Sept. 1, 1964 C. F. CARLSON 3,147,147

XEROGRAPHIC DEVELOPING APPARATUS AND ELECTRODE

Filed June 5, 1961 2 Sheets-Sheet 1

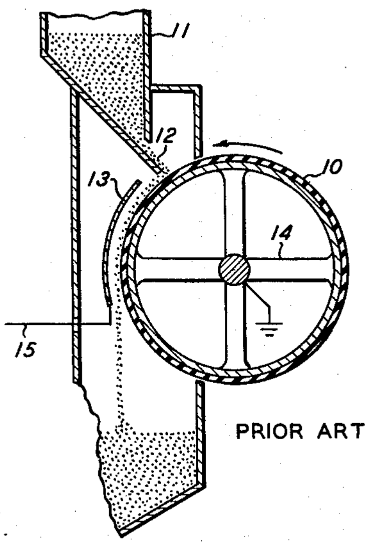

FIG. 1

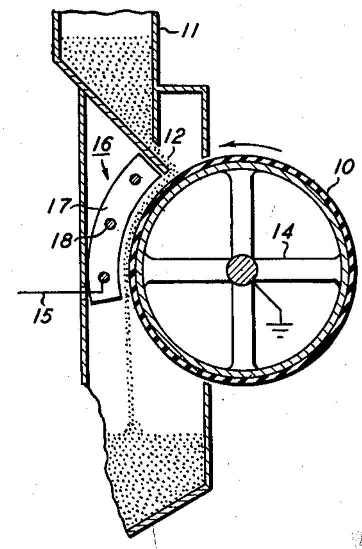

FIG. 2

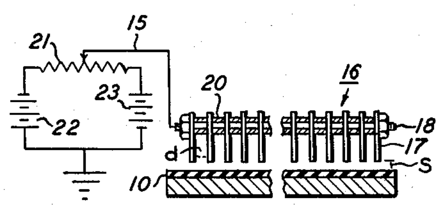

FIG. 3

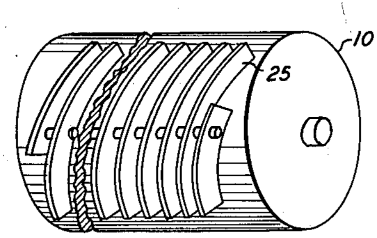

FIG. 5

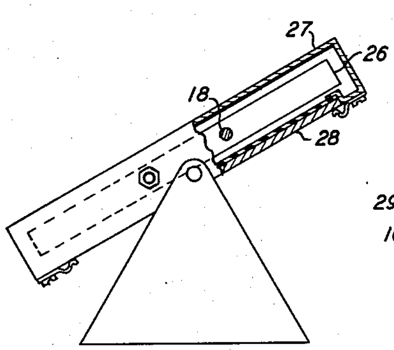

FIG. 6

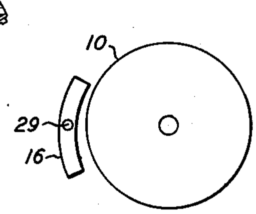

FIG. 7

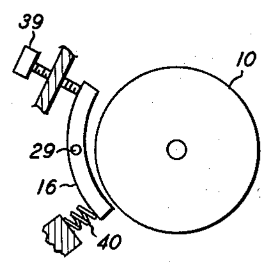

FIG. 8

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XEROGRAPHIC DEVELOPING APPARATUS AND ELECTRODE

Filed June 5, 1961 2 Sheets-Sheet 2

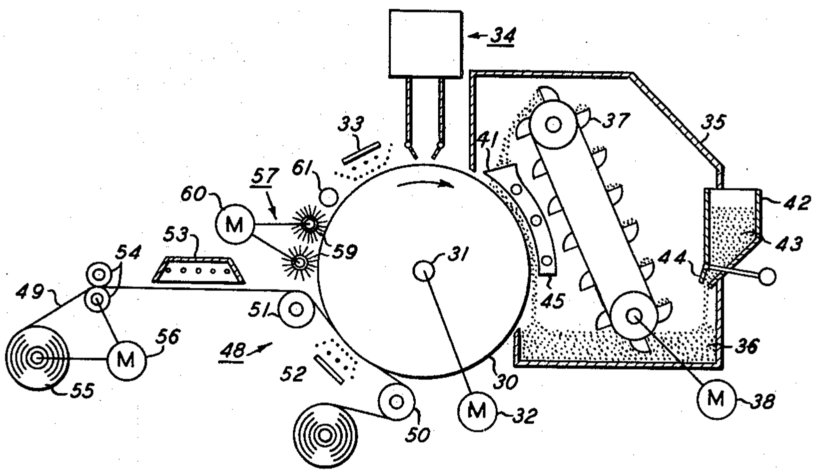

FIG. 10

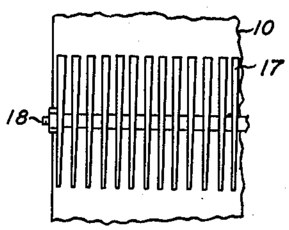

FIG. 4

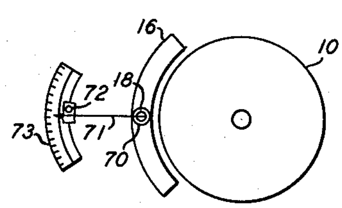

FIG. 9

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XEROGRAPHIC DEVELOPING APPARATUS AND ELECTRODE

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Filed June 5, 1961, Ser. No. 114,803

13 Claims. (Cl. 118—637)

This invention relates to xerography and, in particular, to development of electrostatic latent images.

Electrostatic latent images are sometimes formed by selective dissipation of electrostatic charge from a photoconductive insulating member in accordance with an image pattern or by selectively charging an insulating layer. One customary procedure to utilize an electrostatic latent image, however it may have been formed, is to make it visible by the application of an electroscopic pigmented material. In order for the electroscopic pigmented material to deposit on the electrostatic latent image and adhere thereto, it is necessary that it be brought within the influence of electrostatic lines of force emanating from the image pattern. These lines of force extend between points of different potential and commonly extend between points on the image bearing surface that have a potential gradient between them. When the area of an image pattern has very low contrast from one point to nearby points, the potential gradients are small and lines of force set up are consequently less effective during development. This particularly is true, for example, in a large solid image area where there are no nearby potential gradients on the image surface. The net effect is that frequently no development takes place in the center portion of such areas of uniform potential.

It has been found that positioning an electrode in close proximity to the image bearing surface during development improves the continuity of the development in low contrast image areas. The use of such electrodes is disclosed in U.S. Patents 2,573,881 and 2,777,418. This apparently results from the presence of the electrode which supplies a nearby potential gradient for setting up the electrostatic lines of force. The use of such development electrodes, however, has caused some complications in the developing process. One of the more satisfactory development methods utilizes carrier beads upon which a pigmented electrostatic material is coated and which are cascaded across the image bearing surface. Such a method is disclosed