United States Patent

[11] 3,599,604

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[54] **XEROGRAPHIC DEVELOPMENT APPARATUS**
1 Claim, 4 Drawing Figs.

[52] U.S. Cl. 118/637, 117/17.5
[51] Int. Cl. B05b 5/04
[50] Field of Search 118/637; 117/17.5

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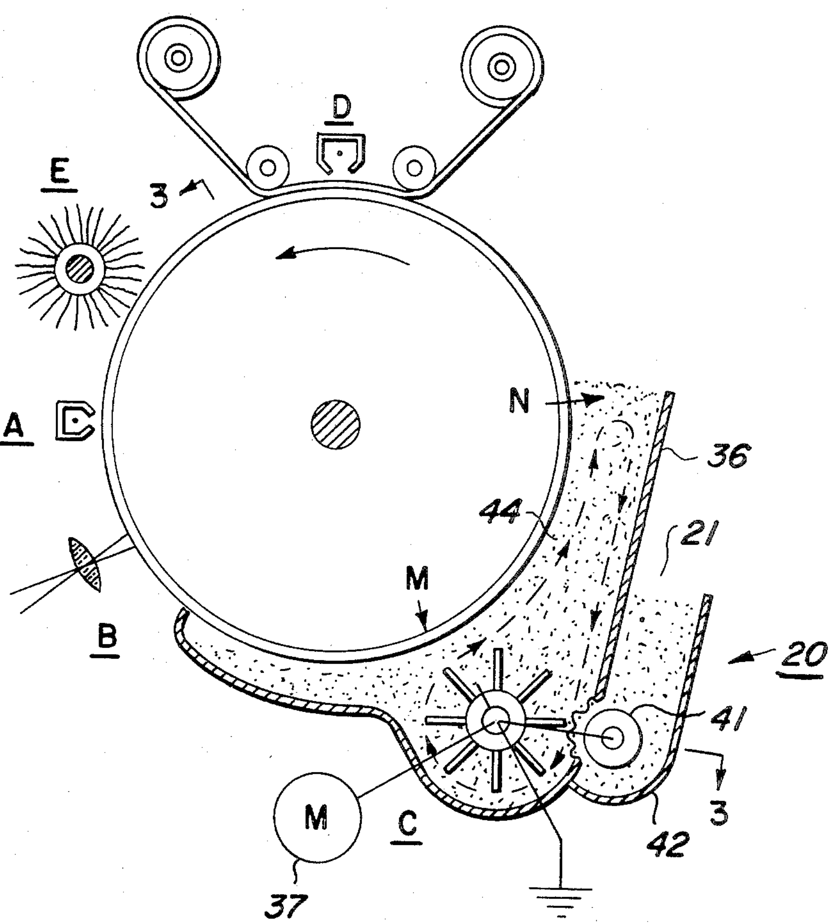
ABSTRACT: Apparatus for developing an electrostatic latent image on a moving photoconductive surface in which the surface is moved in contact with the two-component developer material so that an uphill flow of developer material is established therein, the apparatus having means associated therewith to aid the flow of developer material through the system.



