to produce complete image development in a short period of time. In fact, a slightly overdeveloped condition is produced in this start of development region. More toner then is required for image development at the drum surface at this time which results in some background being developed. However, excessive background development is not harmful in the present apparatus because the background is efficiently and effectively cleaned from the plate surface as the plate moves through the development zone.

A latent electrostatic image produced on a photoconductive surface, such as a selenium drum, characteristically has an electrostatic field charge pattern which is extremely strong and dense along the edges or outer fringes. However, the density and strength of the force field components, particularly the components perpendicular to the plate surface, progressively diminish as you move away from the edge areas. During development the stronger and more dense field components associated with the fringe areas reach out and pull oppositely charged toner particles. However, the weaker and less dense components associated with the large interior solid areas cannot effectively or rapidly capture toner particles and therefore these areas generally appear washed out due to underdevelopment. A low potential development electrode **70**, as illustrated in FIGS. **2** and **3**, is placed in close proximity to the moving plate surface in the start of development region. The term "low potential" as herein used applies broadly to any potential which is lower than the potential found in the nonimaged areas on the drum surface and the term is broad enough to include a grounded electrode, an electrode biased to a polarity opposite to that on the drum surface, or even a floating electrode. A drastic change is noted in the developability of the system, particularly in regard to solid and half-toned image areas, when a low potential electrode is brought into close proximity to an underdeveloped latent electrostatic image on the plate surface. The electrode causes the field components normally associated with the weaker interior force fields to become strengthened and more dense. By controlling the electrical potential applied to the electrode, these fields components can be made directional to force the charged toner particles moving in the flow stream against the image-bearing drum surface.

Electrode **70** is connected to a suitable biasing source **96** through means of wiring **113** and electrical terminal **76**. The electrode is placed at a potential below the potential found in the nonimaged, or exposed areas on the drum surface. A force field is established in this inverted portion of the development zone which acts to force the toner in the flow stream upwardly against the drum surface. The electrode, because it is biased below the background potential, not only strengthens the force fields associated with the solid image areas but also strengthens the force fields associated with the exposed nonimaged areas so that a relatively strong field exists across the entire drum surface in this electroded region. This results in an extremely heavy concentration of toner being made available at the drum surface at the start of the image development. This concentration is illustrated by the heavy dark area in the flow stream as shown in FIG. 3. It should be noted, that the placement of the heavy concentration of toner at the drum surface in this inverted region is controlled by the electrode. The force of gravity, although present, is negated by the force field so that the toner in the stream flows in contact with the inverted drum surface.

To further enhance early image development in the present apparatus, the toner particles moving through the low potential electroded region are first dislodged or freed from the carrier beads so that the particles can be more readily acted upon and controlled by the force field. Dislodgement of the toner is accomplished by impacting the toner ladened carrier beads against the drum surface as the low potential electrode region. A chamfer **79** is cut in the leading edge of electrode **70**. The flow of developer material, because it is moving through an inverted region, is at this time moving in supporting contact with the electroded said of the system and therefore falls into flowing contact with the undercut chamfer which is shaped to redirect the flow upwardly into contact with the drum surface. Upon striking the drum, toner particles are jarred loose from the carrier beads and a powder cloud of free toner material is formed in this start of development region. The free toner which is still moving along under the influence of the flow system, is readily transported to the drum side of the system by the directional electrostatic force fields so that a toner gradient is now created in the flow with a heavy concentration of toner being made available at the drum surface. Although a notch or chamfer is herein used to redirect the developer flow, any suitable means for directing developer material into contact with the drum surface without seriously impeding the developer flow could be similarly utilized.

