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3,415,224

MAGNETIC CASCADE DEVELOPMENT APPARATUS

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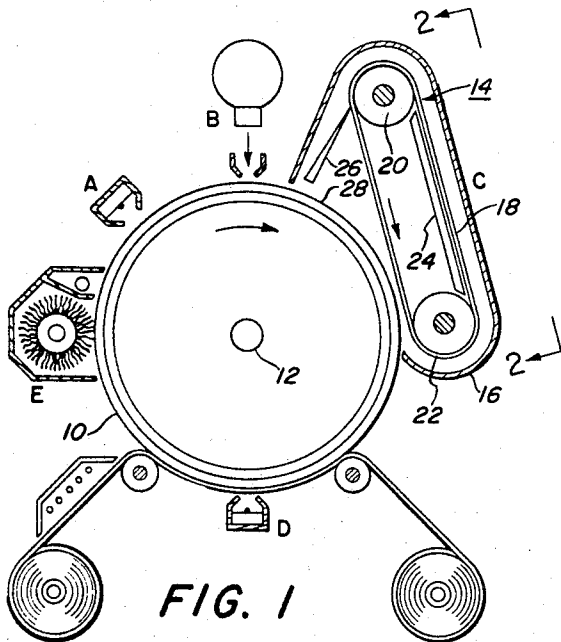


FIG. 1

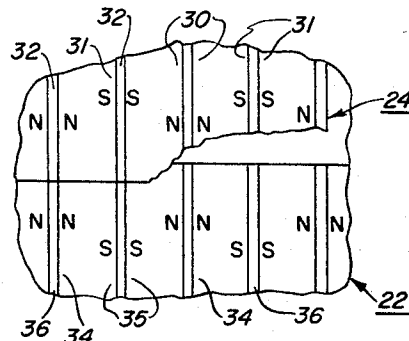


FIG. 3

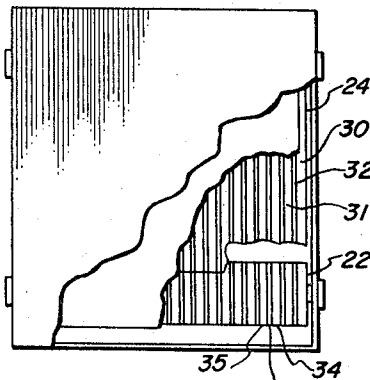


FIG. 2

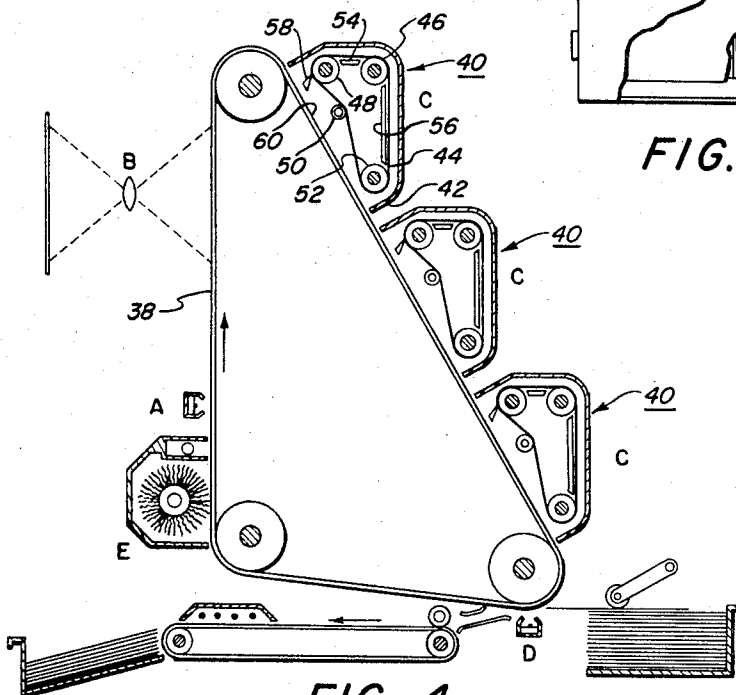


FIG. 4

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MAGNETIC CASCADE DEVELOPMENT
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ABSTRACT OF THE DISCLOSURE