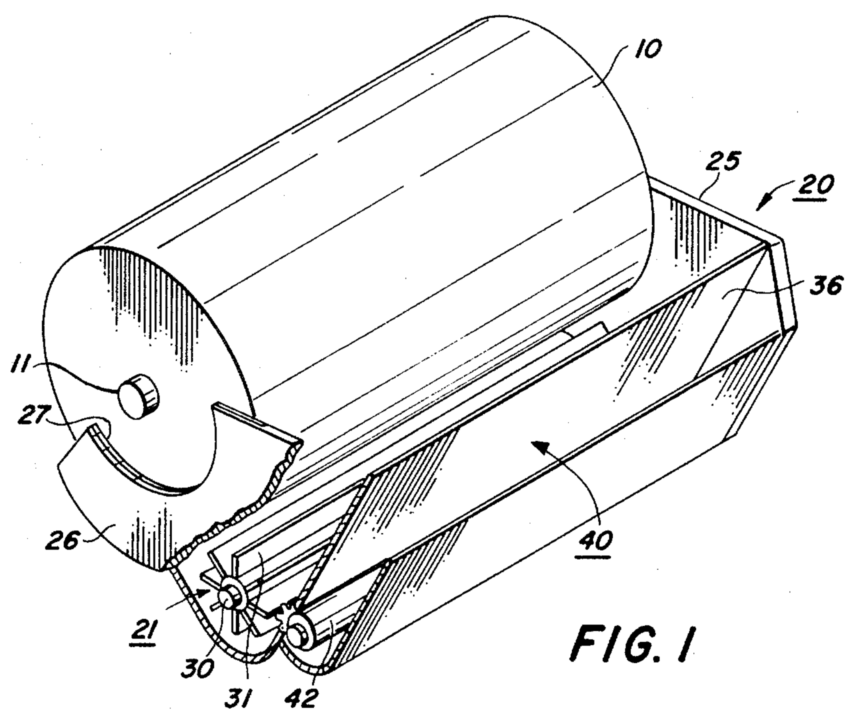


FIG. 1

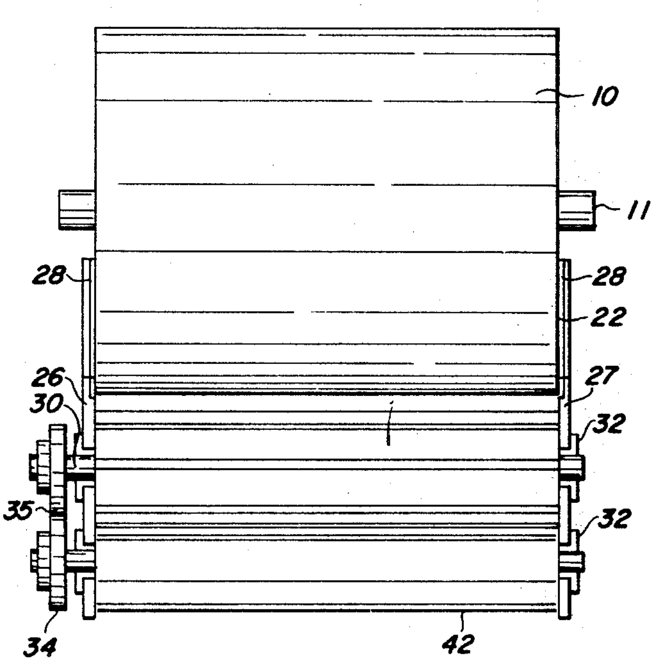


FIG. 3

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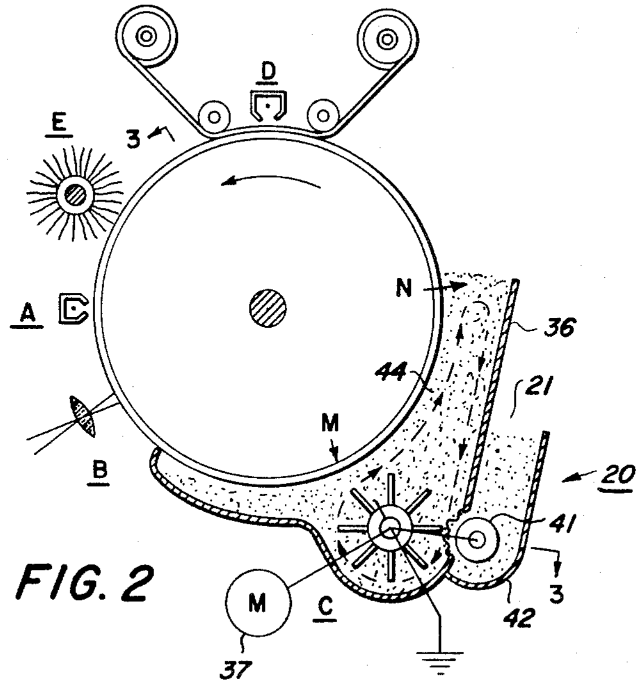