The next subsequent conductive member positioned in relation to the direction of drum rotation is main development electrode **71**. As previously noted, the main development electrode is electrically isolated from the low potential electrode by means of a dielectric block **75**. A suitable biasing source **97** is connected to the main development electrode by means of wiring **114** and electrical terminal **81**. The two adjacent electrodes 70, 71 are of substantially equal thickness. However, the dielectric block is constructed to be of lesser thickness so that a pocket or void is created on the backside of the system in the inverted zone. The developer material in the flow stream readily falls into the void and flows into contact with chamfer 79.

It has been found that the developability of the latent electrostatic images in the low potential electrode region is increased in direct proportion to the number of bead contacts that can be made against the drum surface as well as the velocity at which the beads strike the drum. The angle at which the chamfer directs the beads into contact with the drum surface is therefore optimized in this area both to increase the number of bead contacts and the velocity of bead impact. It should be clear that this optimum angle will vary as the position of the lower potential electrode is changed in relation to the moving photoconductive surface and is not necessarily the same in all development systems.

The main development electrode is placed at an electrical bias such that the electrode has a charge polarity similar to the charge polarity placed on the drum surface and being of a magnitude less than that of the charged image potential but greater than that of the background potential thereon. By placing the main development electrode as a potential somewhere between the image and the background potentials, the electrode acts as a self-regulating device capable of enhancing image development at the same time producing cleaning or scavanging of random background development from the drum surface.

When an initially developed image passes from the low potential electrode region into the main development electrode region, strong force fields associated with the imaged areas predominate and a directional force field is established tending to move the toner in the flow stream into contact with the image bearing drum surface where it is most needed to enhance and complete image development. On the other hand, when a nonimaged area moves into the main development electrode region stronger force field components associated with the development electrode act to attract toner particles toward the charged electrode member. A heavy concentration of toner is therefore found on the backside of the system in these areas and relatively toner deplete carrier beads are presented to the drum surface by the flow stream. The toner deplete carrier beads contacting the drum both mechanically scrub and electrostatically attract loosely held toner from these background areas. The toner removed by the beads either migrates towards the backside of the system or is electrostatically bonded to the bead surface. In any event, the toner material so removed is captured in the flow system and carried along therewith away from the cleaned surface area.

As can be seen, the main development electrode is capable of reacting to the presence or absence of an image moving through the main development electrode region and acts more or less as a switch to shift the toner gradient within the flow stream in response to the drum condition. The two-component developer material in the flow stream is thus utilized in this region to either clean unwanted background from the drum surface or to further enhance development of the latent electrostatic images. In an opposed system as herein described, the leading edge of the electrostatic image is the trigger which starts the toner gradient to shift in response to the change in condition on the drum surface. As previously noted, a time lag in the response of the system is experienced as the toner gradient shifts from one side of the system to the other resulting in underdevelopment of the leading edge of the image. This time delay in the electrical response of the system is mechanically overcome in the present apparatus so that the lead edge effect is eliminated.

Referring now specifically to FIG. 4, a notch or groove 85 is placed in the inverted portion of the main development electrode 71. Developer material moving down the inverted portion of the main development region falls into the void created by the groove. The bottom surface of the groove is shaped so as to once again redirect the main flow stream of developer material upwardly into impinging contact with the moving drum surface. When the main development electrode is acting as a cleaning device, this impingement of the carrier beads against the nonimaged areas aids in mechanically scrubbing or cleaning of residual toner therefrom. Similarly, the impingement of developer material against a developed image area on the drum surface aids in the development process by first physically transporting toner from the backside of the system into contact with the image areas thus overcoming any time delay associated with the toner gradient shift and secondly by creating a toner powder cloud of free toner in and about the image areas where the free toner particles can be readily attracted into the image areas.

Here again, both developability and cleaning have been found to be directly proportional to the number of bead impacts that can be maintained and the velocity at which the beads strike the drum surface. The shape of the notch or groove 85 in the main development electrode therefore is designed to both optimize the number of bead impacts and the velocity at which the beads strike the drum surface. Although a notch is herein disclosed, it should again be made clear that any suitable means capable of directing the flow of developer material into impingement against the drum surface without impeding the developer flow can be utilized.

