United States Patent [19]

Cade et al.

[11] **3,807,997**

[45] **Apr. 30, 1974**

[54] **PLURAL ELECTRODE DEVELOPMENT METHODS FOR LATENT ELECTROSTATIC IMAGES**

[75] Inventors: **Ronald L. Cade,** Fairport; **John F. Knapp,** Webster, both of N.Y.

[73] Assignee: **Xerox Corporation,** Stamford, Conn.

[22] Filed: **Dec. 22, 1972**

[21] Appl. No.: **317,573**

Related U.S. Application Data

[62] Division of Ser. No. 141,240, May 7, 1971, Pat. No. 3,719,169.

[52] **U.S. Cl.** ..... **96/1 SD,** 1 R, 117/17.5, 118/636, 118/637

[51] **Int. Cl.** **G03g**

[58] **Field of Search** ..... 96/1 R, 1 A, 1 SD, 14; 118/636, 637; 117/17.5; 355/3, 15

[56] **References Cited**

UNITED STATES PATENTS

3,670,700	6/1972	Britt et al.	117/17.5
3,663,291	5/1972	Royka	117/17.5
3,416,494	12/1968	Hudson	118/637
2,573,881	11/1951	Walkup et al.	101/426
3,606,863	9/1971	Latone	118/637
3,620,191	11/1971	Lyles	118/637
3,357,399	12/1967	Fisher	118/637
3,638,610	2/1972	Lyles	118/636
3,719,169	3/1973	Cade et al.	118/636

Primary Examiner—Ronald H. Smith
Assistant Examiner—Edward C. Kimlin

[57] **ABSTRACT**

Development methods and develoment electrode apparatus therefor are provided in accordance with the teachings of the present invention wherein at least two development electrodes are employed at a developing station in electrophotographic apparatus. The first development electrode presented to a latent electrostatic image undergoing development displays characteristics which are optimum for high rates of developer flow and hence only reduced development of portions of a latent electrostatic image exhibiting low charge densities and extended areas is achieved but may be accompanied by optimum cleaning. The second development electrode presented to the instant electrostatic image to be developed displays characteristics which are optimized to complete low contrast and extended area development, however, as the majority of developer material is removed, no inhibition of the developer flow occurs at said second development electrode.

4 Claims, 2 Drawing Figures

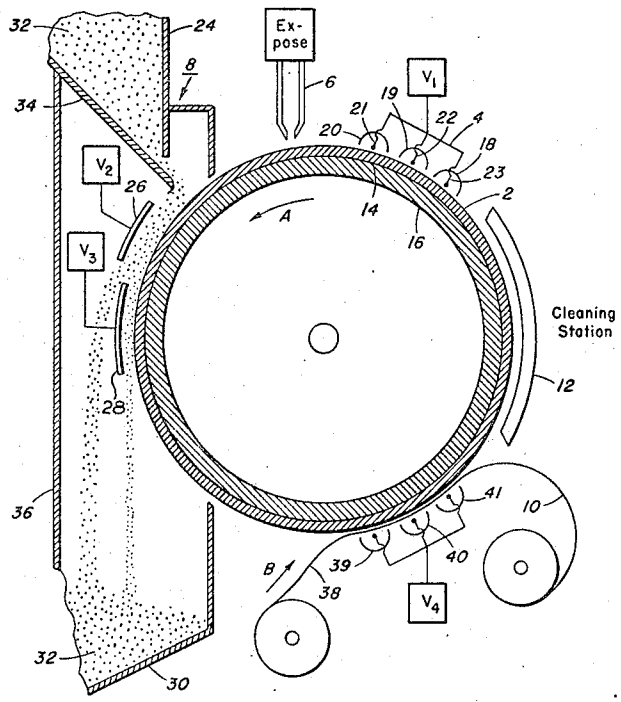


Fig. 1.

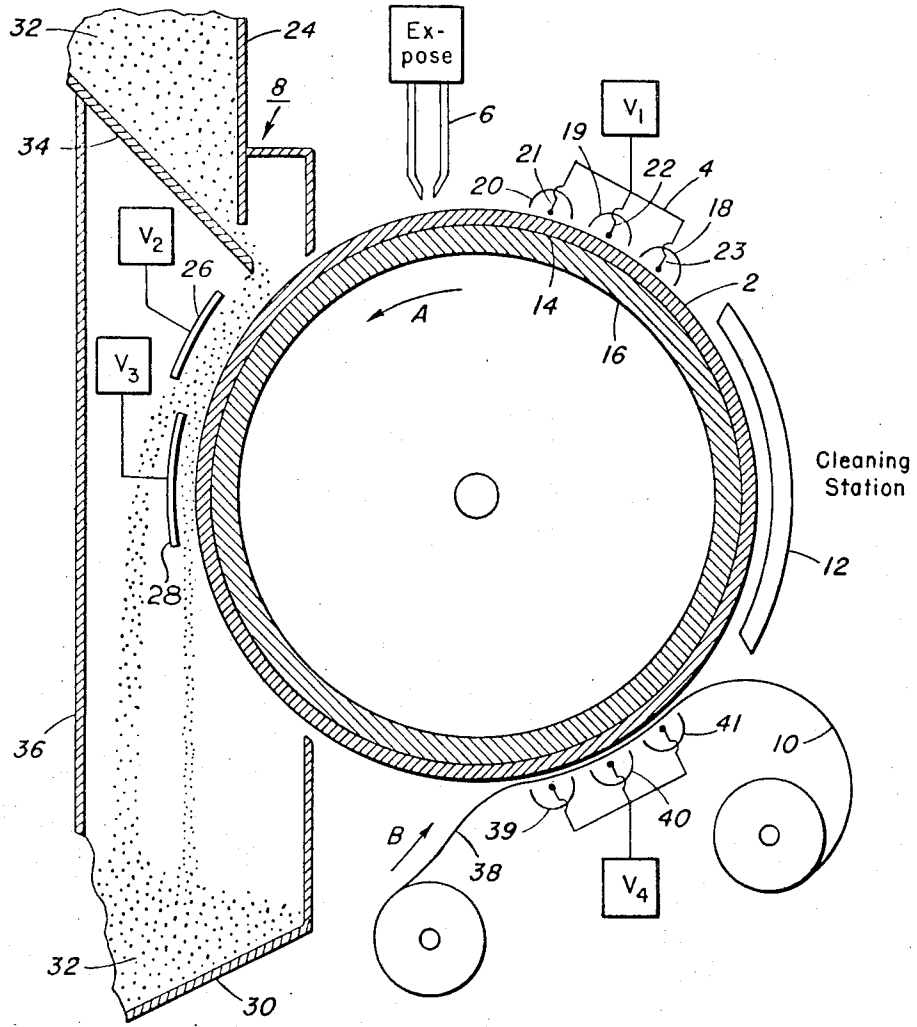
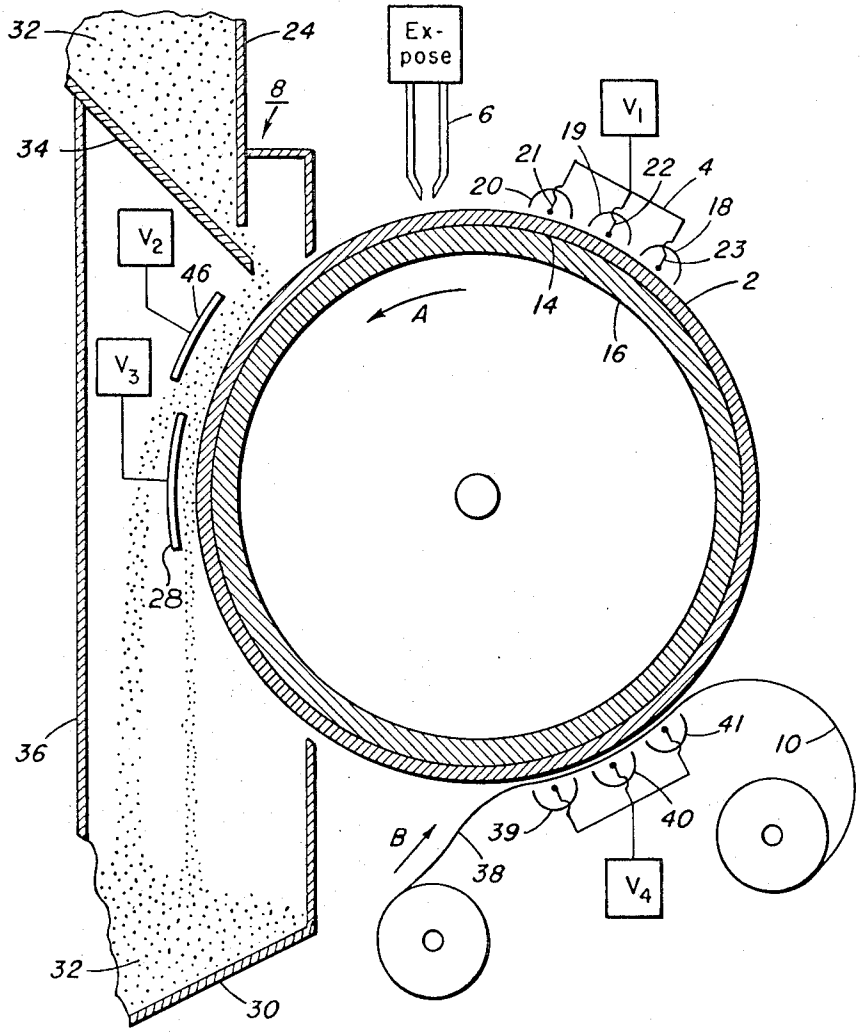

32
24
Ex-
pose
8
6
34
V_1
19
21
22
4
20
18
23
V_2
26
2
A
14
16
V_3
Cleaning
Station
28
12
36
41
10
40
39
B
38
V_4
32
30

Fig. 2.