Xerographic apparatus for the cascade development of latent electrostatic images with a two-component ferromagnetic developer. The apparatus includes a rotating magnetic transport belt having a lower portion positioned across the photoconductive surface adjacent the lower end of the development zone to magnetically attract the cascaded developer away from the photoconductive surface. The upper portion of the transport belt is positioned above the upper end of the development zone and has a scraper blade to remove developer from the transport belt. The scraper blade then guides the developer onto the photoconductive surface at the upper end of the development zone for cascade developing latent electrostatic images formed on the photoconductive surface. A plurality of these development units may be employed sequentially along a photoconductive surface.

This invention relates in general to xerographic development, and in particular, relates to apparatus for cascade developing latent electrostatic images with a ferromagnetic two-component developer mixture.

In the practice of xerography as described in U.S. Patent No. 2,297,691 to Chester F. Carlson, a xerographic surface comprising a layer of photoconductive insulating material affixed to a conductive backing is used to support electrostatic images. In the usual method of carrying out the process, the xerographic plate is electrostatically charged uniformly over its surface and then exposed to a light pattern of the image being reproduced to thereby discharge the charge in the areas where light strikes the layer. The undischarged areas of the layer thus form an electrostatic charge pattern in conformity with the configuration of the original light pattern.

The latent electrostatic image can then be developed by contacting it with a finely divided electrostatically attractable material such as a resinous powder. The powder is held in image areas by the electrostatic fields on the layer. Where the field is greatest, the greatest amount of material is deposited; and where the field is least, little or no material is deposited. Thus, a powder image is produced in conformity with the light image of the copy being reproduced. The powder is subsequently transferred to a sheet of paper or other surface and suitably affixed to thereby form a permanent print.

The electrostatically attractable developing material commonly used in xerography consists of a pigmented resinous powder referred to here as "toner" and a "carrier" of larger granular beads formed with glass, sand or steel cores coated with a material removed in the triboelectric series from the toner so that a triboelectric charge is generated between the toner powder and the granular carrier. The carrier also provides mechanical control so that the toner can be readily handled and brought into contact with the exposed xerographic surface. The toner is then attracted to the electrostatic image from the carrier to produce a visible powder image on the xerographic surface.

The most common technique employed today for

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bringing the developer into contact with a latent electrostatic image-bearing surface for its development is the cascade system. In the cascade system, the developer is cascaded or poured across a segment of a rotating xerographic drum. During the time of contact between the developer and the xerographic surface, the toner-coated carrier moves across the surface while toner particles are electrostatically pulled away from the carrier by the charged areas of the surface and are selectively deposited thereon to form a visible powder image. The partially denuded carrier granules then move beyond the xerographic surface. As toner images are formed, additional toner powder is generally supplied to the developer mixture in proportion to the amount of toner deposited on the xerographic surface to maintain the proper amount of toner in the developer mixture.

Typical of the cascade development systems employed today is that disclosed in U.S. Patent No. 3,062,109 to Mayo et al. According to that disclosure, the developer mixture is moved from a sump region to an area elevated with respect to the photoconductive surface by means of conveyor buckets. The developer is then dropped onto a portion of the xerographic surface for its development. After reaching an area on the xerographic surface which is below the horizontal center line of the xerographic drum, a fixed mechanical pick-off baffle located slightly removed from the drum directs the developer back into the sump region for the recirculation by the conveyor system.

Such conventional cascade systems have been found extremely suitable for the purposes desired. Such systems, however, have inherent limitations. For example, in such systems, it is necessary that the upper end of the conveyor be located above the horizontal center line of the drum or other surfaces being developed. It is further necessary that the development zone extend to a point below the horizontal center line of the surface being developed so that a mechanical pick-off baffle may guide the developer away from the photoconductive surface to a sump area therebelow. Such systems, furthermore, require the use of a developer sump so that the buckets of the conveyor may pick up the developer properly. Furthermore, the use of mechanical pick-off baffle is not always the most efficient system since developer tumbling away from the xerographic surface adjacent the lower portion of the development zone often are bounced through the space between the baffle and the photoconductive surface. This has a tendency to contaminate the other machine parts.