FIG. 2

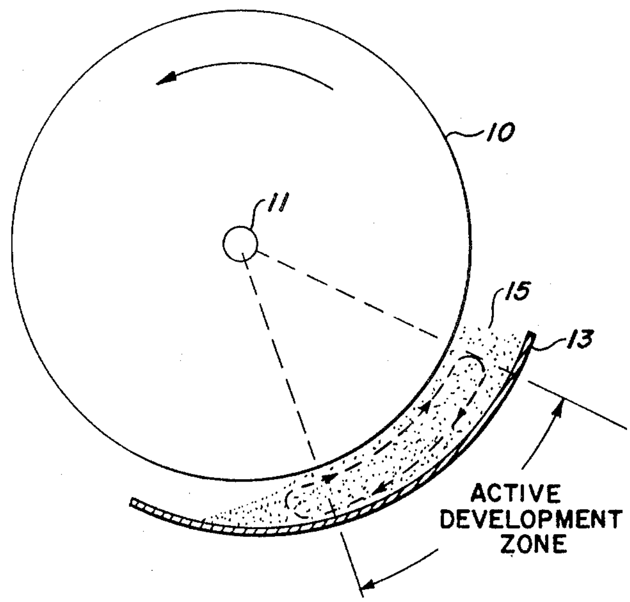

FIG. 4
PRIOR ART

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XEROGRAPHIC DEVELOPMENT APPARATUS

This invention relates in general to xerography and, in particular, apparatus for developing a xerographic image.

In the art of xerography, as originally disclosed by Carlson in U.S. Pat. No. 2,297,691, a plate, comprising a conductive backing upon which is placed a photoconductive insulating material, is charged uniformly and the photoconductive surface then exposed to a light image of an original object to be reproduced. The photoconductive coating is caused to become conductive under the influence of the light image so as to selectively dissipate the electrostatic charge found thereon to produce what is known as a latent electrostatic image. The development of the latent image is generally effected by electrostatically attracting a pigmented resin to the image areas on the plate. The amount of charge found in the image areas determines the amount of resin material attracted thereto. The amount of charge can be said to be proportional to image density and therefor areas of small charge concentration become areas of low toner density while the areas of greater charge concentration become proportionally more dense. A permanent record of the original object is obtained by transferring the developed image to a final support material and fixing the developed image thereto.

A wide variety of pigmented resins have been developed for the purpose of developing a latent electrostatic image, these resins being commonly referred to as "toners." The toner material is generally transported to the image areas by means of a relatively coarser material known as carrier, the carrier being adapted to support a quantity of toner upon its surface. The two-component, that is, the toner and carrier, are selected so that the materials interact electrostatically when placed in close rubbing contact to cause a triboelectric attraction therebetween. This two-component material is known in the xerographic art as "developer material" and this term is used herein to denote a two-component developer comprising carrier and toner material.

Although many workable xerographic development systems are known in the art, most of these systems have been found to be impracticable, in a commercial sense, because they are either too slow, too inefficient, or too complex to readily lend themselves to use in automatic xerographic machines. Cascade development, as illustrated in U.S. Pats. to Walkup et al., 2,573,881 and to Carlson, 2,990,278, because of its many advantages, has become one of the most prevalent methods for developing a latent electrostatic image. In a cascade developing system, two-component developer material is conveyed, as for example by buckets, to a point above an image-bearing xerographic plate and the developer material poured or cascaded over the plate surface. Through the combined mechanical and electrostatic forces involved, toner is dislodged from the carrier material and attracted to the image areas on the photoconductive plate. The cascade system, however, has proven to be space consuming. The need for bulky conveyors or the like add greatly to the size of the xerographic-reproducing apparatus. Unwanted powder clouds also result due to the relatively violent cascade action which, in turn, deposits unwanted toner material in background areas. Furthermore, dropping or cascading the developer material on the plate surface causes plate abrasions resulting in a relatively high rate of plate failures. A high rate of developer material failure due to bead fracture is also noted in the cascade system.

In order to overcome some of the disadvantages found in a prior art and, particularly, those associated with cascade development, a new method of xerographic development was devised in which a moving photoconductive plate surface is brought into contact with a quantity of developer material contained in a housing or the like. Fundamentally, an uphill flow of developer material is established at the plate-developer interface due to the frictional forces involved. These frictional forces are sufficient to carry the developer material along in contact with the moving surface at approximately drum speed. Although not clearly understood, it is believed that development is effected during the period of flowing contact by means of the classical development-scavenging technique as disclosed in the previously mentioned Walkup and Carlson patents. The developer material, upon being released from the plate surface, returns to the backside of the developer housing where it is replenished before once again being returned to the zone of active development. This flow-contact-type system is disclosed in a copending application to Gundlach, Ser. No. 528,846.