Ex-
pose
6
8
24
32
34
V_1
19
21
20
22
4
18
23
2
V_2
46
V_3
A
14
16
28
36
41
10
40
39
B
38
V_4
32
30

PLURAL ELECTRODE DEVELOPMENT METHODS FOR LATENT ELECTROSTATIC IMAGES

This is a division, of application Ser. No. 141,240, filed May 7, 1971, now U.S. Pat. No. 3,719,169.

This invention relates to electrophotographic development techniques and more particularly to improved methods and apparatus for developing latent electrostatic images.

In conventional electrophotographic processes such as taught in U.S. Pat. No. 2,297,691, as issued to Carlson on Oct. 6, 1947, or as contemplated by other electrophotographic techniques well known to those of ordinary skill in the art, a photoreceptor is charged and selectively exposed so that a latent electrostatic image representative of the object to be copied is formed due to the selective discharge of the surface of the photoreceptor in accordance with a light and dark pattern representative of the object to be copied. The latent electrostatic image formed is then developed or rendered viewable generally by the application of charged finely divided particles, known as toner, to the image area of the photoreceptor so that such charged particles are deposited in a selective pattern on the image area of the photoreceptor in accordance with the charge pattern exhibited by the latent electrostatic image formed. The developed image as thus formed may then be fixed to the surface of the photoreceptor or as is usually the case transferred to a transfer member, such as a paper sheet, and then fixed so that the photoreceptor is available for subsequent use.

In the development of a latent electrostatic image by the application of charged toner particles to the surface of a photoreceptor, the contour of the electric field in the region of the latent electrostatic image plays a critical role in the manner in which toner particles will be attracted to and deposited on the surface of the photoreceptor. More particularly, in areas where the latent electrostatic image exhibits sharp electrostatic contrast, such as a portion thereof corresponding to a boundary between a light and dark portion of the object being copied, and is thus characterized by a fringing field, toner particles will densely adhere. However, in areas corresponding to extended dark areas of the object being copied, a fringing field configuration will only obtain at the edges thereof and hence when such an area is developed by the application of oppositely charged toner particles thereto, the edges of such an area will develop out as solid black due to a high density deposition of charged toner particles thereon while portions of the photoreceptor central to such an area would not receive a high density toner deposition and accordingly would not develop out as solid black. This development phenomenon obtains because of the different charge levels, and hence the greater field intensity or sharp voltage contrast exhibited at the boundaries between light and dark portions of an electrostatic image and due to the fact that more toner particles will be deposited in regions of sharp potential difference. Therefore, in the central portions of a large solid image area, the voltage contrast between adjacent points is small and toner deposition during development is proportionally reduced.

While the foregoing development phenomenon is advantageous with respect to the development of latent electrostatic images representing line copy or the like due to the high contrast development which results, the same phenomenon would virtually preclude electrophotographic copying of objects manifesting continuous tone qualities and particularly those characterized by large solid areas associated with a dark image pattern because the resulting developed image derived therefrom would be marked by a halo effect and generally convey a washed-out appearance. However, as is well known to those of ordinary skill in the art, the adverse effects characterizing the foregoing development phenomenon may be completely alleviated by using a device known as a development electrode. Development electrodes in their simplest configuration may take the form of a conductive sheet disposed in close proximity to and parallel with the surface of a photoreceptor on which an electrostatic charge pattern is formed. The development electrode is normally biased with respect to the charge pattern or latent electrostatic image formed on the photoreceptor and such bias may conveniently be selected to be equal to the background level of the latent electrostatic image so that the background will develop out at a uniform white level. The effect of the development electrode is to change the field configuration associated with the latent electrostatic image and to effectively modify the field in the space above large continuous areas of charge. Thus, development electrodes act to vary the field configuration associated with the latent electrostatic image so that the various portions of such latent electrostatic image will be developed in a manner more nearly in proportion to the electrical charge density thereof rather than in a relationship proportional to the voltage gradients which obtain. Additionally, a development electrode acts to intensify the electrical field near the surface of the photoreceptor so that field strength at any point between the surface of the photoreceptor and the development electrode will be proportional to the potential exhibited by the surface of the photoreceptor on which the latent electrostatic image is formed and inversely proportional to the distance between the photoreceptor and the development electrode. Thus, for effective utilization, a development electrode must be disposed in a relatively close relationship to the photoreceptor on which the latent electrostatic image is formed. Therefore, as is well known to those of ordinary skill in the art, the use of a development electrode or a device incorporating the attributes thereof, is virtually mandatory to high quality continuous tone development of latent electrostatic images and to the reproduction of solid black areas of an image to be developed.

Of the many development techniques well known to those of ordinary skill in the art, modified cascade development techniques have found wide areas of application and are in general use in electrophotographic processing equipments due principally to the ease with which large volumes of toner materials may be applied to the surface of a photoreceptor whereby potentially high density image development may be achieved. Cascade development techniques are based upon triboelectrification principles whereby two dissimilar materials are brought into contact with each other and each material exhibits a resulting charge polarity opposite to the other. Accordingly, in cascade development techniques, relatively fine toner particles are mixed with a coarse, beaded material called carrier, as taught for instance in U.S. Patl No. 2,297,691, to form developer material whereupon the toner particles become triboelectrically charged and adhere to the surfaces of the

carrier beads. Development of a latent electrostatic image may then be carried out by cascading the developer material formed over the surface of the photoreceptor and as the carrier beads pass over the portions of the surface of the photoreceptor occupied by the latent electrostatic image, the electrostatic forces manifested by the latent electrostatic image will overcome the electrostatic bond between the toner particles and carrier beads so that such toner particles will be deposited on the image area of the photoreceptor. The cascading of the developer material may be accomplished by simply pouring developer material over a photoreceptor in the form of a plate and rocking the photoreceptor to accomplish developer motion and carrier bead removal. Alternatively, in continuous process electrophotographic copying apparatus wherein the photoreceptor normally takes the form of a drum or a continuous web, the developer material is flowed over the surface of the photoreceptor using a gravitational flow and the large amount of toner and bead material recovered therefrom is recycled for subsequent use.

The cascade development technique briefly outlined above presents a rather ideal mode of development for latent electrostatic images representing line copy and the like because the field configuration associated therewith, as aforesaid, coupled with the large amount of available toner particles applied thereto results in a viewable image configuration having solidly black characteristics and sharp contrast. However, when cascade development techniques are used in conjunction with latent electrostatic images exhibiting continuous tone characteristics and/or having large or solid black areas associated therewith, the resulting image developed will manifest the washed-out and haloed appearance described above. Accordingly, for the successful application of cascade development techniques to the development of latent electrostatic images exhibiting continuous tone, development must take place in the presence of a development electrode for the reasons detailed above.

