Sept. 20, 1971 G. ZWEIG 3,605,693

DEVELOPMENT ELECTRODE

Filed Sept. 9, 1969 2 Sheets-Sheet 1

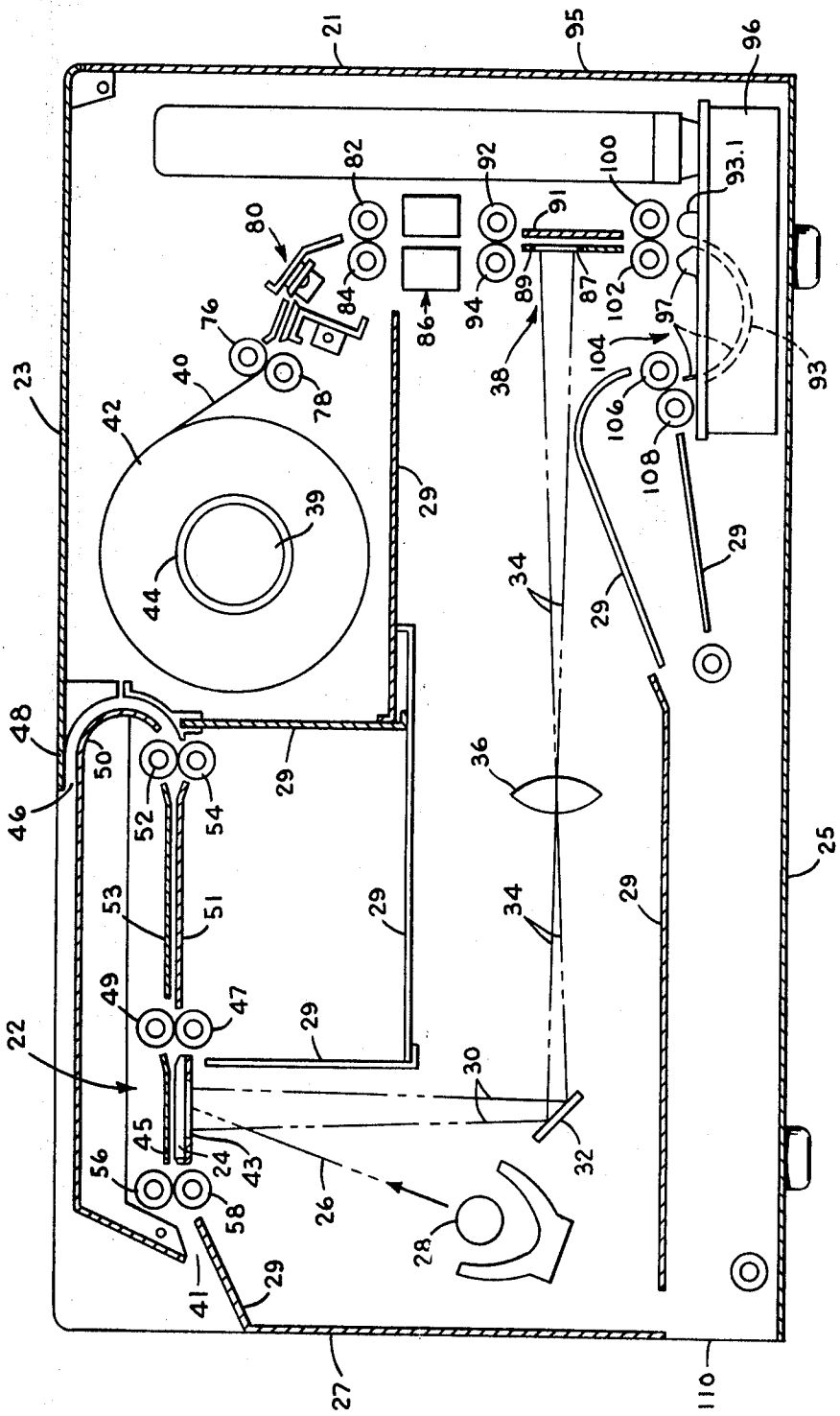


FIG. 1

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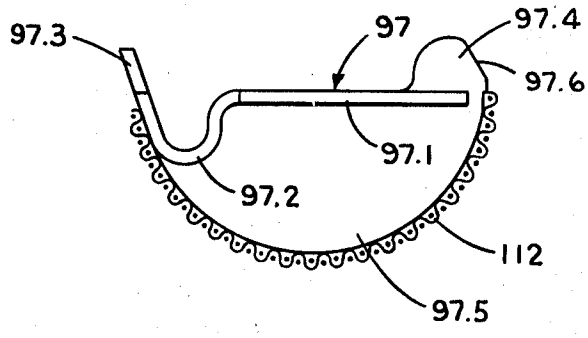