The development system of the instant invention is adapted primarily as a substitute for the conventional bucket conveyor system. It is adapted to be employed with two-component developer having ferromagnetic properties. Such a magnetic developer is known in the art per se and is described, for example, in U.S. Patent No. 2,618,551 to Walkup and U.S. Patent No. 2,874,063 to Grieg. The present invention contemplates a rotatable endless belt positioned with its lower region adjacent the lower portion of the development zone to magnetically attract the cascaded developer away from the photoconductive surface and entrain it on the belt for transporting it to an elevated location. The developer may then be removed from the belt and fed onto the upper region of the development zone for cascade developing images formed on the rotating xerographic surface.

While it may appear that the modification proposed by the instant application is merely in a new conveyor system, its use in conjunction with a cascade development zone has extended utility to a xerographic development zone in which it is employed. This extended utility is characterized in low developer bead leakage from and beyond the development zone, a reduction in size in the

development zone; greater latitude of location for development zone, etc.

It is, therefore, an object of the present invention to develop latent electrostatic images with two-component ferromagnetic developer.

It is a further object of the instant invention to develop latent electrostatic images with a cascade system over an extended range of areas on the xerographic surface.

It is a further object of the instant invention to control cascade development adjacent the lower portion of the

It is a further object of this invention to magnetically remove cascading developer from the lower portion of a cascade development zone.

It is a further object of the instant invention to reduce the size of cascade development systems.

It is a further object of the instant invention to reduce developer bead leakage adjacent the lower portion of cascade development systems.

It is a further object of the instant invention to cascade developed latent electrostatic images at various locations on a common xerographic surface.

These and other objects of the invention are obtained by a cascade development system employing two-component ferromagnetic developer. The apparatus includes a rotating magnetic transport belt having a lower portion positioned across the photoconductive surface adjacent the lower end of the development zone to magnetically attract the cascade developer away from the photoconductive surface. The upper portion of the transport belt is positioned above the upper end of the development zone. The apparatus includes a scraper blade to remove developer from the transport belt and to guide it onto the photoconductive surface at the upper end of the development zone for the cascade development of latent electrostatic images formed on the photoconductive surface.

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

FIG. 1 is the diagrammatic sectional view illustration of a xerographic machine adapted for continuous and automatic use which is employing the development system of the instant invention.

FIG. 2 is a plan view showing the conveyor assembly taken in the direction of the arrows 2—2 of FIG. 1 with parts of the belt broken away for greater clarity.

FIG. 3 is an enlarged showing of the magnetic members of FIG. 2 with the poles of the magnetic pieces indicated.

FIG. 4 is a diagrammatic sectional view of a xerographic machine adapted for continuous and automatic use and employing a plurality of developing stations constructed in accordance with the instant invention.

Shown in FIG. 1 is a xerographic machine employing a developer conveyor constructed in accordance with the instant invention. The elements of this machine, which are constructed for continuous and automatic operation, are all conventional in the xerographic arts except for the novel development system, which forms the basis of the instant application. For the purpose of the present disclosure the several xerographic processing stations in the path of movement of the xerographic surface for each machine may be briefly described as follows:

A charging station A, at which a uniform electrostatic charge is deposited on the photoconductive layer of the xerographic drum;

An exposure station B, at which the light or radiation pattern of copy to be reproduced is projected onto the drum surface to dissipate the drum charge in the exposed areas thereof to thereby leave a latent electrostatic image of the copy to be reproduced;

A developing station C, at which a xerographic development material, including toner particles having an electro-

static charge opposite to that of the electrostatic latent image, are cascaded across the drum surface, whereby the toner particles adhere to the electrostatic latent image to form a xerographic powdered image in the configuration of the copy being reproduced;

A transfer station D, at which the xerographic powder image is electrostatically transferred from the drum surface to a transfer material or a support surface; and

A drum cleaning and discharge station E, at which the drum surface is brushed to remove residual toner particles remaining thereon after image transfer, and at which the drum surface is exposed to a relatively bright light source to effect substantially complete discharge of any residual electrostatic charge remaining thereon.