In a typical two component developer materials in general use, the carrier beads employed to triboelectrically charge the toner material display a typical size variation ranging from 250 to 600 μm in diameter although carrier beads as small as 100 μm are known. Therefore, when developer employing carrier material of this nature is utilized in continuous process electrophotographic equipment, it will be appreciated that if a development electrode is placed sufficiently close to the surface of the photoreceptor so that field varying characteristics thereof have a substantial effect, the developer material will have a tendency to bunch between the surface of the photoreceptor and the development electrode. This bunching of the developer material not only inhibits the free flow of developer necessary for proper development in cascade development applications, but in addition thereto often results in smudging of the developed image, scratching and deterioration due to abrasion of the surface of the photoreceptor together with significantly reduced development times. As cascade development techniques are generally preferred, substantial efforts have been devoted to solving the problem posed by the conflicting requirements of a location for the development electrode proximate to the surface of the photoreceptor and the use of appropriate volumes of developer material which are freely cascaded or flowed over the surface of the photoreceptor so that a densely populated, rapidly developed toner image may be formed. However, as the spatial requirements of a properly positioned development electrode, as aforesaid, are generally adverse to the requirements of cascade development techniques, the solutions presently available have tended to proceed by way of compromising the parameters employed for both the development electrode relied upon and the cascade development technique employed. Thus, in certain electrophotographic copying systems, smaller volumes of developer material are cascaded over the surface of the photoreceptor in an effort to reduce the bunching effect caused by the development electrode and the development electrode is placed a further distance away from the surface of the photoreceptor than would otherwise be selected; however, this compromise has not been highly desirable because it results in development speeds and hence machine speeds which are greatly reduced while the effects produced by the development electrode are attenuated. Other solutions proceed by using specialized development electrodes, as disclosed for instance in U.S. Pat. Nos. 3,147,147, to C. F. Carlson, and 3,011,474, to H. O. Ulrich wherein the development electrode is apertured or laminated in form and thus configurated in a manner to optimize the flow of developer material while development electrode spacings are employed which are calculated to avoid bunching of the developer material. However, as grooved, laminated or apertured development electrodes are expensive to manufacture and must be rather large in surface area due to the discontinuous surfaces employed, and furthermore since such specialized development electrodes may not be closely disposed to the surface of the photoreceptor on which the latent electrostatic image is formed, these solutions have been viewed as less than ideal.

Additionally, although virtually all continuous process electrophotographic equipments in general use employ a separate cleaning station to remove residual toner particles from the surface of a reusable photoreceptor prior to each use thereof, recent advances in the art of cascade development techniques, as set forth in Application Ser. No. 789,031 to R. L. Cade and S. W. Volkers entitled Imaging Systems as filed on Dec. 31, 1968 and assigned to the Xerox Corporation, have indicated that the step of cleaning or the removal of residual toner particles from the surface of the photoreceptor may be accomplished subsequent to the formation of a new latent electrostatic image and during the development of such new latent electrostatic image. This technique of development cleaning is considered to possess potential attributes which would be highly desirable in continuous process electrophotographic equipment because successful development cleaning techniques would enable the deletion of specialized cleaning apparatus from continuous process electrophotographic equipment employing cascade development techniques. Thus, not only would the resulting structure of electrophotographic equipments employing development cleaning be highly simplified, but in addition thereto, the manufacturing and maintenance costs associated with a separate cleaning stage would be avoided.

Therefore, it is an object of this invention to provide development methods and development electrode apparatus therefor for use in developing latent electrostatic images wherein field variations affected by the

development electrode configuration employed are maximized while large volumes of toner materials may be applied during the development of such latent electrostatic image.

A further object of this invention is to provide development cleaning methods and apparatus therefor wherein residual toner particles from a preceding development may be removed while high quality, continuous tone development of a latent electrostatic image is obtained.

A further object of this invention is to provide split electrode developing apparatus wherein the characteristics of one portion of said split electrode is optimized for use with large volumes of developer material having a high flow rate while another portion of said split electrode has characteristics which are optimum for the development of low density and extended area portions of a latent electrostatic image but may only receive developer material at relatively reduced flow rates.

Various other objects and advantages of the present invention will become clear from the following detailed description of several exemplary embodiments thereof, and the novel features will be particularly pointed out in conjunction with the claims appended hereto.

In accordance with the teachings of the present invention development methods and development electrode apparatus therefor are provided wherein at least two development electrodes are employed at a developing station of electrophotographic apparatus, the first development electrode presented to a latent electrostatic image to be developed displays characteristics which are optimum for high rates of developer flow and hence only reduced development of low charge densities and extended image areas is achieved but may be accompanied by optimum cleaning; the second development electrode presented to said latent electrostatic image to be developed displays characteristics which are optimized to complete low contrast and extended area development, however, as the majority of developer material is already removed, no bunching or inhibition of the developer flow occurs at said second development electrode. The invention will be more clearly understood by reference to the following detailed description of several exemplary embodiments thereof in conjunction with the accompanying drawing in which:

FIG. 1 illustrates an exemplary embodiment of this invention wherein the methods of development and apparatus therefor as taught herein are shown in combination with typical electrophotographic equipment; and

FIG. 2 illustrates another exemplary embodiment of this invention wherein methods of development cleaning and apparatus therefor as contemplated herein are shown in combination with a modified version of the electrophotographic equipment shown in FIG. 1.

Referring now to the drawings and more particularly to FIG. 1 thereof, there is shown an exemplary embodiment of the present invention wherein the methods of development contemplated herein are embodied in exemplary development electrode structure therefor and depicted in conjunction with typical electrophotographic processing equipment. The electrophotographic processing equipment illustrated in FIG. 1 and described below has been set forth because the methods of development and the development electrode structure therefor taught by this invention are considered to best admit of a full and complete disclosure within an environment in which they might ordinarily be expected to function; however, as will be readily appreciated by those of ordinary skill in the art, the details of the electrophotography processing equipment, and the processes set forth form no part of the present invention per se and accordingly are disclosed for the purposes of explanation rather than limitation.

As shown in FIG. 1, the electrophotographic equipment illustrated takes the form of continuous processing electrophotographic apparatus based on the concepts originally disclosed in U.S. Pat. No. 2,297,691, issued to Carlson on Oct. 6, 1942, and accordingly comprises a photoreceptor **2**, a charging station **4**, an exposure station **6**, a development station **8**, a transfer station **10** and a cleaning station **12**. The photoreceptor **2** as illustrated in FIG. 1 may take the conventional form of a drum or endless web adapted to rotate in the direction indicated by the arrow A or alternatively, the photoreceptor **2** may take the form of a web, sheet or plate arranged to be conveyed past horizontally disposed processing stations by conventional winding, reeling or conveying techniques. In any event, the photoreceptor **2** may take any well-known structural configuration and for the purpose of the instant disclosure has been illustrated as a simple two layer drum **2** including an insulating member **14** and a conductive member **16**. As the photoreceptor **2** forms no part of the instant invention per se, it is here sufficient for an appropriate understanding of this disclosure to appreciate that if the embodiment of this invention depicted in FIG. 1 is employed in conjunction with conventional electrophotographic techniques, the conductive memer **16** may be formed of any suitable conductive material or a nonconductor overcoated with a conductive foil. Similarly, the insulating member **14** would ordinarily be formed of a material displaying photoconductive characteristics such that the member **14** is normally insulating and exhibits excellent charge retentivity but may be rendered selectively conductive by the application of electromagnetic radiation thereto through a light and dark pattern representing an object to be copied or alternatively, reflection exposure techniques may be employed. The materials relied upon in the formation of the insulating member **14** may be selected from any of the well-known group of materials conventionally employed in electrophotographic processes such as amorphous selenium, alloys of sulfur, arsenic or tellurium with selenium doped with materials such as thallium, cadmium sulfide, cadmium selenide, etc., particulate photoconductive materials such as zinc sulfide, zinc cadmium sulfide, French process zinc oxide, phthalocyanine, cadmium sulfide, cadmium selenide, zinc silicate, cadmium sulfoselenide, linear quinacridones, etc., dispersed in an insulating inorganic film forming binder such as a glass or an insulating organic film forming binder such as an epoxy resin, a silicone resin, an alkyd resin, a styrenebutadiene resin, a wax or the like. Other typical photoconductive insulating materials include: blends, copolymers, terpolymers, etc., of photoconductors and non-photoconductive materials which are either copolymerizable or miscible together to form solid solutions and organic photoconductive materials of this type include: anthracene, polyvinylanthracene, anthraquinone, oxidiazole derivatives such as 2,5-bis-(p-aminophenyl)-1,3,4-oxadiazole; 2-phenylbenzoxazole; and charge transfer

complexes made by complexing resins such as polyvinyl carbazole, phenolaldehydes, epoxies, phenoxies, polycarbonates, etc., with Lewis acids such as phthalic anhydride; 2,4,7-trinitroflourenone; metallic chlorides such as aluminum, zinc or ferric chloride; 4,4'-bis (dimethylamino) benzophenone; chloranil, picric acid; 1,3,5-trinitrobenzene; 1-chloranthraquinone; bromal; 4-nitrobenzaldehyde; 4-nitrophenol; acetic anhydride; maleic anhydride; boron trichlroide; maleic acid, cinnamic acid; benzoinc acid; tartaric acid; malonic acid and mixtures thereof. The insulating member **14** may be made either transparent or radiation absorbing in nature by the choice of he photoconductive insulating material selected and as will be appreciated by those of ordinary skill in the art; a multi-layer insulating material could be readily substituted for the single layer member **14** illustrated in FIG. **1**. The photoreceptor **2** is disposed in an operative relationship with each of the processing stations arranged about the periphery thereof so that upon appropriate energization of the illustrated electrophotographic equipment, the rotation of the photoreceptor **2** in the direction indicated by the arrow A, as aforesaid, will subject each point on the periphery of the insulating member **14** to the process step performed at each such station.