FIG. 2

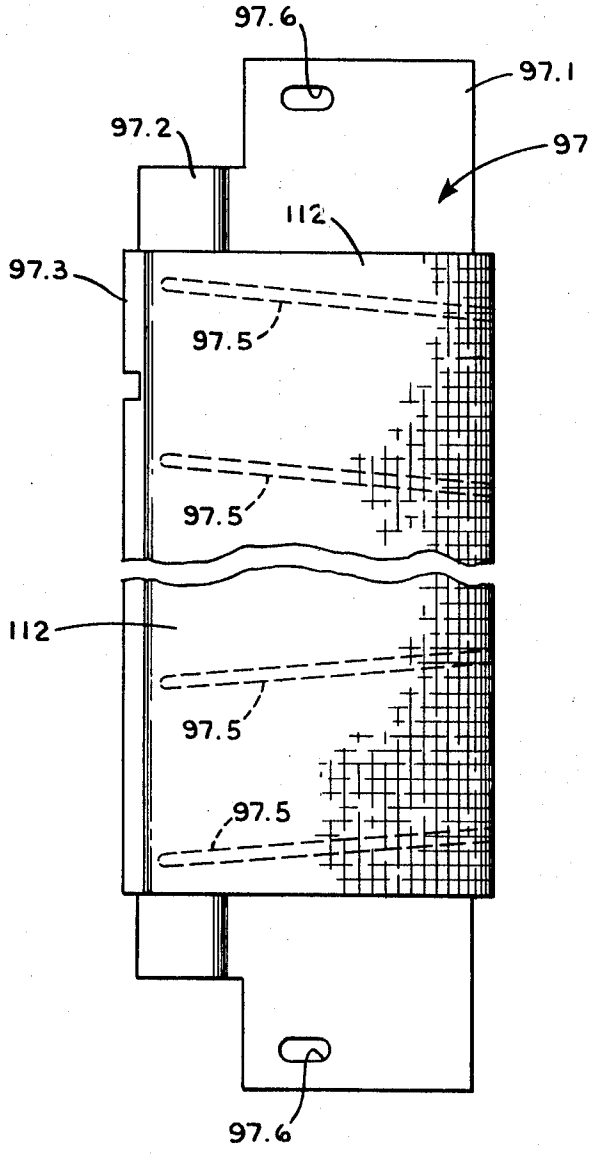


FIG. 3

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DEVELOPMENT ELECTRODE

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U.S. Cl. 118—637 8 Claims

ABSTRACT OF THE DISCLOSURE

A porous, electrically floating electrode, such as a metal screen, is employed in a liquid toner process for electrostatic image development.

FIELD OF THE INVENTION

This invention relates generally to photocopying, and is particularly concerned with image development in electrostatic photocopying equipment of the type which employs a liquid toner.

THE PRIOR ART

At the present time there are several types of development processes which are used in electrostatic photocopying machines. One of these employs an airborne stream of "toner" or pigment material directed at the surface of the copy paper. In such a system, examples of which are seen in British Patent 1,029,536 and French Patent 1,507,-916, the toner material is ejected from a nozzle in the form of an aerosol spray. The other type of development process, an example of which is seen in U.S. Patents 3,415,223, and 3,359,945 employs a liquid toner bath in which the copy paper is completely submerged. This bath is normally a colloidal suspension of toner particles in a high dielectric dispersant liquid.

In both the airborne and liquid-borne development processes described a development electrode has been found necessary to overcome the difficulty commonly known as "edge effect" (also referred to as "halo," or lack of "fill-in"). Electrostatic copying processes have an inherent tendency to wash out the interior of an extended black area of the image, coloring only the edges of that area black. In a standard text on electrostatic copying, "Electrophotography" by Schaffert (Focal Press, New York City), it is pointed out that this effect is due to the sharper voltage contrasts which occur at the edges of the black image areas when the photocopy paper is charged electrosatically to form a latent image. Schaffert also notes that the usual solution to this problem is the placing of an electrode in close proximity to the image-bearing surface of the copy paper during development, which prevents edge effect by altering the electrical field configuration in the central portion of the black areas of the image. The development electrode disclosed in the Schaffert text takes the form of a solid metal plate in close proximity to the photocopy paper, and it is suggested by Schaffert that this electrode should be connected to a fixed electrical potential level, i.e. either shorted directly to the backing plate behind the photocopy paper or held at a fixed positive or negative level relative to that plate.