The latent electrostatic images to be developed are formed on a xerographic surface 10 formed in the shape of a drum or other cylinder. The drum is adapted to be rotated about its axis by a main drum drive shaft 12 by any conventional power source, not shown. The movement of the drum permits its surface to be moved past the various processing stations including the development zone.

The developing instrumentalities include a conveyor assembly 14 and related elements confined within a housing 16 adjacent one of the upper quadrants of the xerographic drum. The conveyor assembly 14 includes an endless rotatable belt 18 trained around a pair of rollers 20 and 22. Both of these rollers are trained for rotation in the direction of the arrow as shown with at least one of the rollers connected to a suitable source of power to drive it in that direction.

Adjacent an inner surface of the belt 18 is a magnetic plate 24 to assist in creating a magnetic field adjacent the flat portion of the belt remote from the xerographic drum. This plate assists in holding the magnetic developer adjacent the belt in this area against the action of gravity to permit the belt to raise the developer to its elevated location. Positioned adjacent the upper roller 20 of the conveyor assembly is a scraper blade 26 which functions to scrape developer from the conveyor assembly and to guide into the upper portion of the cascade development zone 28. Scraper blade 26 may also be located beyond the magnetic field of the roller 20.

The construction of the developer conveyor assembly 14 is better seen in FIGS. 2 and 3. As shown in these figures, the magnetic plate 24 is constructed of a plurality of magnetic sections having north and south poles 30 and 31 and non-magnetic metallic spacers 32 running in the direction of movement of the belt 18. This allows the magnetic field to emanate from the plate 24 through and beyond the non-magnetic belt 18. The magnetic field of this plate 24 is supplemented by rollers 20 and 22 which are also formed of magnetic sections. Roller 22, which is constructed in the same manner as roller 20, is constructed of discs having alternating north and south sections 34 and 35 separated by non-magnetic metallic discs 36 therebetween. The field lines emanating from these discs also form magnetic flux lines adjacent and through non-magnetic belt 18 to constitute a magnetic field adjacent the belt from the nine o'clock position of the lower roller 22 as shown in FIG. 1 all the way to the nine o'clock position of the upper belt 20 as shown in FIG. 1 in the direction of the motion of the belt.

As two-component ferromagnetic developer is cascaded across the xerographic surface 10 through the development zone 28, it will enter the magnetic field of the lower roller 22. When this occurs, the developer will be entrained by the field into contact with the rotating belt 18. Since the system relies on the magnetic properties between the developer and conveyor assembly 14 to remove it from the xerographic surface, it is not necessary that the lower portion of the cascade development zone be located adjacent the horizontal center line of the xerographic drum. Furthermore, there is no need to employ a mechanical pick-off baffle beneath the horizontal

center line of the drum to move the developer away from the drum and into a sump area. Once the cascaded developer has been entrained on the magnetic field adjacent the belt 18, the movement of the rollers and belt continuously move the developer around the lower roller 22, up the flat segment of the belt adjacent the plate 24 and around the upper roller 20. During this time the developer is transferred from the magnetic field of the lower roller, into the field of the plate and then into the field of the upper roller in a continuous fashion whereby no developer is lost from the belt 18.

As the continuous stream of developer magnetically held on the belt 18 is moved from the twelve o'clock to the nine o'clock position of the roller 20, it is contacted by a scraper blade 26 which functions to scrape the developer from the belt to exterior of the magnetic field thereof. This plate, like the conveyor belt 18 and rollers 20 and 22, extends across the development zone a length at least equal to the length of the photoconductive drum to ensure total development across the length of the drum. The plate 26 after scraping the developer from the belt 18, guides it along a path into the development zone 28 adjacent the upper end thereof.