The charging station **4** may take the conventional form of one or more charging devices **18–20** which act in the well-known manner to sensitize the photoreceptor **2** by charging the surface of the insulating member **14** to a uniform potential. Although any conventional form of charging devices **18–20** may here be relied upon to impose a charge level on the surface of the photoreceptor **2**, corotron devices having half-round shield configurations have been illustrated in FIG. **1** because the utilization of corotrons in typical electrophotographic equipment is usually preferred. The structure and mode of operation of corotrons such as are illustrated in FIG. **1** are well known and are described in detail in U.S. Pat. Nos. 2,836,725, and 2,879,395, to Vyverberg and Walkup, respectively. Therefore, for the purposes of the instant disclosure, it is sufficient to appreciate that each of the coronodes **21–23** of the depicted corotrons is commonly connected to an appropriate source of high potential V_1 and such corotrons act in the conventional manner to impose a uniform potential charge on the surface of the photoreceptor **2** disposed thereunder. In FIG. **1**, a plurality of charging devices **18–20** has been illustrated since a multiple corotron configuration normally provides more uniform charging across the width of the photoreceptor **2** than would be otherwise available. This occurs because ion charging current from the various portions of an individual coronode disposed longitudinally across the width of a photoreceptor will not ordinarily be uniform and thus the use of plural corotrons will tend to average the charge delivered to various points across the width of the photoreceptor to a uniform level. However, if specialized charging apparatus is relied upon or if minor nonuniformities in the level of charge imposed are acceptable, only a single corotron or other charging device may be employed. Further, for the purposes of the instant disclosure, it may be assumed that the charging station **4** acts to charge the surface portions of the photoreceptor **2** passing thereunder to a uniform level of one thousand volts (1,000V), although, as well known to those of ordinary skill in the art, other arbitrary voltage levels may be selected.

The exposure station **6** is also disposed about the periphery of the photoreceptor **2** and may take the conventional form of a projection system or the like wherein optical trasmission or reflection techniques are relied upon to image a light and dark pattern representing the object to be copied onto the surface of the insulating memer **14** disposed thereunder. In FIG. **1**, a slit exposure device has been generally indicated, however, any optical system which relies upon lenses or the like may be readily employed. Additionally, although the exposure station **6** illustrated in FIG. **1**, has been shown positioned in such manner that the rotating photoreceptor is initially sensitized by the charging station **4** and subsequently exposed, it will be apparent that the processing steps of charging and exposure may be carried out simultaneously by altering the position of the exposure station **6** and/or the charging station **4**. Furthermore, although only the simplified processing steps of a single charging operation and a single exposure are depicted in FIG. **1**, it will be obvious that additional electrophotographic processing steps such as another charging operation may be employed in the formation of the latent electrostatic image or the latent electrostatic image formed may be reversed or otherwise altered by the use of such additional processing steps as is well known to those of ordinary skill in the art. The photoreceptor **2** is next presented to the developing station indicated generally at **8** where a latent electrostatic image formed is developed in accordance with the teachings of the present invention.

The development station **8**, as illustrated in FIG. **1** comprises hopper means **24** suitable for subjecting appropriate portions of the photoreceptor **2** to a cascade development step or the like, a split or first and second development electrode means **26** and **28** disposed in a predetermined relationship with the periphery of the insulating member **14** so as to function in accordance with the development methods taught herein and a reservoir **30** for supplying developer material. The hopper means **24** may take any of the conventional forms of devices generally employed in electrophotographic equipment to flow developer materials onto selected portions of the photoreceptor **2** surface disposed thereunder. The hopper means **24** is filled to an appropriate level with conventional developer materials, indicated at **32**, which include the previously described carrier beads and toner material. The hopper means **24** also includes a ramp **34** which has a selected inclination so that developer materials from the hopper **24** will be flowed over the surface of the photoreceptor **2** then associated therewith at preferably high flow rate for the developer materials selected so that cascade development may be rapidly accomplished in a manner to yield high contrast images. The flow rate of developer material from the hopper means **24** may typically reside at a level of fifty grams per inch of photoreceptor length per second (50 gms./in./ sec.) if conventional glass core carrier beads are employed in the developer material utilized while substantially larger flow rates as defined by the foregoing units are employed when conventional steel core carrier beads are relied upon. Thus, the rates at which developer material is cascaded over the surface of the photoreceptor **2** by the hopper means **24** are preferably high but may vary between one and one hundred grams per inch per second (1–100 gms./in./-sec.) depending upon the developer material selected. Furthermore, although relatively high flow rates for the

developer materials are preferred, if lower speeds of rotation for the photoreceptor **2** are acceptable, the flow of material from the hopper means **24** may be significantly reduced.

The reservoir **30** may be conventional in form and is disposed beneath the portion of the photoreceptor **2** which receives developer material from the hopper means **24.** The reservoir **30** is ordinarily maintained filled to a predetermined level with developer material indicated at **32** and acts to receive residue developer material from the surface of the photoreceptor **2** as well as carrier beads from which toner material has been removed during the development process. Additionally, the reservoir **30** is provided with means, not shown, through which toner material may be periodically introduced so that the toner material expended during development may be replaced and conventional conveyor means, not shown, is provided between the hopper means **24** and the reservoir **30** so that developer material **32** from the reservoir **30** is supplied to the hopper means **24** during such times as the depicted electrophotographic equipment is energized to thereby maintain the level of the developer material **32** in the hopper means **24** at a predetermined level. A partition **36** is additionally provided in the manner illustrated in FIG. **1** so as to extend from a lower portion of the ramp **34** of the hopper means **24** toward the reservoir **30** so that a chamber isolating the photoreceptor **2** and the first and second development electrodes **26** and **28** from the conveyor means, not shown, and developer material therein is established. Although, in FIG. **1,** the hopper means **24** is relied upon to flow developer material over the surface of the photoreceptor **2,** it will be appreciated by those of ordinary skill in the art that the conveyor means taken separately or in combination with a ramp could be relied upon to cascade developer material **32** over the surface of photoreceptor **2** as could any other conventional means well known to those of ordinary skill in the art.

The first and second development electrodes **26** and **28** are disposed within the chamber formed by the partition **36** and are positioned opposite to peripheral surface portions of the photoreceptor **2** in the manner illustrated in FIG. **1.** Each of the first and second development electrodes **26** and **28** may take the form of a conductive plate which preferably exhibits a curved cross-section so that the surfaces thereof are parallel to the peripheral portions of the photoreceptor surface adjacent thereto; however, development electrodes in the form of a flat plate may alternatively be used. The first and second development electrodes **26** and **28** would each generally be continuous and hence would preferably provide a continuous surface area disposed opposite to peripheral portions of the photoreceptor **2,** although, laminated or apertured surface configurations could also be used. In addition, the surfaces of the first and second development electrodes **26** and **28** and particularly the surface of the first development electrode **26** could be grooved in the direction of developer material flow to thereby increase the flow rate thereof. Each of the first and second development electrodes **26** and **28** would have a width, as measured along the axial width of the photoreceptor **2** or into the paper, which is substantially conterminous to that of the photoreceptor and would have a typical length, as measured along the periphery of the photoreceptor, of approximately 1 inch when relatively small diameter photoreceptor drums are employed. The length of each of the development electrodes **26** and **28** may widely vary and may generally be considered to admit of a combined length equal to approximately 25 percent of circumference of the photoreceptor drum provided such length may be otherwise accommodated by the housing employed. For instance, if a conventional 25 inch circumference photoreceptor drum were employed, the combined lengths of the first and second development electrodes **26** and **28** could be about 6 inches and naturally larger drums would permit longer electrode lengths. In high speed electrophotographic equipment more development electrode area is needed to obtain greater development time and hence relatively large development electrodes would be preferred. Other factors to be considered in the choice of the lengths for the first and second development electrodes **26** and **28,** as well known to those of ordinary skill in the art, are the bias levels associated therewith, the size of the latent electrostatic image formed, the spacing of the first and second development electrodes **26** and **28** from the photoreceptor **2** as well as the potential levels generally associated with the latent electrostatic image formed. It should be noted, however, that the lengths of the first and second development electrodes **26** and **28** should be selected so that the combined length thereof will not prohibit adequate spacing therebetween or a free gravitational flow of developer material. Furthermore, if the lengths of the first and second development electrodes **26** and **28** are selected in a manner so as to be unequal, it is preferred that the length of the second development electrode **28** be larger than that of the first development electrode **26** because, as shall be seen below, the second development electrode **28** accomplishes low density and extended area development and hence fine image development which should be attended by greater field modifying characteristics.