The next subsequent electrode in relation to the direction of drum travel is a cleanup electrode 72. As illustrated in FIG. 2, the cleanup electrode is positioned in the upper part of the development zone adjacent to the opening through which fresh developer material is first introduced into the development zone. The cleanup electrode is physically positioned adjacent to the main development electrode and electrically isolated therefrom by means of a dielectric block 92. The cleanup electrode functions primarily to establish an extremely high directional force field capable of attracting toner material to the electroded side of the system to control the movement of free or weakly held toner particles through the upper part of the development zone. The cleanup electrode further functions to condition the carrier beads moving in contact with the plate in this region to clean unwanted background from the plate surface.

The cleanup electrode is connected to a suitable bias source 98 by means of wire 115 and electrical terminal 95. The biasing source functions to place the cleanup electrode at an extremely high potential of a polarity similar to the polarity found in the charged image areas on the drum surface. An extremely strong directional force field is produced in this upper region of a strength sufficient to force free or weakly held toner particles away from the drum surface. Any free toner material found in the region of the cleanup electrode region is therefore moved under controlled conditions along the backside of the system. The charge field established in this region is of sufficient strength to also strip some of the toner, particularly weakly attracted toner from the beads flowing in contact with the drum and move this toner toward the back or electroded side of the development zone. With a preponderance of the toner material concentrated in the backside of the flow stream, beads moving in contact with the drum surface are relatively deplete of toner particles and therefore can more readily function to scrub and electrostatically attract weakly held background development from the drum surface. As can be seen, the cleanup electrode produces a twofold effect to prevent background development from leaving the development zone. First, the free toner and weakly held toner is forced away from the plate surface and secondly carrier beads at the plate surface are conditioned to mechanically and electrostatically clean background from the plate. By determining the image charge found on the photoconductive surface, and by placing an electrical charge on the cleanup electrode substantially above this charge, this is, somewhere in the range of between 150–700 volts above image potential, the above noted results can be effectively obtained.

It should be apparent now that the movement of developer material into the active development zone in the present apparatus must be controlled both electrostatically and mechanically in order to suppress and control the formation of unwanted powder clouds in this introductory region. As illustrated in FIG. 5, the developer entrance chute 60 is primarily formed by a horizontally extended inclined conductive baffle 73 and a horizontally extended arcuate-shaped shield 74. Although not shown, both ends of the chute between the baffle and the shield are closed by means of an insulating material wherein the chute is capable of supporting therein a quantity of two-component developer material. The inclined baffle 73 has a downwardly extended leg 86 thereon which turns at a relatively gentle radius into the development zone and extends downward therein to form a portion of the backwall of the development system. The shield 74, which is formed of a conductive material, is supported in a relatively horizontal position upon an insulating support 90. The lower portion of the shield terminates in a lip 87 which is positioned adjacent to the turned portion of the inclined baffle plate between the baffle and the photoconductor. Lip 87 is complimentary to the curvature of the turned portion of leg 86 on the lower baffle and cooperates therewith to form an entrance throat 61 extending horizontally across the width of the development zone. The chute is basically funneled shaped tapering down from a relatively wide mouth to a restricted throat 61. The throat opening is substantially equal in width to the distance maintained between the drum surface and the control electrodes so that a similar volume rate of flow is supported in the introductory zone as is maintained in the active development zone. In operation, the buckets deliver a continuous supply of developer material into the funnel-shaped entrance chute. Although this developer material is normally delivered into the entrance chute at a relatively high velocity, the velocity of the developer material is initially throttled in the chute before it is delivered through the throat entrance into the active development region. The initial reduction in the developer flow velocity combined with the gentle flow path presented to the developer material results in a significant reduction in mechanical agitation of the two-component developer material thus suppressing the tendency of the material to form powder clouds in and about the introductory region to the development zone.