At this point, the developer directly falls across the rotating xerographic surface until it is again entrained by the magnetic fields adjacent the lower roller 22. When moved from the xerographic surface 10 into entrainment with the belt 18, the magnetic property of the developer carrier is employed to move the developer to the belt, with the toner particles attached to the carrier by the triboelectric attraction therebetween.

In any cascade development system some portion of toner particles become removed from their associated carrier granules by the jarring action of the developer as it tumbles across the development zone. In a cascade system employing a mechanical pick-off baffle and sump located beneath the horizontal center line of the drum, there is a tendency for the toner particles to become separated from the carrier granules by the mechanical forces acting on and in the developer. These unassociated toner particles often then become attached to the xerographic drum by mechanical as well as electrostatic forces. This deposition of toner on non-image areas of the photoconductive surface by mechanical forces is characterized by toner deposition in background areas of the final copy. By employing the magnetic fields to attract the developer away from photoconductive surface, this unwanted toner deposition is greatly reduced since the carrier and toner are removed from the xerographic surface at the same relative location on the xerographic surface. Consequently, copy created with the cascade development system of the instant invention is characterized by a reduction in background toner depositions.

The use of the magnetic fields to remove the developer from the drum also eliminates the need for a sump or developer reservoir beneath the lower reach of the rotating conveyor assembly. This saving of space is important due to the desire to make more compact xerographic machines. Furthermore, the percent of developer escaping entrainment from the lower magnetic roller 22 has been shown to be far less than the leakage incurred in cascade systems employing mechanical pick-off baffles. Consequently, although the embodiments illustrated on the attached sketches show a portion of the housing as located in the area where a mechanical pick-off baffle would be employed, this is done merely as an expedient to make a housing free from contaminating effects. There is no need for the pick-off baffle and this extension does not function as such. It may, however, be desirable to employ an arcuate plate beneath the lower roller 22 so that any slight amount of developer lost from magnetic entrainment would be reattracted to the belt and roller by the magnetic forces of the roller 22.

Although the embodiments of the instant invention do not show the use of a toner dispenser to add additional

toner to the system in replacement of that lost in the system due to the development of images, one could readily be placed at any position over the upper roller 20 or scraper blade 26. Furthermore, developer cross-mix plates could be positioned on the upper surface of the scraper plate 26 or in contact with the belt 18 above the upper roller 20, or any other suitable location to create a cross blending of the developer within the system.

Shown in FIG. 4 is a second embodiment of the instant invention. This embodiment operates on the same principles as those described with respect to the embodiment of FIGS. 1, 2 and 3. The only difference is that a plurality of the above-described development systems have been positioned adjacent a single xerographic surface. For the purpose of describing the instant invention, the plural development stations have arbitrarily been shown to be employed in conjunction with a photoconductive surface formed as an endless belt 38 rotatable through similar xerographic processing stations in direction of the arrow as shown. These plural development stations could readily be employed on a drum-shaped xerographic surface.

The plurality of developing stations in the FIG. 4 embodiment are indicated generally at 40. Each of these development stations are identical in construction and therefore only one will be described.

Each of these development stations 40 is housed within a machine housing 42 and includes an endless rotatable belt 44 trained around a plurality of rollers 46, 48, 50 and 52. Power is imparted to at least one of the rollers by any conventional power source, not shown. Each of the rollers is constructed of the magnetic discs as disclosed with respect to the rollers of the embodiment of FIGS. 1 and 2 except for roller 50 since developer is not being magnetically transported at this region. Located behind the belt 44 adjacent the reaches thereof wherein developer must be conveyed are magnetic backing plates 54 and 56. These backing plates are constructed in the same manner as plates 24 described above. Furthermore, a scraping blade 58 is located adjacent the upper roller 48 in proximity to the upper portion of the cascade development zone 60.

Scraper blade 58 could be dispensed with in this embodiment. This is because the developer would gravity fall from the belt onto the development zone as it moved out of the magnetic field of roller 48. A developer guiding plate, however, would be desirable to minimize developer impact as it struck the xerographic surface.