in U.S. Patent 2,573,881 and may use a development material such as disclosed in U.S. Patent 2,940,934. For the most effective use, the development electrodes require close spacing to the image bearing surface. When cascade development is used, the development material has a tendency to bunch up between the image bearing surface and the development electrode with consequent smudging of the image as well as scratching and abrasive deterioration of the image bearing surface. Known development electrodes have also commonly impeded the flow of developing material over the image bearing surface, thus slowing the development process. Some of these problems can be overcome by cascading less material at a time, but use of less developer material either requires a reduction of machine speed or produces a less densely developed image. Attempts to replace the solid plate development electrode with a series of wires or a perforated plate have resulted in a loss of effectiveness in the electrode. An effective development electrode appears to require a large surface area in close proximity to the image bearing surface.

Now in accordance with the present invention means have been discovered for maintaining a large effective development electrode surface in good proximity to an

image bearing surface without the need of a solid plate parallel to such surface and enabling high speed development while maintaining dense image formation. Thus it is an object of the invention to define novel and improved development electrodes.

It is a further object of the invention to define development electrodes for high speed development.

It is a further object of the invention to define novel development electrodes having large effective surface areas.

It is still a further object of the invention to define novel xerographic apparatus for continuous tone image reproduction.

Further objects and features of the invention will become apparent while reading the following description in connection with the drawings wherein:

FIG. 1 is prior art;

FIG. 2 is a diagrammatic side view of part of a xerographic apparatus utilizing a development electrode in accordance with the present invention;

FIG. 3 is a cross sectional view of a development electrode and an image member in accordance with the invention;

FIG. 4 is a front elevation of an embodiment of a development electrode and an image member in accordance with the invention;

FIG. 5 is a perspective view of an embodiment of a development electrode and an image member in accordance with the invention;

FIG. 6 is a side elevation of a developer tray utilizing another embodiment of the present invention;

FIG. 7 is a side elevation of a xerographic drum in combination with an embodiment of the invention;

FIG. 8 is a side elevation of a xerographic drum in combination with another embodiment of the invention;

FIG. 9 is a side elevation of a xerographic drum in combination with still another embodiment of the invention; and,

FIG. 10 is a diagrammatic view of a xerographic apparatus in accordance with the invention.