In the airborne toner systems shown in the British and French references cited above, the development electrode takes the form of a metal screen, in order to permit the aerosol toner stream to be sprayed through the electrode to the image-bearing surface of the copy paper. Since the development electrode closely covers the image-bearing surface, it would be very difficult for an airborne toner stream to reach the paper if the electrode were not perforated. In such an airborne toner device the choice between a perforated and an imperforate electrode does not have any secodnary implications.

In liquid-borne toner processes, the prior art has not been able to devise a completely satisfactory development electrode. Various types of electrode, and various electrical connections or lack of electrical connection thereto, have been tried; but each arrangement has either been unsuccessful in the elimination of edge effect or has caused serious secondary problems. In retrospect, it appears that this difficutly arose because the art has heretofore confined itself to imperforate electrodes, as opposed to porous ones. The explanation for this restrictiveness may lie in the fact a liquid toner process completely submerges the copy paper in the liquid toner bath, thus inherently solving the problem of delivering the toner to the image-bearing surface of the paper. Since there was not the same problem of access to the copy paper as in an airborne toner device, the art apparently failed to see any necessity for a screen electrode in a liquid toner device.

Yet experience with imperforate development electrodes in liquid toner devices has been universally poor. Some designers have employed imperforate development electrodes which were electrically grounded or otherwise maintained at a fixed electrical potential. This type of electrode performs well in eliminating edge effect, but it has the disadvantage of producing background, i.e. a gray cast, or in some cases a black flecking, uniformly distributed over the white areas of the image. This result is attributed to the fact that a grounded electrode is overly effective in developing the latent electrostatic image; it too faithfully reproduces a uniform residual charge which remains in the white image areas. At the present time, many of the electrostatic photocopying machines which are sold commercially are subject to this type of defect, which visibly lowers the quality of the copy.

The art has also tried electrically floating, imperforate development electrodes in a liquid-borne toner environment, expecting that a floating electrical potential would avoid the background problem. However, the results achieved with this approach have been discouraging. In order to be successful in eliminating edge effect, the development electrode must be in close proximity to the image-bearing surface of the photocopy paper. The spacing normally used is described as a condition of "virtual contact," meaning that the copy paper is separated from the development electrode only by a mono-molecular film of toner. Such close contact, while necessary to the elimination of edge effect, causes severe and unacceptable degradation of the copy quality in the case of an imperforate, electrically floating electrode.

The explanation for this degradation seems to be that when a highly charged area appears on the copy paper, i.e. a black image area, it draws a great many toner particles toward the copy paper and away from the confronting surface of the development electrode, leaving a relatively toner-free volume of dispersant liquid near the electrode. The toner dispersion as a whole is electrically neutral, but is composed of toner particles and dispersant molecules having mutually opposed electrical charges. Thus the described separation of toner and dispersant in a particular region causes a localized electrical polarization of the toner. Furthermore, since the confined space between the copy paper surface and the development electrode is only large enough for a mono-molecular layer of toner, it is difficult for such a localized pocket of polarized toner material to disperse by diffusing into the surrounding volume of unpolarized toner material. As a result, the polarized pocket remains intact for some time after its corresponding image area has passed by as the copy paper progresses through the toner tank, and this intact pocket of polarized material may have an adverse effect on following areas of the copy paper. It is this effect

which is suspected of causing severe degradation of copy quality when an imperforate development electrode is allowed to float electrically.

This degradation may take one of two forms, depending upon whether the development electrode is a rotating roller, as in U.S. Pat. No. 3,415,223, or is stationary. If the rotating roller type of electrode is used, a photographically negative ghost image is observed one cycle of roller rotation behind the proper location of the corresponding photographically positive image. On the other hand, if a stationary electrode is employed, two problems arise. First, the electrode tends to bind the copy paper, perhaps because the stationary electrode does not receive sufficient inflow of toner liquid to lubricate the passage of the copy paper in view of the virtual contact between the paper and the electrode. Second, the sliding contact between the electrode and the copy paper produces "deposition offset," a smearing of toner particles across the image-bearing surface of the copy paper, visible as distinct black smear lines which are highly objectionable. Any attempt to avoid these difficulties by widening the space between the copy paper and the development electrode reduces its effectiveness in eliminating edge effect.