The inclined baffle 73, which makes up the lower wall of the entrance chute 60 is placed at a relatively high potential by means of a suitable biasing source 99 acting through wire 116 and terminal 88. The lower baffle is placed at an electrical bias having the same polarity as the charged polarity of the images on the drum surface, however, the magnitude of the charge is substantially greater than the image charge potential and the chute electrically isolated from the cleanup electrode by means of a dielectric block 93. On the other hand, the shield 74 is placed at a relatively low potential, a potential lower than the entrance chute potential, by means of biasing source 100 acting through wire 117 and terminal 89. Here again, the term low potential is used broadly as described above. By maintaining the shield at a relatively low potential while holding the baffle at a relatively high potential, extremely strong force field is created in the introductory region capable of attracting and/or forcing charged toner particles moving through this region to the backside of the system. It has been found that the reinforced force field created in the entrance chute establishes a toner gradient in the flow of developer material prior to the material coming in contact with the drum surface.

Again, because the dependent leg 86 on the lower portion of lower baffle 73 turns gently into the development zone and because the velocity of the developer material passing through the entrance chute is substantially throttled, little mechanical agitation of the toner is experienced in this introductory region thereby suppressing the tendency of powder clouds from being formed. Furthermore, the magnitude and strength to which the two baffle plates are biased creates an extraordinarily strong directional force field in the introductory region tending to attract any free and loosely held toner material in this region away from the photoconductive surface. These two effects combine to insure that little or no random toner particles migrate toward the plate surface as the material is introduced into the active development zone.

An optimum combination for the system as herein disclosed is one in which the conductive electroded members are spaced between the 0.070 and 0.080 inches from the drum surface and the low potential electrode biased at a substantially ground potential while holding the main development electrode at between 50 and 150 volts above the background voltage on the plate surface. It has been found that a triangular shaped groove in the main development electrode have an included angle of approximately 120° will give good results when positioned 10° to 20° below the horizontal centerline of the drum. Furthermore, because the response produced by the main development electrode is slower than that produced by the low potential electrode, it has been found that the main development electrode should be from three to four times longer in relation to the direction of developer flow than the low potential electrode. To further obtain optimum results it is desirous to place the cleanup electrode at a potential between 150 and 700 volts above the image potential found on the charge plate surface while the conductive shield and baffle comprising the entrance chute are funneled down towards each other so that they form a throat which is between 0,065 and 0.080 inches wide at the introductory region to the development zone and the inclined baffle biased to a potential between 300 and 700 volts above the image potential found on the plate surface and the shield placed at approximately a ground potential.

It should be clear from the prior discussion that the development system herein described is a dynamic flow system. That is, the toner gradient which is established in the flow stream and which is directed towards or away from a moving drum surface is not necessarily captured and held by the electrode but is in fact carried along under the influence of the carrier beads in the flow stream. It should be therefore obvious that the electrodes do not become collectors of loose toner material but merely function as a means of controlling the concentration of toner in the flow as it moves through the development zone. By varying the intensity and direction of the component force fields created in various parts of the development zone and by redirecting the flow of developer material at predetermined points to impinge the material against the photoconductive surface, the developability of the system is enchanced and controlled so that a quality xerographic image is produced. The system as herein disclosed is not gravity dependent and therefore is not limited to use in any specific machine configuration. That is, the electrostatic and mechanical control of the two-component developer flow is equally well adapted for use in any development system utilizing a flow of two-component disclosure material as charged developing mechanism. toner

For purposes of explanatory convenience, references may have been made in this disclosure to positively charge carrier materials and negatively charged toner particles. It should be understood that a description of this specific nature of the potentials involved on the respective conductive members is not intended to limit this invention to this specific relationship. It would be possible to utilize carrier and toner materials having vastly different relationships in regard to their triboelectric characteristics. This of course would result in the requiring of similar changes in the relationship of the biased charges found on the various conductive members. All references to positive or negative charges in this disclosure are therefore to be considered as defining a relationship to oppositely charged bodies which may be either positive or negative as long as this relationship of like or dissimilar charges is maintained.