Many geometric configurations are discussed and disclosed in the Gundlach application, however, they all employ the same basic development principle of development. Although the basic flow-contact system disclosed by Gundlach overcomes some of the previously mentioned disadvantages found in the prior art, the flow-contact system has certain inherent disadvantages. The flow-contact system is basically a slow system in that a relatively small volume of material is moved through the system during each developing cycle. Addition of new toner material to basic flow-contact housing has also proven to be a major problem primarily due to the extremely low flow rates maintained therein. It has been found that a preponderance of new toner added to the housing stagnates in voids and pockets and never finds its way into the flow stream. This stagnation is believed to be due to the lack of agitation found in the slow, gentle developer flow.

It is therefore a primary object of this invention to improve xerographic development apparatus.

Yet another object of this invention is to improve the efficiency of a xerographic development apparatus.

Another object of this invention is to eliminate space charge build up in a flow-contact development system.

It is yet another object of this invention to improve flow-contact development.

It is yet another object of this invention to improve toner distribution and mixing throughout a flow-contact development system.

It is still another object of this invention to increase the developer flow rate in a flow-contact system.

It is another object of this invention to reduce the amount of time required to bring a flow-contact development system to optimum operating conditions.

These and other objects of the present invention are attained by means of a developer housing being capable of holding a quantity of two-component developer material having an opening for receiving a moving photoreceptive surface therein, the surface being moved in contact with developer material to establish a flow pattern within the developer housing and a vane-type mixer positioned in the housing sump area to aid the flow of developer materials in said housing and to mix the developer material.

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

FIG. 1 is a isometric view of a developer system suitable for use with a xerographic drum, the system embodying the present invention and having portions thereof broken away to show the internal construction of the apparatus;

FIG. 2 illustrates schematically a preferred embodiment of the development apparatus of the instant invention adapted for continuous use in an automatic xerographic machine;

FIG. 3 is a sectional view of the development apparatus taken along line 3–3 of FIG. 2 with the xerographic drum shown invisible;

FIG. 4 is an illustration of the basic flow-contact configuration found in the prior art.

A brief discussion of basic flow-contact development and the flow mechanism associated therewith is believed warranted at this time in order to more fully understand the teachings of the present invention. In the basic system as shown in FIG. 4, drum 10 is rotatably mounted so as to move in the direction indicated through a clam shell shaped housing 13. The housing contains sufficient developer material so that the drum contacts the developer material 15 as it moves through the housing to establish a flow pattern therein. This flow of material is depicted by the arrows associated therewith. A thin layer of developer material adjacent to the drum surface moves in an uphill direction at approximately drum speed while the entire back layer of developer (the backside of the system) moves down more or less as a unit to fill the void left by the upwardly moving material.

This uphill flow of developer material in contact with the drum surface defines what is herein referred to as the active development zone. Theoretically, properly charged and toner leaded developer material is delivered to the start of the active development zone from the supply of developer material found on the backside of the system. The developer material introduced into the active zone is carried along in contact with the drum surface as the drum rotates where development takes place by means of the classical xerographic development-scavenging mechanism. The developer material continues to flow along in contact with the drum until the frictional forces holding the developer at the interface are overcome, as for example the drum leaving the sump area. The developer material leaving the active developing zone returns to the backside of the system to fill the void created by the upward flow of material. As can be seen, the carrier beads leaving the active development zone have given up their toner in the development process and therefore must be replenished on the backside of the system before they can once again be returned to the start of the active development zone.

It has been found that the flow rate in the basic flow-contact-type system is not limited by the drum developer interface motion but rather by the time required to return replenished developer material to the active development through the backside of the system. Because this is a closed system, the volume rate of flow through the active development zone is equal to the rate of flow found on the backside of the system. In fact tests have shown that by providing an infinite supply of developer material to the start of the active development zone, a flow rate approximately eight times greater than found in the basic C-shell system can be attained.

From the prior discussion, it should be clear that the backside of the developer system should have the steepest return geometry possible in order to provide the more rapid flow rate through the system. However, the angle of repose of the developer material acts to limit the return geometry of the system. The angle of repose is the maximum angle with the horizontal at which a quantity of loose particulate material will retain its position before sliding. As shown in FIG. 4, the angle of repose of the developer material within the developer housing 12 precludes the developer from contacting the drum surface for a considerable distance as the drum rotates through the housing. In fact, for most commercially available particulate developer materials, contact between drum and developer is made at about 45° from the vertical. As can be seen, the material angle of repose severely limits the length of the active development zone and severely restricts the return geometry of the system.