Development of electrostatic latent images with a closely spaced development electrode is known. FIG. 1 illustrates the relevant portion of a xerographic apparatus using such an electrode. In FIG. 1, xerographic image bearing drum **10** comprising a conductive cylinder coated with a photoconductive insulating layer on which an electrostatic image has been formed by charging and exposure steps, as shown and described, for example in U.S. Patent 2,965,756 is illustrated rotating through a development station. The development station includes source **11**, of electroscopic particles or electroscopic particles coated on larger carrier particles, which cascades the particles **12** against rotating drum **10**. Development electrode **13** is positioned in close proximity to drum **10** at the zone where the electroscopic particles **12** are cascaded over the drum. A conductor **15** is connected to the electrode **13** and may connect the electrode to ground or to a suitable reference potential. As illustrated, the electrode **13** is spaced a distance from drum **10** permitting the electroscopic particles **12** to pass freely between the electrode and the drum without binding or bunching. The spacing required for this is greater than desirable for efficient operation of a development electrode.

The development electrode of the invention has a series of edges positioned more closely to the image surface than has been possible in prior development electrodes of the conductive plate type. At the same time the novel electrode of the invention has a greater total surface area and allows developer to flow more freely than such prior electrodes. FIGURE 2 illustrates apparatus similar to that of FIGURE 1 utilizing the novel development electrode of the invention. Development electrode **16** consists of a series of conductive plates **17** which are fastened together as by bolts **18** in spaced assembly.

The spacing of plates **17** is more clearly illustrated in FIG. 3. Distance *d* of the spacing between adjoining plates must be greater than the largest diameter of particles used in the development material such as the carrier particles, where used, and is selected to provide the the closest spacing attainable without impeding the free flow of cascade developer particles. This distance is preferably greater than twice the largest diameter of the largest particles used in a development material and in a preferred embodiment is three times the diameter of such particles. When the cascade development material has carrier particles with a diameter less than ten mils, for example, the spacing distance *d* in a preferred embodiment is no more than thirty mils. With carrier of 20 mils diameter the spacing is desirably at least 40 mils and may be 60 mils. The spacing *d* and hence the particle size in the developer used should be kept adequately small so that a substantially uniform electrostatic field is presented at the image bearing surface. The development electrode is positioned in closely spaced relationship to the electrostatic image-bearing surface of member **10** supported by supporting structure **14**. The distance *s* between the edges of the electrode plates and the image-bearing member **10** should be of the same order as the spacing between the plates of the development electrode **16**. The spacing between the electrode plates may be maintained by conductive spacers **20** or by integral ridges on the plates themselves or other suitable means. The electrode plates **17** are positioned in parallel planes perpendicular to the axis of rotation of the image bearing member **10**. The thickness of the electrode plates is not critical but is preferably in the order of the diameter of the largest particles in the developer. The width of the plates is several times, for instance at least ten times the distance *s*, thereby allowing for passage of a large mass of developer past the developing station. Due to the tumbling action fresh developer is brought against the drum at various stages in the travel and without jamming, since the spacing between plates is great enough to allow free flow at all times. The whole assembly is fastened together as by bolt **18** by which the assembly may then be supported. Obviously, the number of plates in the stack is usually much greater than those shown for clarity of illustration.

When the development electrode of the invention is used with a xerographic drum, as illustrated in FIG. 2, the edges of the individual electrode plates are cut in a curved manner so that they may be disposed in an arrangement with their edges coaxial with the surface of the xerographic drum. The edges of the electrode plates away from the drum may be curved as shown or straight. The length of the plates for most effective use is such that they will extend along the entire development zone. However, this is not essential and in some instances, a shorter length of development electrode may be preferred.