While this invention has been disclosed with references to the structure described herein, it is not to be confined to the details as set forth, and this application is to cover all modifications and changes which may come with the scope of the following claims.

What is claimed is:

1. Apparatus for developing a latent electrostatic image on an image support member, including

a member for supporting a latent electrostatic image thereon adapted to move along a predetermined path of travel,

a series of control electrodes positioned in close parallel relation with said member as the member moves along the predetermined path of travel to form a substantially enclosed extended development zone for containing a moving stream of finely divided two-component developer material,

biasing means associated with said electrodes for placing each succeeding electrode in the direction of travel of the support member at a higher potential such that a latent electrostatic image on the member is developed and the member then cleaned of residual background development remaining thereon, and

means to move said member along the path of travel in opposition to the flow of developer material.

2. The apparatus of claim 1 wherein the electrodes are separated by insulating blocks to form a continuous wall opposite said moving member.

3. The apparatus of claim 1 wherein the member is a drum arranged to rotate past the series of electrodes.

4. The apparatus of claim 3 wherein at least a part of said development zone is in close parallel relation with an inverted portion of the drum surface.

5. Apparatus for developing an electrostatic latent image formed on an image support member, including

a plurality of extended electrodes supported in close parallel relation with said moving support member, said electrodes including

a development electrode biased to a potential lower than the background potential found in the nonimaged area of said member,

an intermediate electrode biased to a potential between the image potential and the background potential on the image support member,

a cleanup electrode biased to a potential substantially higher than the image potential found on said member,

means to provide a continuous flow of two-component developer material between said member and said member in contact with said member, and

means to move the image support member along a predetermined path of travel against the flow of developer.

6. The apparatus of claim 5 wherein said intermediate electrode is between three and four times longer in the direction of developer flow than said development electrode.

7. The apparatus of claim 6 wherein said development electrode has means associated therewith to direct the flow of developer material into impingement against the moving support member

8. The apparatus of claim 7 having further means to suppress the formation of powder clouds in and about the introductory region that a flow of two-component developer material is introduced into the development zone.

9. A xerographic development apparatus of the type wherein a continuous flow of two-component developer material is moved in contact with a member supporting a latent electrostatic image to develop the image thereon, said apparatus including

a series of electrically isolated conductive electrodes placed in close parallel relation to the image support member to form a substantially enclosed development zone, said electrodes including

a development electrode biased to a potential below the background potential on the member to establish a force field sufficient to produce a heavy concentration of toner in the developer flow moving in contact with the support member,

an intermediate electrode biased to a potential between the image potential and the background potential on the support member and being positioned adjacent to said development electrode in the direction of developer flow wherein toner in the developer flow is forced into contact with the image areas on the support member and is simultaneously attracted away from the nonimaged areas on the support member,

a cleanup electrode positioned adjacent said last electrode being biased to potential substantially above the image potential on the support member to force a heavy concentration of toner in a flow stream toward said cleanup electrode,

and means to move the support member upwardly against the developer flow.

10. The apparatus of claim 9 wherein the electrodes are separated by means of insulating blocks.

11. The apparatus of claim 10 wherein said development electrode has means associated therewith for directing the flow of developer material moving between the support member and said electrode into impinging contact with the support member.

12. The apparatus of claim 11 wherein said intermediate electrode has further means associated therewith for redirecting the flow of developer material moving between said electrode and said support member into impingement with the support member.

13. The apparatus of claim 12 having further means to move the support member in the direction of developer flow.

14. The apparatus of claim 12 further including an entrance chute for introducing a flow of developer material into the development zone, and electrical means for biasing said chute such that a heavy concentration of toner in the flow stream is moving through the introductory region along the side of the development zone opposed to said support member.

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