It should be noted, however, that basic flow-contact development is nevertheless a highly efficient system. With a volumetric flow rate somewhere in the nature of between 200 and 400 times less than the flow rate found in most commercially available development systems, as for example cascade, the basic flow-contact system is able to produce good copy by efficiently utilizing the developer available. This high efficiency is evidenced by the extremely starved condition of the carrier beads as they leave the active development zone.

The apparatus of the present invention for improving xerographic development system as well as eliminating the difficulties associated therewith is shown in FIGS. 1, 2, and 3. Although it will become apparent that the instant invention is well adapted for use in any suitable xerographic reproduction apparatus, it is shown herein embodied in a drum-type xerographic apparatus for purposes of illustration. As shown in FIG. 2, drum 10 is mounted on shaft 11 and the shaft rotatably supported in the frame of the xerographic machine (not shown). The major xerographic processing components are mounted around the drum periphery so that they are able to act thereon as the drum continually rotates through the various stations.

In general, the several xerographic processing stations in the path of movement of the drum surface may be described functionally as follows:

- a charging station A, at which a uniform electrostatic charge is deposited on the surface of the photoconductive drum;
- an exposure station B, at which a light or radiation pattern of a copy to be reproduced is projected onto the xerographic drum to dissipate the charge in the exposed areas to form a latent electrostatic image thereon;
- a developing station C, at which the xerographic developing material, including toner particles having an electrostatic charge opposite to that of the electrostatic image, are placed in contact with the moving drum surface whereby the toner particles are caused to adhere to the electrostatic latent image found thereon;
- a transfer station D, where the developed electrostatic image is transferred from the plate surface to a final support material, and;
- a drum cleaning and charging station E, at which the plate surface is brushed to remove residual toner particles remaining thereon after image transfer and at which time the plate surface is exposed to a relatively intense light source to effect substantially complete discharge of any residual electrostatic charge found thereon.

In the apparatus of the instant invention, housing 20 is formed to provide an extremely steep return geometry through which flows starved developer material 15 leaving the active development zone. Rotatably mounted in the lower portion of the developer housing is a vane mixer 21. It should be noted that the impeller 31 of the vane mixer act not only like a pump impeller to move the material along but also acts as a mixing device to rapidly and effectively mix and triboelectrify material acted upon.

The top portion of housing 20 has an opening for receiving in rotatable relationship therein a portion of drum surface 10. The housing, and the top opening therein, extend at least the longitudinal length of the drum and the housing is closed at each end by means of end plates 25 and 26, respectively, (FIG. 3). Seals 28 are mounted between the drum and the end plates to prevent developer material from falling therebetween. In operation, sufficient developer material is placed within housing 20 so that the rotating drum surface, as it passes through the housing, is brought into moving contact with the developer. The region adjacent to the rotating drum, in which the developer material contacts the photoconductive surface, describes the active development zone in the instant invention.

Vane mixer 21 comprises a shaft portion 30 and an impeller portion 31, the impeller portion having paddle wheellike impeller blades mounted thereon which extend at least as long as the longitudinal length of the drum surface. The vane mixer is rotatably mounted in the lower portion of the housing 20 in bearing blocks 32 provided in end plates 25 and 26, respectively, and is driven through means of a sprocket 35 rigidly affixed to the extended portion of shaft 30. As shown in FIG. 2, the impeller is driven in a clockwise direction by any suitable drive means, as for example motor 36, acting through sprocket 35.

In operation, toner loaded carrier material enters the start of the active development zone at approximately point M and the developer material is carried along in contact with the photoconductive surface as the drum rotates in the direction indicated. The developer material brought in contact with the drum developes the electrostatic latent image thereon through the classical development-scavenging mechanism as described in the previously mentioned Walkup patent. That is, the electrostatic latent image possessing a higher electrostatic attraction than that possessed by the carrier material causes the toner to be attracted from the carrier onto the drum surface in the image areas. The developer material continues to move in friction contact with the drum surface until the friction force is by the drum moving out of contact with the developer in the sump of the housing. This point is marked N FIG. 2. The toner-starved carrier falls into the void created on the backside of the system by the continuous stream of new material entering the active development zone.