The first development electrode **26** would typically be spaced approximately two-tenths of an inch from the surface of the photoreceptor **2,** although any spacing from eight one hundredths of an inch to one half an inch would be appropriate. Optimum spacing of the first development electrode means **26** would substantially vary in accordance with the bias used therewith, the size of the developer material particles and particularly the carrier bead diameters employed, the flow rate of the developer material from the hopper **24** and the potential levels associated with the latent electrostatic image formed; however, as shall be rendered apparent below, the actual spacing from the photoreceptor **2** selected for the first development electrode **26** should be determined, upon a consideration of each of the foregoing factors, with a view toward maintaining a high rate of developer material flow even though the development of extended area and low density portions of the latent electrostatic image are substantially reduced. The first development electrode **26** is connected to a suitable source of potential V_2, which may here take the form of a conventional d.c. source. The source of potential V_2 according to the pure development mode of operation illustrated in FIG. **1** applies a bias to the first development electrode **26** which may be selected at a level equal to or slightly greater than the potential level associated with the background of the latent electrostatic image formed so that such background portions of the latent electrostatic image would appear neutral or of the same charge polarity as the triboelec-

trically charged toner material whereby the background would develop as pure white. Thus, in a typical case, if the background of latent electrostatic images formed on the photoreceptor 2 generally resided between 50 and 100 volts positive, the potential source V_2 would be selected so as to apply 100 to 300 volts to the first development electrode 26.

The second development electrode 28 here acts, as will be seen below, in the presence of a reduced developer material flow rate to achieve fine development of the extended and/or low density portions of the latent electrostatic image formed on the photoreceptor 2. Accordingly, the spacing of the second development electrode 28 from the surface of the photoreceptor 2 is optimized for such fine development and is typically disposed at approximately one-half the distance from the photoreceptor 2 as the first development electrode 26. Thus, the second development electrode 28 would typically be spaced approximately seventy-five thousandths of an inch from the surface of the photoreceptor 2 with a spacing range of four hundredths of an inch to a quarter of an inch being generally available to compensate for such factors as the flow rate of developer material, the bias level associated with the second development electrode, the size of the developer material particles and particularly the carrier bead diameters employed and the potential levels associated with the latent electrostatic image formed. The second development electrode 28 is connected to a suitable source of potential V_3 which may take the same form as potential source V_2. The source of potential V_3 acts to apply a potential level to the second development electrode 28 which may also be selected as equal to or greater than the potential level associated with the background of the latent electrostatic image formed so that the development of such latent electrostatic image which takes place at the second development electrode 28 will develop such background portions as pure white. Thus, the voltage level applied by the potential source V_3 to the second development electrode 28 may here be precisely the same as that applied by the potential source V_2 to the first development electrode 26, although highly advantageous results may sometimes be obtained by slightly raising or lowering the potential applied to the second development electrode 28 from that applied to the first development electrode 26 so that more controlled development may be achieved. As will be apparent, when the same bias levels are applied to the first and second development electrodes 26 and 28, a common potential source may be substituted for the individual sources illustrated.

Upon completion of the rotation of the periphery of the photoreceptor 2 through the development station 8, the portion of the photoreceptor 2 having a developed image thereon next proceeds to the image transfer station 10 whereat image transfer takes place. The image transfer station 10 comprises a transfer member 38 and charging means 39–41 for imposing a predetermined charge on such transfer member 38 to thereby affect transfer of the toner image from the surface of the photoreceptor 2 to the transfer member 38. The transfer member 38 may take the form of a sheet, web or drum formed of suitable transfer material such as paper, plastic or any of the other well-known materials conventionally employed as transfer materials. The charging means 39–41 may take the form of a plurality of half-round corotrons, as illustrated, which may be structured in the same manner as the charging means illustrated at the charging station 2 and described above. Alternatively, any other conventional form of charging means such as those discussed in conjunction with the charging station 2 may be employed in place of the charging means 39–41 illustrated in FIG. 1, it being appreciated that any charging means capable of imposing a predetermined charge level on the surface of the transfer member 38 may be employed at the image transfer station 10. The charging means 39–41 illustrated in FIG. 1 are connected to a suitable source of potential V_4 which again may take the form of a conventional d.c. supply. Although in the embodiment of the invention illustrated in FIG. 1, only a single polarity charging operation is indicated at the image transfer station 10, it will be appreciated by those of ordinary skill in the art, that image transfer may be accomplished with a subsequent stripping operation by using a pair of oppositely poled corotrons connected to a floating supply such as described in U.S. Pat. No. 3,244,083, issued to R. W. Gundlach on Apr. 15, 1966.

Upon completion of the electrophotographic operation at the transfer station 10, the image portion of the photoreceptor 2 next passes to the cleaning station 12 where residual toner particles are removed from the surface of the photoreceptor 2 preparatory to the subsequent formation of a new latent electrostatic image on the photoreceptor 2. The cleaning station 12 may take the conventional form of rotating fur brush cleaning means, wiper means or cascade cleaning means which act in the well-known manner to remove residual toner from the surface of the photoreceptor 2. As each of these techniques is well known to those of ordinary skill in the art, it is here sufficient to simply state that the cleaning station 12 acts to remove residual toner particles from the surface of the photoreceptor 2 to thereby place the same in condition for reuse.

In the operation of the embodiment of this invention illustrated in FIG. 1, it will be appreciated that a latent electrostatic image of the object to be copied will initially be formed on the photoreceptor 2 by the combined action of the charging station 4 and the exposure station 6. The latent electrostatic image is formed, upon the energization of the electrophotographic apparatus depicted in FIG. 1, by conventional electrophotographic processes well known to those of ordinary skill in the art. Thus, when the electrophotographic apparatus illustrated in FIG. 1 is energized, the charging means 18–20 present at the charging station 4 will impose a charge on the portions of the photoreceptor passing therebeneath by the application of ion charging current thereto. The surface of the photoreceptor 2 will thus be charged to a uniform potential by the action of the charging means 18–20 which are illustrated in FIG. 1 as comprising conventinal corotrons. Accordingly, it will be appreciated, that the charging station 4 acts in the conventional manner to sensitize the surface of the photoreceptor 2 by charging the same to a uniform potential which for the purposes of the instant disclosure may be assumed to be 1,000V. although any suitable magnitude and/or polarity charge configuration may be selectively imposed on the surface of the photoreceptor 2. Upon the completion of the charging or sensitizing operation which takes place at the charging station 4, the rotation of the photoreceptor 2 in the direction indicated by the arrow A will bring the previously

charged portions of the photoreceptor 2 into an operative relationship with the exposure station 6. The exposure station 6 acts in the well-known manner to selectively expose the pontoconductive portion of the photoreceptor 2, which here takes the form of the insulating member 14, to electromagnetic radiation from the object to be copied. Thus, the exposure station 6 acts to image a light and dark pattern representative of the image to be formed on the charged surface of the insulating member 14 of the photoreceptor 2. Upon exposure, the photoconductive insulating member 14 is rendered selectively conductive, in the well-known manner, so that the charge levels on the light struck portions thereof are substantially reduced while charge levels on portions thereof which correspond to dark portions of the image area are maintained at the relatively high charge levels imposed at the charging station 4. Thus, in this well-known manner, a latent electrostatic image is formed on the photoreceptor 2 by the combined action of the charging station 4 and the exposure station 6 disposed about the periphery thereof. For the purposes of the development operation set forth hereinafter, it may be assumed that the charge level variation of the latent electrostatic image formed manifests voltage levels of approximately 800 volts at portions of the image area corresponding to dark portions of the light and dark exposure pattern while the light struck portions of the image area on the surface of the photoreceptor 2 corresponding to background areas of the image reside at approximately 100 volts. The image area or the portions of the photoreceptor 2 having the latent electrostatic image formed thereon are next brought into an operative relationship with the development station 8 due to the rotation of the photoreceptor 2 in the direction indicated by the arrow A.