FIG. 3 is a cross-sectional view showing the individual development electrode plates as viewed from their leading edges. A biasing arrangement is connected to the development electrode at bolt **18** through conductive wire **15**. The biasing arrangement includes a voltage divider **21** connected to a positive voltage supply **23** on one end and a negative voltage supply **22** on the other end. The bias potential may thus be varied between positive and negative voltages. The usual practice is to set this biasing potential to approximate the background potential in the electrostatic latent image to be developed. Thus with no potential differences between the development electrode and the background areas of the image, no developer particles will be attracted in those areas. On occasion, it is desirable to vary the biasing potential somewhat in order to increase or decrease image density. With greater potential difference between the development electrode and the image areas of the latent electrostatic image, the attracting force will be stronger and will produce a denser image. While it is not considered necessary to illustrate it further, it is to be understood that some form of development electrode potential biasing arrangement would be used in each of the embodiments of the invention.

While the above embodiments show the plates of the development electrodes as parallel to each other in planes perpendicular to the axis of the image bearing member **10**, in some cases the plates may diverge slightly from each other progressively from the top to the bottom of the developing zone, or as illustrated in FIG. 4 the plate **17** may be thinner at the bottom of the developing zone to reduce the possibility of jamming of developer as it flows downward.

Another embodiment of the development electrode according to the invention permitting somewhat greater spacing between the individual plates of the electrode is illustrated in FIG. 5. Since the electrostatic fields set up between a latent image and the development electrode are strongest where the two are in closest proximity, there is some tendency with widely spaced electrode plates to have greater development density in lines occurring directly beneath the plates. To prevent this, the development electrode plates **25** in FIG. 5 are skewed slightly with relation to the line of rotation of the surface to be developed **10**. While the amount of skew is not critical and can be as great as 10 degrees out of perpendicular to the axis, in a preferred embodiment, the development electrode plates are set askew so that the lagging edge of one plate falls in the same line over the surface to be developed as the leading edge of one next adjacent plate. With this arrangement, all points of the electrostatic latent image fall directly beneath a development electrode plate edge at some time during development.

While the skewed development electrode of the embodiment illustrated in FIG. 5 is applicable only to xerographic development arrangements where the surface bearing the electrostatic latent image is moved relative to the development electrode, the invention is not limited thereto. In FIG. 6, an embodiment of the electrode according to the invention is shown for use with a flat image-bearing surface. The development electrode **26** in FIG. 6 has straight edges so that its edges are parallel to a flat surface to be developed. The operation of the development apparatus shown in FIG. 6 consists in placing particulate developer material in the developer tray **27**, placing an electrostatic image bearing member **28** with its image bearing surface down, on top of the tray and rocking the tray upside down. The rocking motion causes the developer material to cascade back and forth over the image bearing surface and between the image bearing surface and the electrode **26**. In one embodiment of such developing apparatus, the development electrode **26** is fastened directly to the development tray by bolts **18** which also hold the plates of the electrode in assembly.

In development of extended image density ranges, it has been found beneficial to develop under conditions that vary during the development process. For example, if the effects of the image fields are reduced at the commencement of development and increased as development continues, a greater density range is obtained. In accordance with an embodiment of the present invention, the spacing of the development electrode from the surface to be developed can vary from the top to the bottom. In FIG. 7 the electrode assembly of the invention is mounted in an adjustable manner as for example on a pivotable bolt **29** upon which the development electrode may be rocked slightly one way or the other to set it in any desired position. In the position illustrated in FIG. 7, the upper end of the electrode is closer to the image bearing surface **10**, but it is obvious that it can be moved and clamped with the bottom end of the electrode closer to the image bearing surface. As discussed above, a development electrode for most efficient use should extend the entire length of the development zone. Sometimes, however, it is desirable to use a shorter electrode as where space is a problem. Thus the electrode **16** in FIG. 7 has been illustrated somewhat shorter than would be the usual case. It will be noted that in rotating drum apparatus all portions of the image bearing member will be under the development electrode through a substantial segment of the development arc even with a somewhat shortened electrode.