As can be seen, each of the individual development stations 40 is positioned adjacent the xerographic surface. This is possible since it is not necessary that the lower end of the development zone be positioned below the horizontal center line of the drum as was previously required in prior art cascade systems. Although three development stations 40 have been shown in FIG. 4 embodiment, it is clearly seen that any number could be so employed. Furthermore, the plurality of these development stations could be positioned adjacent an upper quadrant of quadrants of a xerographic drum.

With the instant development zone it is thus possible to cascade developer a single latent electrostatic image with toner particles of a first color and polarity and then develop the same partially developed image with toner particles of a second color and a second polarity so that the resulting image is comprised of first color toner in first areas and a second color toner in second areas. This type of a system is described in U.S. Patent No. 3,045,644 to Schwartz. In the Schwartz disclosure, however, it was disclosed that such a technique was capable of being carried out with fur or magnetic brush development systems. But by employing the development system of the instant invention, it is now possible to create two color images by cascade development.

It is also possible to create color prints in the manner suggested by Hayford et al. in U.S. Patent 3,057,720.

In this instance, three development stations 40 would be employed, each of which would be provided with one of the three primary colors. In such a system, the xerographic surface would be charged and then exposed to an image representing one color of a multicolor original. This would then be developed by movement through the cascade zone having the desired color. The other two cascade zones would be inoperative. The xerographic surface would then be moved through the transfer station where transfer to a paper, positioned to be in registration with the image during transfer, would occur. After cleaning, it would then be recharged and re-imaged to a second image representative of the second color of the multicolor original. This latent electrostatic image would then be developed by movement through the second development station having the second color toner while the first and third development station were inactivated. After transfer in registration with the first image, the sequence would then be repeated by imaging it to a third image and developing it with the third color developer for a third in-registration transfer to the final copy sheet to create the composite toner image on the copy sheet representing the entire color original. The compound toner image would then be fused for creation of the multicolor copy of the original. It should also be understood that any number of colors and developments could be employed.

This particular method of creation of multicolor xerographic prints, as stated above, is old as disclosed, for example, in the Hayford et al. patent mentioned hereinabove. But the development station of the instant invention permits the Hayford et al. method to be readily practiced on a continuous and automatic xerographic machine.

While the instant invention as to its objects and advantages has been described herein as carried in specific embodiments thereof, it is not desired to be limited thereby; but it is intended to cover the invention broadly within the scope of the appended claims.

What is claimed is:

1. Apparatus for cascade developing latent electrostatic images on a photoconductive surface with magnetic developer including:

- a rotatable endless belt,
- first roller means to position a portion of the belt adjacent the photoconductive surface in proximity to the lower portion of the cascade development zone,
- second roller means to position a portion of the belt above the upper portion of the cascade development zone,
- guide means to direct developer from adjacent the second roller into the cascade development zone,
- means to create a magnetic field through the endless

belt from adjacent the end of the cascade zone to at least an area adjacent the guide means, and drive means to rotate the belt in a direction whereby cascading two-component developer on the photoconductive surface is entrained by the magnetic field adjacent the second roller and transported to an area at least adjacent the guide means.

2. The apparatus as set forth in claim 1 wherein the first roller means is formed of magnetic field producing sections and constitutes at least a portion of the means to create the magnetic field.

3. The apparatus as set forth in claim 2 and further including a magnetic plate positioned interior of the endless belt at a location between the first and second roller means adjacent the extent of the belt remote from the development zone.

4. Apparatus for cascade developing latent electrostatic images on a photoconductive surface with magnetic developer including:

means to deposit magnetic developer onto the photoconductive surface adjacent the upper portion of the development zone,

magnetic field producing means positioned across the photoconductive surface to define the lower portion of the cascade development zone, said magnetic field producing means being of sufficient magnitude to entrain cascading developer, and

means to move developer magnetically entrained by the field producing means to a location remote from the photoconductive surface.

5. The apparatus as set forth in claim 4 wherein the field producing means is a cylinder having magnetic sections.

6. The apparatus as set forth in claim 5 wherein the means to move the developer includes a belt rotatable with the cylinder to convey developer, entrained by the magnetic sections of the cylinder, to an elevated location for again being cascaded down the photoconductive surface.

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