The description of the operation of the development station 8 will assume that a positive to positive development mode is desired and that the photoreceptor is positively charged. Therefore, the developer material selected is such that negatively charged toner particles are relied upon; however, as will be apparent to those of ordinary skill in the art, a negative to positive mode of development could be alternatively elected by the selection of developer materials resulting in positively charged toner particles or that with a negatively charged photoreceptor the developer materials selected could be such that negative to negative or positive to negative modes of development result. Accordingly, at the developer station 8, the reservoir 30 will be filled to a predetermined level with developer material whose characteristics are such that the carrier beads exhibit a positive charge while the toner material acquires a negative charge due to the phenomenon of triboelectrification. Furthermore, as the reservoir 30 is filled to a predetermined level with developer material, the hopper means 24 due to the action of the conveyor means, not shown, will also be filled to a desired level with such developer material. As was stated above, the ramp 34 present in the hopper means 24 exhibits an angle of inclination calculated to insure that developer material 32 will be cascaded or flowed over the surface of the photoreceptor 2 disposed thereunder at a flow rate which is relatively high when the core material of the selected carrier material is considered. Thus, as indicated in FIG. 1, developer material in the form of carrier beads having oppositely charged negative toner material clinging to the surface thereof due to the electrostatic force of attraction therebetween will be cascaded over the surface of the photoreceptor 2 at a flow rate which is preferably high with respect to the core material selected for the carrier beads. For the purposes of the instant disclosure, the flow rate at which developer material is supplied from the hopper means 24 to the photoreceptor 2 may be assumed to take an exemplary value of 50 grams per inch per second although wide variations therein are available for the reasons aforesaid.

The developer material delivered to the photoreceptor 2 from the hopper means 24 will flow over the surface of the photoreceptor 2 in the form of carrier beads having a plurality of toner particles clinging to the surface thereof due to the electrostatic force of attraction exhibited therebetween. As the developer material 32 is applied to the surface of the photoreceptor 2, the latent electrostatic image formed on the surface of the photoreceptor 2 will be initially subjected to the field modifying effects of the first development electrode 26 which is biased by the potential source V_2 to a voltage calculated to insure that the background portions of the latent electrostatic image on the photoreceptor 2 will develop out as pure white. Therefore, as the background portions of the latent electostatic image have here been assumed to reside at potential levels ranging from 50 to 100 volts, it may here be assumed that the first development electrode is biased to a level of 200 volts although any value between 50 and 500 volts would be available depending on the result desired. The first development electrode 26 is spaced an appropriate distance from the surface of the photoreceptor 2, which may here be assumed to be two tenths of an inch, so as to maintain a high developer material flow rate even through the spacing appropriate for such high flow rate will reduce the field modifying effects of the first development electrode 26 so that the development of the low density and extended area portions of the latent electrostatic image are substantially reduced. This high flow rate may be further assured by grooving or otherwise structuring the first development electrode 26 to increase the flow rate. Therefore, as these conditions obtain in the space intermediate the periphery of the photoreceptor 2 and the first development electrode 26, the developer material being cascaded over the surface of the photoreceptor 2 in the vicinity of such first development electrode will proceed at a rate which is not substantially impeded; however, the development accomplished at the surface of the photoreceptor underlying the first development electrode 26 will be such that only the portions of the latent electrostatic image exhibiting substantial voltage contrasts will manifest electrostatic forces capable of overcoming the carrier bead to toner bond of the developer material so that toner material is deposited thereon. Thus, the first development electrode 26 tends to optimize developer material flow in the space influenced thereby, while the field modifying effects produced for the development of a continuous tone latent electrostatic image are reduced so that toner material will not be here deposited on low density or extended areas of the latent electrostatic image undergoing development.

The second development electrode 28 is closely positioned with respect to the surface of the photoreceptor 2 and may be biased in the pure development embodiment of this invention illustrated in FIG. 1 to the same level as was the first development electrode 26. Thus,

the second development electrode 28 may here be assumed to be spaced from the surface of the photoreceptor 2 by a distance of approximately seventy-five thousandths of an inch and to be biased to a level of approximately 200 volts so that the flow of developer material will be substantially reduced while the field effecting characteristics of the second developer electrode 28 are substantial. When these conditions obtain, as is indicated in FIG. 1, the flow rate of developer material intermediate the second development electrode 28 and the surface of the photoreceptor 2 will be reduced to approximately 15 grams per inch of photoreceptor per second with the conditions assumed above while excess developer material applied to the photoreceptor 2 from the hopper means 24 will flow directly into the reservoir 30 by passing through a gap intermediate the first and second development electrodes 26 and 28 in the manner indicated in FIG. 1. Furthermore, as will be appreciated by those of ordinary skill in the art, the first development electrode 26 may be positioned at a precise peripheral location about the surface of the photoreceptor and structured and/or shaped so as to assure that the main portion of the flow of developer material between the first development electrode 26 and the photoreceptor 2 is directed through the gap between the first and second development electrodes 26 and 28 into the reservoir 30. Thus, under these conditions, the second development electrode 28 will have a very substantial effect on the field exhibited by the latent electrostatic image on the photoreceptor 2 so that all portions of the electrostatic latent image will be developed out, for the reasons aforesaid, substantially in proportion to the charge levels thereon. Accordingly, the increased field exhibited by all portions of the latent electrostatic image residing at a voltage level which exceeds the bias level of the second development electrode 28 when the latent electrostatic image is under the influence of the second development electrode 28 will readily overcome the carrier to toner bonds of cascading developer material in proportion to their magnitude whereby all portions of the latent electrostatic image except for the background areas thereof will have a dense toner deposition thereon in accordance with the charge levels associated with such image portions. Furthermore, as the flow rate of the developer material in the region between the second development electrode 28 and the photoreceptor 2 is substantially reduced, no bunching of developer material will occur so that the aforementioned deleterious effects thereof will be avoided.

Thus it will be seen that the reliance upon the first and second development electrodes 26 and 28 taught by the instant invention enables both large amounts of developer material to be cascaded over the image area of the photoreceptor 2 to assure the presence of large volumes of toner material and the attendant high development speeds associated therewith while low density and extended area portions of the latent electrostatic image formed are developed out under the influence of the second development electrode 28 which exhibits substantial field modifying effects to assure that development is completed under conditions which are optimum for the development of continuous tone images exhibiting solid area coverage. Furthermore, due to the nature of the first and second development electrodes 26 and 28, the optimized development specified herein is carried out under conditions whereby high developer material flow is maintained to assure that high development speeds are achieved without impeding this flow in a manner whereby bunching of the developer material will take place and adversely affect the development of the image. Accordingly, the methods of development and the apparatus therefor in accordance with the teachings of this invention as illustrated in combination with the exemplary electrophotographic apparatus shown in FIG. 1 enables advantageous cascade development techniques to be employed in the development of continuous tone latent electrostatic images without compromising the image formed or the speed at which development is carried out in response to the requirements of the development electrode means utilized.

Upon the completion of the development step carried out at the development station 8 in the foregoing manner, toner material is deposited on the image area of the photoreceptor 2 in accordance with the charge configuration of the latent electrostatic image formed due to the electrostatic force of attraction between the negatively charged toner particles and the positively charged latent electrostatic image. When the image area of the photoreceptor 2 arrives at the transfer station 10, the transfer member 38 will be disposed on the surface of the photoreceptor 2 in such manner that the transfer member will be in physical contact with the toner image formed at only a few points on the surface thereof due to the absence of a strong force of attraction between the adjacent surfaces of the transfer member 38 and the photoreceptor 2 while the remaining adjacent surface portions may be separated by an air gap of several microns. The transfer member 38, as aforesaid, may for the purposes of this disclosure be considered to take the form of the web illustrated in FIG. 1 and is adapted for motion in the direction indicated by the arrow B in such manner that the speed of the portion of the transfer member 38 adjacent to the surface of the photoreceptor 2 is equal to the angular velocity of the photoreceptor 2. When the successive portions of the photoreceptor 2 having the transfer member 38 disposed thereon are displaced so as to be in a charging relationship with the charging means 39–41, portions of the transfer member 38 in a charging relationship therewith will receive positive ion charging current along the width thereof so that such surface portions are positively charged to a uniform potential. The positive charges applied to the surface of transfer member 38 will migrate in the well-known manner to the opposite surface thereof adjacent to the toner image and hence will induce negative charges in corresponding portions of the conductive backing 16 of the photoreceptor 2. The charge on the portions of the transfer member 38 receiving positive ion charging current from the charging means 39–41 will produce a very substantial force of attraction between corresponding portions of the adjacent surfaces of the transfer member 38 and the photoreceptor 2 thereby bringing such portions of the transfer member 38 into intimate contact with the portions of the toner image on the adjacent portions of the photoreceptor 2. When these conditions obtain, the field strength between the charged portion of the transfer member 38 and the adjacent portion of the photoreceptor 2 will be sufficient to cause most of the negatively charged toner to be transferred from the photoreceptor 2 to the transfer member 38. This operation will be continued for successive portions of the transfer member 38 on a contin-

uous basis until the entire toner image has been transferred to the transfer member 38. Thus, in the well-known manner, the toner image formed on the photoreceptor 2 by the developing step carried out at the development station 8 is transferred to the transfer member 38 so that only residual toner material from the step of development remains on the surface of the photoreceptor 2.