SUMMARY OF THE INVENTION

This invention provides the only known development electrode for use in a liquid-borne toner process which is fully effective in eliminating edge effect, yet does not bind the copy paper or sacrifice image quality to the alternative evils of ghost imaging and deposition offset. For the first time in a liquid toner process the electrode takes the form of a porous or perforated member, e.g. a metal screen; and the surprising discovery has been made that this type of electrode can be electrically floating, so as to avoid producing background, yet does not thereby open the door to the problems associated with toner depletion.

Apparently the porosity of such an electrode permits diffusion therethrough, so that the balance between oppositely charged toner and dispersant particles can be rapidly restored. This diffusion presumably takes the form of an oppositely directed random migration to toner and dispersant particles, in which toner particles from the larger volume of liquid on the opposite side of the electrode diffuse through the electrode to replace the toner particles which have been depleted, while excess dispersant molecules diffuse out of the toner-free region and rejoin the larger volume of liquid on the opposite side of the electrode. This apparently has the effect of restoring the electrical balance in the confined space between the copy paper and the development electrode, thus avoiding the tendency of an electrically floating development electrode to produce ghost images or deposition offset. Moreover, it seems that the fresh liquid diffusing through the electrode lubricates it so that no problem of binding is encountered, even when the electrode is stationary.

As a result of this invention, the designer of electrostatic copying apparatus need no longer face the Hobson's choice between various ways of degrading copy quality, i. e. edge effect, background, ghost images or deposition offset. For the first time, a liquid toner process is capable of producing the highest quality electrostatic reproductions, including large black areas, without trade-off or compromise of any kind.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of an electrostatic photocopying machine employing a liquid toner for development purposes, and including a porous development electrode in accordance with the present invention. The side panel of this machine is removed for purposes of illustration.

FIG. 2 is a side elevational view of a development electrode assembly in accordance with this invention, taken from the photocopying machine of FIG. 1.

And FIG. 3 is a bottom plan view of the same development electrode assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In general terms, the photocopying machine illustrated in FIG. 1 comprises a copying station **22** at which an original document is scanned by the beam **26** of a lamp **28**. An image of the original document, indicated by rays **30**, is reflected from the surface of the document toward a mirror **32**, which redirects the image along the path indicated by rays **34**. The latter rays are focused by a lens **36** upon a printing station **38**.

The original document is manually inserted into a feed channel **46** formed between upper and lower guide plates **48** and **50**. Such insertion causes the document to pass around the bend seen in the channel **46**, until it is gripped between a pair of motor-driven feed rollers **52** and **54**, which convey the document between a second pair of guide plates **51** and **53** to a second pair of motor-driven feed rollers **47** and **49**. The latter rollers then convey the document through the copying station **22**. Within the copying station the document passes between an upper guide plate **45** and a transparent glass plate **24** which is supported by a bracket **43**. As it emerges from the copying station **22**, the document is withdrawn by still another pair of motor-dirven feed rollers **56** and **58**, and discharged through an exit port **41**.

A strip of copy paper **40** is taken, by means of a pair of motor-driven feed rollers **76** and **78**, from a supply roll **42** wound upon a spool **44** which is rotatably mounted upon a shaft **39**. Rollers **76** and **78** pass the copy paper through a cut-off knife mechanism **80** to another pair of motor-driven feed rollers **82** and **84**. After an appropriate length of copy paper has been fed past the cut-off knife mechanism **80**, the machine actuates the cut-off knife, to cut the copy paper to the length of the original document.

The rollers **82** and **84** feed the photocopy paper **40** through an electrostatic charging mechanism **86**. Upon emerging from this charging mechanism, the copy paper is gripped by another pair of motor-driven feed rollers **92** and **94** to be conveyed between a pair of guide plates **89** and **91** within the printing station **38**. The front guide plate **89** of the printing station is formed with a window **87** to permit passage of the image rays **34**.