Back plate **36** of housing **20** is mounted at a substantially small angle with the vertical so that a relatively steep return geometry is seen by the developer material leaving the active development zone at point N. However, as previously noted, the flow of developer material through a C-shell system is not basically dependent upon the geometry of the system. A relatively shallow flow pattern, as described in FIG. 4, would be established within housing **20** if it were not for the pressure head added to the system by means of vane mixer **21**. Impeller **31** rotating in the direction indicated, pumps the developer material from the bottom of housing **20** towards the start of the active development zone at point M. The pump action of the vane mixer displaces developer material long the bottom portion of back plate **36** creating a void which is quickly filled because of the steep geometry of the system. Starved toner beads leaving the active development zone now are forced to follow the steep geometry of the housing rather than the naturally shallow return found in the basic C-shell pattern thus establishing a more rapid flow within the system.

The active development zone in a flow-contact-type system should be of sufficient length in order for the carrier beads to give up toner in the development process. In a flow system, as herein described, the length of the active development zone determines the amount of time the developer is in contact with the image. As previously noted, flow contact development is an extremely efficient system in which a large percentage of toner material on the carrier is given up to the latent electrostatic image thereby leaving the carrier substantially denuded. A denuded or starved carrier bead in the active development zone tends to act as a scavenger in that it ceases to act as a donor and acts to pull toner away from the developed xerographic images. It is therefore desirable in a flow-contact system to control the length of the active development zone to minimize the scavenging effect.

A roll **42** positioned in toner hopper **40** is rotatably mounted in bearing blocks **43** and the bearing blocks positioned in end plates **25** and **26**, respectively. In this preferred embodiment, roll **42** is a smooth surface stainless steel roll which is rotated through the toner hopper at a speed to produce sufficient mechanical action to carry the finely divided toner material into the main housing **20**. Roll **42** is positioned in opening **41** so that an aperture is formed between the roll on the sidewall of the opening such that toner can pass therebetween but the coarser carrier material is precluded from backing up into the toner housing. Although not necessary, a fine mesh screen **44** is also positioned adjacent to the said aperture. on the developer housing side of opening **41** through which toner material to pass into the main flow stream of the developer material but prevents the carrier material from flowing in contact with the rotating roller **42**.

As shown in FIG. **3**, the shaft portion of roller **42** extends exterior to the developer housing and has rigidly affixed thereto gear **38**. Gear **38**, in turn, is matted to the drive gear on the vane mixer. The gear ratio between the matting, gears is preselected so that roller **42** rotates at a speed so that toner addition is compatible with the flow rate being maintained by the vane mixer **21**. Increasing the speed of the vane mixer will, in effect, cause more toner to be added to the system thus making the system self-regulating.

Space charge build up around the carrier material is entirely eliminated in the present invention by placing the vane mixer at a ground potential. In order for developer material to reach the active development zone, the developer material must be acted upon by the vane mixer **21**. It has been found that the grounded vane mixer efficiently bleeds off any space charge build up that might occur in the backside of the system thereby assuring that only properly charged developer material reaches the start of the active development zone.

The apparatus of the present invention lends itself to use in automatic xerographic apparatus not only because of its high efficiency but also because of its rapid response upon start up. The vane mixer system, as herein disclosed, when properly loaded with developer material reaches optimum operating conditions in a matter of seconds. This ability to rapidly reach operating conditions gives the present apparatus the capabilities needed in rapid automatic xerographic machines.

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

What we claim is:

1. In a copying apparatus in which a latent electrostatic image on a photoconductive surface in the form of a rotatably mounted xerographic drum is rotated at a predetermined speed in an upheld direction past a development station positioned at the lower quadrant thereof, the development station including a housing having an opening to receive a portion of the rotating drum therein, wherein the housing is adapted to hold a quantity of two component developer material including carrier and toner particles in contact with the portion of the drum surface along an active development zone whereby a flow of developer material is moved in contact with the drum surface as the drum rotates through the housing, an improved development apparatus comprising impeller means positioned in said housing for pumping developer material from the bottom portion of the housing toward the start of the active development zone, means to drive said impeller means relative to the rotating drum surface at a speed sufficient to maintain a proper flow of developer material through said housing in contact with the drum surface, means to maintain said impeller at a ground potential during development to ensure that properly charged developer material is introduced at the start of the active development zone continuously, and hopper means located on the downhill side of the developer flow in direct communication with the developer flow within the housing for introducing additional toner particles to the developer material as toner particles are consumed during development.