The image portion of the photoreceptor 2 is next brought into an operative relationship with the cleaning station 12 so that residual toner material may be removed from the image portion of the photoreceptor 2 prior to reuse. The cleaning station 12 may be entirely conventional, as aforesaid, so that if nontacky toner material is relied upon, the image portion of the photoreceptor 2 may be wiped by a conventional rotating fur brush or cotton wiping means may be employed. Alternatively, the cleaning station 12 may employ cascade cleaning techniques wherein granular material, which acts similarly to the carrier beads in a two component developer material, is cascaded over the image portion of the photoreceptor in the well-known manner and residual toner particles are attracted from the surface of the photoreceptor 2 by triboelectric attraction without danger of marring or scratching the surface of the photoreceptor. Upon the completion of the cleaning step, the electrophotographic equipment illustrated in FIG. 1 may be again utilized to form a toner image of an original to be copied whereupon the steps of the formation of a latent electrostatic image, development, transfer and cleaning may again be repeated.

In the typical electrophotographic equipment illustrated in FIG. 1 and described above, an individual cleaning stage for the removal of residual toner was provided and hence the exemplary embodiment of this invention disclosed in association therewith was directed solely to the development aspects of the present invention wherein a split or first and second development electrode configuration was relied upon to allow cascade development techniques or the like to be utilized for the development of a continuous tone image without comprising the development technique employed to allow for the utilization of development electrode means. However, the attributes of the instant invention are not limited to advantageous development techniques but, in addition thereto, allow cleaning and development to take place within a single processing stage. An exemplary embodiment of this invention wherein cleaning and development are combined within a single processing stage is described below in conjunction with FIG. 2.

FIG. 2 illustrates another exemplary embodiment of the present invention wehrein methods of development cleaning and apparatus therefor are shown in combination with a modified version of the electrophotographic equipment shown in FIG. 1. As will be noted upon an inspection of FIG. 2, the structure illustrated therein corresponds essentially to that shown in FIG. 1 with the single exception that the cleaning station 12 has been omitted since, as will be seen below, cleaning is performed in this embodiment of the present invention within the development station. Therefore, in order to avoid undue repetition and reiteration, structure illustrated in FIG. 2 which corresponds to similar structure already described in conjunction with FIG. 1 has retained previously utilized reference designations and the description of structure in FIG. 2 common to that illustrated in FIG. 1 and described above shall proceed by way of reference to the descriptive material set forth in connection with FIG. 1. Accordingly, it will thus be appreciated that any of the alterations, modifications or varying parameter ranges set forth in the descriptive material presented in association with FIG. 1 shall be fully applicable to the structure depicted in FIG. 2 unless otherwise specified.

The electrophotographic processing equipment illustrated in FIG. 2 comprises a photoreceptor 2, a charging station 4, an exposure station 6, a development station 8 and a transfer member 10. The photoreceptor 2, charging station 4, exposure station 6 and transfer station 10 may each take the same structural form, perform the same functions and admit of the same variations as the correspondingly annotated structure illustrated in FIG. 1. Similarly, the development station 8 is disposed about a peripheral portion of the photoreceptor 2 in the same manner as was described in conjunction with FIG. 1 and comprises hopper means 24, a reservoir 30 and conveyor means (not shown) all of which may structurally take the same form and perform the same function as was described above. In this embodiment of the invention, however, the ramp 34, as present within the hopper means 24 is preferably disposed at an angle of inclination which will assure that the flow rate at which developer material is cascaded over the surface of the photoreceptor 2 is high because not only are such high flow rates desirable from the standpoint of rapid development and the formation of densely populated toner images, but in addition thereto, as is well known to those of ordinary skill in the art, the removal of residual toner images by cascading developer material in an electroded system is enhanced by relatively high flow rates for the developer material utilized. Thus, although flow rates for the developer material 34 in the ranges specified above in conjunction with FIG. 1 are fully applicable to the instant embodiment of the present invention, it is preferred that a relatively high rate be selected, again considering the core material of the carrier chosen, so that more efficient development cleaning will result.

In addition, the development station 8 also includes first and second development electrodes 46 and 28. The first and second development electrodes 46 and 28 are disposed about the periphery of the photoreceptor 2 and within the development station 8 in precisely the same manner as was described above in conjunction with the first and second development electrodes 26 and 28 depicted in FIG. 1. Furthermore, the first and second development electrodes 46 and 28 as shown in FIG. 2 may also take the same structural configurations and exhibit the same displacements from the surface of the photoreceptor 2 as well as the variations thereof which were described in conjunction with the first and second development electrodes 26 and 28 shown in FIG. 1; however, a slightly greater displacement than specified above may be here appropriate for the first development electrode 46 to accommodate a larger flow rate of developer material 32 from the hopper means 24. The second development electrode 28 here serves in the presence of a substantially reduced flow of developer material, of the same magnitude and obtained in the same manner as described in conjunction with FIG. 1, to develop extended area and/or low density portions of the latent electrostatic image formed and hence, as indicated by the reference numeral asso-

ciated therewith, takes the same form, performs the same functions and admits of the same variations as the second development electrode 28 described above in conjunction with FIG. 1. The second development electrode 28 shown in FIG. 2 is connected to a source of potential V_3 which supplies an appropriate background bias level thereto as aforesaid.

The first development electrode 46, however, here performs the dual functions of cleaning the surface of the photoreceptor 2 and the development of portions of the electrostatic image displaying large charge variations. The cleaning function of the first development electrode 46 is achieved by a reliance on the ability of cascading developer material and more particularly carrier beads therein, which are not associated with a sufficiently large number of toner particles to render the resultant developer particle electrically neutral, to scavenge residual toner particles from the surface of the photoreceptor 2 when such residual toner particles are not strongly adhered to the surface of the photoreceptor 2 by a subsequently established latent electrostatic image. To assure the presence of a sufficient number of carrier beads associated with less than a full complement of toner particles clinging thereto, such cleaning of residual toner particles from the surface of the photoconductor 2 should take place not only in the presence of a high flow rate but additionally a sufficiently large bias on the surface of the first development electrode 46 to effectively encourage the removal of toner particles from the carrier beads in the cascading developer material. For this reason, the first development electrode 46 is connected to a potential source V_5, which may be entirely conventional, and preferably applies a substantial bias level to the first development electrode 46. Thus, while in the FIG. 1 embodiment of this invention the bias level applied to the first development electrode 26 was related to the background level of the latent electrostatic image formed, here, the bias level applied to the first development electrode 46 may range from 0 to a 1,000 volts and preferably should be at or above the charge levels of portions of the latent electrostatic image corresponding to the dark portion of the light and dark exposure pattern. The development function of the first development electrode 46, wherein only the portions of the latent electrostatic image displaying high voltage contrasts are developed due to the substantial distance between the surface of the photoreceptor and the first development electrode occurs in the same manner as was described in conjunction with FIG. 1; however, here the development which takes place at the first electrode means 46 may be slightly less efficient than was the case in the FIG. 1 embodiment because conditions are preferably optimized in favor of cleaning with the high flow rate and high bias level rather than in terms of development. Thus, in the embodiment illustrated in FIG. 2, the development electrode configuration according to the instant invention functions to achieve both cleaning and reduced development at the first development electrode 46 while fine development of low density and extended area portions of the latent electrostatic image is carried out at the second development electrode 28 in the same manner as accomplished in the FIG. 1 embodiment.

In the explanation of the operation of the electrophotographic processing equipment illustrated in FIG. 2 and more particularly in the description of the development and cleaning mode of operation illustrated therein, it will be again assumed that a positive to positive development mode is desired; it being appreciated that any of the alternatives thereto mentioned with regard to FIG. 1 will be readily available herein. Thus, the developer material illustrated as present within the reservoir 30 and the hopper means 24 will be assumed to be such that negative toner partices are available for the formation of a toner image. Furthermore, it will be additionally assumed that prior to the cycle of operation about to be considered, a previous cycle of operation was performed wherein a toner image was developed and transferred so that residual toner particles are present on the surface of the photoreceptor 2 which is to undergo the cycle of operation set forth below.

In the operation of the embodiment of this invention illustrated in FIG. 2, it will be appreciated that a latent electrostatic image of the object to be copied is formed on the surface of the photoreceptor 2 by the steps of charging the photoreceptor 2 to a uniform potential and thereafter selectively discharging such photoreceptor 2 in accordance with a light and dark exposure pattern representing the object to be copied. This may be accomplished in the conventional manner by the charging station 4 and the exposure station 6 by the same techniques described in connection with FIG. 1. However, prior to establishing the latent electrostatic image, it may be advantageous to flood the surface of the photoreceptor 2 with electromagnetic radiation, in the well-known manner, so that the photoconductive layer is fully discharged prior to the formation of a new latent electrostatic image. In any event, a latent electrostatic image is formed in the same manner as described in conjunction with FIG. 1 and the image portion of the photoreceptor 2 is then displaced in the direction of rotation indicated by the arrow A so that development and cleaning may be carried out at the development station 8. It should be noted that under the conditions which here obtain, the image portion of the photoreceptor 2 not only has a latent electrostatic image formed thereon but, in addition thereto, residual toner particles may be present on the surface of the photoreceptor 2 due to previous use.