An embodiment similar to that discussed in connection with FIG. 7 is illustrated in FIG. 8. The embodiment of FIG. 8 shows the more efficient electrode covering the full length of the developing zone and with the addition of a tensioning spring **40** and an adjustable stop screw **39**. In this embodiment the development electrode is freely pivotable on pivot member **29**. Stop screw **39** determines the maximum spacing between the top end of electrode **16** and the surface of drum **10**. Tensioning spring **40** is a light weight spring providing adequate pressure to rock the bottom end of the development electrode in toward the surface of the drum causing the upper end to swing out against the stop screw. In addition the spring is preferably of low enough compressive strength to allow the development electrode to rock away from the surface of the drum in the event of pressure caused by excessive developer material or an unusually large particle passing through the development zone. While described in accordance with the specific detail of the drawing, this embodiment is not intended as limiting but includes all manner of conventional limiting and spring loading devices appropriate in such a configuration. For instance, spring loading on the pivotal point **29** in the absence of a limiting stop can permit rocking movement in both directions about a preset point determined by the spring setting. As an example of pivotal point spring loading, FIG. 9 shows an embodiment of the novel development electrode with a xerographic drum and using a pivot point spring loading device. Referring to FIG. 9, development electrode **16** is mounted adjacent to xerographic drum **10** in support pivot collars **70**. Fastening bolt **18**, holding the plates of the delevopment electrode in assembly is rotatably supported by pivot collars **70**. In addition one end of spring member **71** is connected to bolt **18**. A second end of spring member **71** is adapted for clamping by clamp **72** to calibration plate **73**. Clamp **72** is slideably engaged to calibration plate **73** to permit the second end of spring member **71** to be positioned and clamped at any calibration point on plate **73**. Calibration plate **73** may suitably be calibrated in degrees related to the eccentricity between development electrode **16** and drum **10**. When the spring member is clamped toward the top of plate **73** the top end of electrode **16** will be closer to drum **10** and when the spring member is clamped toward the bottom of plate **73** the top end of electrode **16** will be farther away from drum **10**. In any position of the spring member, the electrode will follow by rotating in pivot-support collars **70**. During a development process the electrode will pivot readily in the pivot support collars and against the spring tension to permit free passage of abnormal agglomerations of developer or unduly large particles. When electrode **16** is caused to swing against spring **71** during development, the spring will return it to the calibrated position.

While, as discussed above, the development electrode of the invention is applicable to flat plate equipment it is particularly valuable in a rotary drum xerographic apparatus. In such apparatus, cascade development using carrier beads as previously discussed has proved the most satisfactory. Also in such apparatus, it is particularly important that the drum can be revolved continuously through its operations without danger of jamming or of deleterious effects to its reproducing surface. High speed is also desirable in such apparatus.

A novel automatic rotary drum apparatus in accordance with the inventive concepts is illustrated in FIG. 10. In FIG. 10 a xerographic drum **30** is rotated on an axis **31** by motor **32** through the various stations for performing a xerographic process. Thus the drum **30** rotates past a charging station **33** where the photoconductive insulating surface of the drum is electrostatically charged as by a corona discharge device. The charged surface area is then rotated to an exposure station **34** where it is illuminated by an image pattern. The exposure station includes a projection system, such as a slit exposure device, for optically projecting a moving image pattern synchronized with the motion onto the sensitized surface of the drum. After exposure, the drum is rotated through a development station **35** in which an electroscopic particulate development material **36** is transported, by a conveyor system **37** driven by motor **38**, and cascaded down onto an extended portion **41** of development electrode **45** and against the surface of the drum **30**. A hopper **42** supplies a controlled amount of additional developer powder **43** to the developing system through controlled opening **44**. A development electrode **45** in accordance with the invention and as described in relation to FIGS. 2 and 3 is positioned within the development station and adjacent to the surface of the drum. Following the development station in the direction of rotation of the drum is a transfer station **48**. At the transfer station, a transfer web **49** is supported in a movable manner against the surface of the drum **30** by pulleys **50** and **51**. An electrostatic charging device **52** is positioned adjacent to the transfer web at its point of contact with the drum **30**. In operation the charging device **52**, illustrated as being a corona discharge device, induces transfer of the developed image to the transfer web **49** and the image is then fixed on the transfer web at a fixing station **53**. At the fixing station a heat radiator thermally fixes the image to the transfer web which is then passed between drive rollers **54** to takeup reel **55** driven by a motor **56**. Following the transfer station is a cleaning station **57** where rotary brushes **59** driven by motor **60** are arranged to remove residual image material from the drum surface. The cleaning station also includes a source of illumination **61** which illuminates the photoconductive surface to remove any traces of the electrostatic latent image that may remain. The development electrode **45** of the invention enables high speed operation of the apparatus producing low contrast reproductions without jamming of the development material or excessive deterioration of the drum surface.