When the image portion of the photoreceptor 2 arrives at the development station 8, the reservoir 30 and the hopper means 24 will both be filled to their respective predetermined levels with developer material of the type described in conjunction with FIG. 1. Accordingly, developer material will be cascaded over the surface of the photoreceptor 2 by the hopper means 24 at a rate which may be again assumed to be 50 grams per inch per second although, as aforesaid, other high rates of flow for the developer material are clearly available depending on the density of the carrier beads relied upon therein. As the developer material is cascaded over the surface of the photoreceptor 2 and follows a path intermediate the first development electrode 46 and the photoreceptor 2, carrier beads not having a full complement of toner particles associated therewith will scavenge residual toner particles from the portions of the surface of the photoreceptor which do not correspond to portions of the newly formed latent electrostatic image having large charge contrast while toner clinging to the surface of other carrier beads will deposit on surface portions of the photoreceptor 2 corresponding portions of the newly formed latent electrostatic image which do exhibit large charge contrast.

The scavenging thus carried out accomplishes the removal of residual toner particles while the toner deposition not only achieves development of portions of the latent electrostatic image exhibiting large voltage contrasts but in addition thereto frees more carrier beads for cleaning purposes. As was stated above, it is preferred in the instant embodiment of this invention that the bias applied to the first development electrode **46** by the potential source V_5 be high so as to aid in the removal of residual toner emaining on the surface of the photoreceptor from the development and subsequent transfer of a previously formed latent electrostatic image. This high bias level on the first development electrode **46** not only acts to modify the field associated with the latent electrostatic image for the purposes of development in a similar manner to that described for the first development electrode **26** in conjunction with FIG. **1**, but in addition thereto, aids in the cleaning function carried out by the first development electrode **46** by making available more carrier beads for cleaning purposes by aiding in the removal of toner therefrom. The manner in which the first development electrode **46** aids cleaning will be understood by an appreciation that so long as a positive bias level is imposed on the first development electrode **46** some toner particles will be removed from cascading carrier beads and drawn thereto whereby additional carrier beads not having a full complement of toner particles associated therewith will be freed for the purposes of development and as the bias level on the first development electrode **46** is increased the number of carrier beads thus rendered available will be substantially increased. When the bias level associated with the first development electrode **46** is at or only a few hundred volts above the background level of the latent electrostatic image and high flow rates as indicated above are utilized, soft, gentle cleaning will take place while, in similar manner to the embodiment of the invention disclosed in FIG. **1**, suitable coarse development of portions of the latent electrostatic image exhibiting appropriate voltage contrasts will take place. However, as the bias level associated with the first development electrode **46** is increased substantially above the background level of the latent electrostatic image formed, the cleaning rate will be markedly increased due to the manner in which the first development electrode **46** will overcome the toner-carrier bead bond and draw toner particles thereto, but under these conditions less development will take place in the vicinity of the first development electrode **46** as more portions of the latent electrostatic image will appear negative with respect to the first development electrode **46.** Furthermore, in this regard, the conditions appropriate for cleaning and development which take place under the influence of the first development electrode **46** can be so weighted in favor of cleaning, for instance by placing a bias level on the first development electrode **46** which exceeds the level of all portions of the latent electrostatic image, that the rate of cleaning will be substantially increased but with a corresponding reduction in the rate of development. However, should it be desired to increase the rate of cleaning to the point where the second development electrode **28** can no longer compensate for the development lost, a third development electrode spaced for high rates of developer material flow could be interposed between the first and second development electrodes **46** and **28** and the first development electrode **46** may be coated with a layer of conductive teflon or the like to avoid toner buildup thereon. Thus, it is seen that cleaning of residual toner material from the photoreceptor as well as development of portions of the latent electrostatic image exhibiting substantial voltage contrasts is achieved at a high flow rate of developer material under the influence of the first development electrode **46.**

As the second development electrode **28** is displaced, as aforesaid, at approximately one-half the distance from the surface of the photoreceptor **2** with respect to the first development electrode **46,** the flow rate of developer material cascading between the second development electrode **28** and the surface of the photoreceptor **2** will be markedly reduced. Such reduced flow rate may be assumed to be the same as described in connection with the FIG. **1** embodiment; however, as will be appreciated by those of ordinary skill in the art, the flow rate and hence the spacing of the second development electrode **28** as is appropriate therefor may be increased to compensate for extremely reduced coarse development at the first development electrode **46.** The developer material representing the difference in flow rates between the first and second development electrodes **46** and **28** will cascade into reservoir **30** through the path indicated in FIG. **2** between the first and second development electrodes **46** and **28** while developer material not utilized in the fine development which takes place at the second development electrode **28** flows into the reservoir **30** through the flow path indicated. Thus, both cleaning and development are here accomplished within the development station **8** by the first and second development electrodes **46** and **28** and the proportioned flow rates of developer material enabled thereby. Upon the completion of the development and cleaning operation carried out at the development station **8,** the toner image formed may be transferred and subsequently fixed at the transfer station **10** in the same manner as was described in conjunction with FIG. **1.** Thereafter, a new latent electrostatic image may be formed as no independent cleaning operation is required according to this embodiment of the present invention.

Although the methods of development and development cleaning as well as apparatus therefor taught by the present invention have been disclosed in conjunction with two detailed exemplary embodiments thereof, it will be appreciated that many modifications and alterations to the techniques set forth are available and hence contemplated by the instant invention. For instance, although the development electrode configurations described herein have been depicted as providing a continuous surface which is parallel to the surface area of the photoreceptor; grooved, laminated, apertured or other discontinuous surface configurations for such electrode structure may be employed and this is particularly so when such surface configurations are relied upon to enhance the flow rate of developer material or the conveyance thereof to the reservoir or sump. Furthermore, the development electrode structure need not exhibit a surface area which is parallel to the surface of the photoreceptor nor must the development electrode structure exhibit a surface area displaying a constant displacement from the surface of the photoreceptor. In addition, although first and second development electrodes have been illustrated herein, it will be appreciated that a split, unitary structure may be em-

ployed, especially when a common bias level is relied upon or alternatively more than two development electrodes may be utilized when it is desired to further increase graduations with respect to the developer material flow rates, the coarse and fine development employed and/or the rates associated with cleaning and development. Furthermore, it will be apparent that although a specific electrophotographic process was set forth herein to provide an appropriate environment for the disclosure of the instant invention, the inventive concepts set forth may be relied upon in conjunction with any electrophotographic process which results in the development of a toner image.

While the invention has been described in connection with several exemplary embodiments, it will be understood that many modifications thereof will be readily apparent to those of ordinary skill in the art and that this application is intended to cover any adaptations or variations thereof. Therefore, it is manifestly intended that this invention be only limited by the claims and the equivalents thereof.

What is claimed is:

1. A method of development comprising the steps of:

cascading developer material at a high flow rate over a surface associated with a latent electrostatic image;

positioning a first development electrode adjacent to said surface at a location proximate to the application of said developer material thereto;

spacing said first development electrode a sufficient distance from said surface to allow said developer material to pass between said surface and said first development electrode at said high flow rate;

positioning a second development electrode adjacent to said surface in the vicinity of said first development electrode; spacing said second development electrode a smaller distance from said surface than said first development electrode to thereby enable only reduced quantities of developer material to pass between said surface and second development electrode and further spacing said second development electrode a sufficient distance from said first development electrode means to allow developer material passing between said first development electrode and said surface and exceeding said reduced quantity to pass therebetween: and

applying a reference potential to said first and second development electrodes to enable said first and second development electrodes to modify fields exhibited by said latent electrostatic image associated with said surface.

2. . A method for developing a latent electrostatic image on a photoreceptive surface comprising:

cascading a developer stream over the image between a first electrode and the photoreceptive surface at a given flow rate,

passing a portion of the developer stream between a second electrode and the photoreceptive surface at a reduced flow rate while passing the remaining portion of the developer stream between the two electrodes to a developer sump.

3. A method as recited in claim 2 wherein a potential is applied to the first electrode which ranges from the potential associated with the background of the latent image to above the potential of the latent image.

4. A method as recited in claim 2 wherein a different potential is applied to the first and second electrode so that the developer stream essentially acts to clean the photoreceptive surface of residual toner when passing between the first electrode and the photoreceptive surface and that portion of the developer stream passing between the second electrode and the photoreceptive surface acts to develop the latent image.

* * * * *