While the present invention has been described as carried out in specific embodiments thereof, there is no desire to be limited thereby, but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. In an electrostatic image reproduction apparatus, including a surface for carrying an electrostatic latent image to be developed with cascading developer particles, a development electrode comprising an array of parallel plates spaced apart a distance at least greater than the largest dimension of developer particle to be cascaded, said plates being arranged extending substantially outwardly from the plane of the image-bearing surface with one edge set of said plates spaced from the image-bearing surface a distance at least greater than the largest dimension of developer particle to be cascaded, said plate edges presenting a substantially uniform electrostatic field to said image-bearing surface while positioned extending generally in the direction of cascade movement of the developer particles as to allow cascading particles traversing the image-bearing surface to pass substantially uniformly unimpeded under and between said plates.

2. Developing apparatus for cascade development of electrostatic latent images comprising support means to support an image-bearing member, means to cascade electroscopic developer particles across the surface of an

image-bearing member supported on said support means, and a development electrode positioned for close spacing with relation to an image-bearing member on said support means, said development electrode comprising a plurality of plates spaced apart a distance at least greater than the largest dimension of developer particle to be cascaded and having a set of edges spaced from the image surface a distance at least greater than the largest dimension of developer particle to be cascaded to present a substantially uniform electrostatic field to said image-bearing member while positioned generally in the direction of cascade movement of the developer particles to allow developer particles cascading across the surface of the image-bearing member to pass substantially uniformly unimpeded under and between said plates.

3. Development apparatus as in claim 2 in which the plate edges of said development electrode are positioned for a spacing from an image bearing member on said support means of between 2 and 6 times the dimension of the largest developer particle to be cascaded.

4. Development apparatus as in claim 2 in which said closely spaced plates are separated from each other by a distance about three times the dimension of the largest developer particle to be cascaded.

5. Development apparatus as in claim 2 in which the development electrode plates provide a surface area greater than three times the adjacent surface area of an image-bearing member supported on said support means.

6. Xerographic apparatus for development of electrostatic latent images comprising rotational support means to support an electroscopic latent image-bearing drum member which contains the image on the peripheral surface thereof, means to cascade electroscopic developer particles across the surface of a drum member on its support means, and a development electrode comprising a plurality of closely-spaced conductive plates disposed in parallel planes extending generally perpendicular to the rotational axis of a drum member mounted on its support, said plates being spaced apart a distance at least greater than the largest dimension of developer particle to be cascaded and having a set of edges supported spaced from the image-bearing surface a distance at least greater than the largest dimension of developer particle to be cascaded to present a substantially uniform electrostatic field to the image surface of the drum member on its support while positioned generally in the direction of cascade movement of the developer particles as to allow developer particles cascading across the surface of the image-bearing drum

member to pass continuously and substantially uniformly unimpeded under and between said plates.

7. Xerographic apparatus as in claim 6 in which the said edges of the conductive plates are arcuate and arranged substantially parallel to the peripheral image-bearing surface of the drum on its support.

8. Xerographic apparatus as in claim 6 including adjustable positioning means adapted to vary the relative distance between different portions of said plate edges and the image-bearing drum surface.

9. Apparatus according to claim 6 in which the conductive plates are disposed in parallel planes askew from the direction of rotation of said support means by an angle of about one to ten degrees.

10. Apparatus according to claim 6 in which the parallel plates are spaced less than thirty mils from each other and the said edge portions thereof are less than thirty mils from the surface of said drum.

11. A development electrode for improving the continuity of cascade development in rotary xerographic reproducing apparatus comprising an assembly of closely-spaced conductive plates spaced apart a distance at least greater than the largest dimension of developer particle to be cascaded and extending generally in the direction of cascade movement of the developer particles, pivotal support means supporting said assembly, adjustment means connected to said pivotal support means for preselecting a normal position of said assembly with an edge set of said plates spaced from the image surface a distance at least greater than the largest dimension of developer particle to be cascaded, and tensioning means connected to said pivotal support means urging said assembly to said preselected normal position while allowing said assembly to readily shift position to permit the passing of agglomerations of developer material of dimensions greater than the dimensions of said defined passage and then return to said normal position.

12. A development electrode in accordance with claim 11 in which said plates of said assembly are positioned and disposed substantially parallel to each other.

13. A development electrode in accordance with claim 11 in which said plates are positioned with a spacing between plates of between 10 and 60 mils.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,147,147 September 1, 1964

Chester F. Carlson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 46, for "electrostatic" read -- electroscopic --.

Signed and sealed this 30th day of March 1965.

SEAL)
ttest:

T W. SWIDER
g Officer

EDWARD J. BRENNER
Commissioner of Patents

UNITED STATES PATENT OFFICE
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