Upon emerging from the printing station **38**, the copy paper **40** is gripped by another pair of motor-driven feed rollers **100** and **102** for delivery to development apparatus generally designated **104**. The latter comprises a tank **96** containing a conventional toner bath which comprises a colloidal suspension of black toner particles within a high dielectric dispersant liquid. An upstanding reservoir **95** supplies the tank **96** with sufficient toner to maintain a high level therein. As it passes through the tank **96**, the copy paper **40** is guided through a U-shaped path defined between a concavely curved lower guide element **93** and a corresponding convexly curved upper guide element **97**. This path takes the copy paper first downwardly below the surface of the toner bath and then upwardly from the tank **96**. As it emerges, the copy paper is gripped by another pair of motor-driven rollers **106** and **108** and then delivered to suitable mechanisms, not illustrated, for drying the photocopy and delivering it to an exit port **110**. The machine is housed in a cabinet comprising a rear panel **21**, a top panel **23**, floor panel **25**, and front panel **27**, with various internal partitions **29**.

As seen in FIGS. 2 and 3, the upper guide element **97** comprises a generally horizontal plate **97.1** which at its forward end merges into a U-shaped channel member **97.2** terminating in a slanted but generally upwardly extending guide extension **97.3**. The rear portion of the up-

per surface of plate **97.1** is formed with a plurality of upstanding vanes **97.4**, which register vertically with respective downwardly projecting guide partitions **97.5**. The lower edges of these guide partitions **97.5** are convexly curved to cooperate with the lower guide member **93** in defining the curved path which the copy paper **40** takes while passing through the toner tank **96**. Edges **97.6** of the upstanding vanes **97.4** are shaped to cooperate with an upstanding extension **93.1** of the lower guide member **93** (see FIG. 1) for initially guiding the leading edge of the copy paper **40** into the channel between guides **97** and **93** as it enters the toner tank **96**. Finally, as the copy paper **40** emerges from the toner tank, the upstanding guide extension **97.3** guides the paper toward the feed rollers **106** and **108**. A pair of bolt openings **97.6** are formed in the horizontal plate **97.1** for attaching the upper guide element **97** to appropriate supporting elements (not shown) within the photocopying machine. The copy paper guide mechanism as so far described is conventional, and incorporated in liquid toner type electrostatic copying machines which are now on the market.

In accordance with the present invention, a porous development electrode **112** is formed in a suitably curved configuration and secured in place over the lower edges of the downwardly projecting guide partitions **97.5** over most of the horizontal extent of the guide element **97**. The development electrode **112** must of course be formed of electrically conductive material, but must also be sufficiently porous to be readily permeable to the toner particles and dispersant molecules of the toner bath. A preferred material for the development electrode **112** is a screen comprising a network of relatively fine metal wires with sufficiently large spaces therebetween to provide a high degree of permeability to the toner bath.

One advantage of employing a screen electrode is that the individual wires thereof tend to concentrate the electrostatic lines of force extending from the development electrode to the confronting surface of the photocopy paper **40** as it passes through the toner tank **96**. This serves to enhance the well known edge effect eliminating characteristic of development electrodes generally. At the same time, the close spacing and uniform distribution of the screen wires has a tendency to average out the electrostatic field over the image-bearing surface of the copy paper, so that the effect of the development electrode is uniformly distributed over the image area.

In order to eliminate background, an effect which is associated with grounded electrodes, the screen **112** is electrically floating. To accomplish this in a preferred manner, the upper guide element **97** comprises a single piece of molded plastic material which is electrically insulating, and the electrically conducting screen element **112**, which is light enough to be flexible, is bent into a curvature which conforms to the profile of the lower edges of the guide partitions **97.5**, and is secured thereto. Attachment of the screen **112** to guide **97** is preferably done with a suitable adhesive material which is impervious to the toner bath, or by heat-sealing to the plastic material of element **97**, riveting, or other conventional means. The mounting holes **97.6** are located beyond the ends of the screen member **112**, so that the guide member **97** can be mounted upon a portion of the metal frame of the photocopy machine, and the screen **112** can be mounted on the plastic guide element **97** as described, without putting the screen **112** in electrical contact with the metal frame. Thus the guide **97** keeps the screen electrode **112** in a condition of electrical isolation, so that its voltage floats in relation to surrounding conductive materials. The only material which can come in contact with the screen electrode **112** is the insulating plastic of the guide element **97**, the insulating toner bath within the tank **96**, and the coating on the image-bearing surface of the copy paper **40**, which is conductive only when exposed to light.

Because it is kept electrically floating in this fashion, the electrode **112** completely eliminates background. At the same time, the electrode is in virtual contact with the image-bearing surface of the photocopy paper and thus eliminates edge effect at least as well as conventional imperforate development electrodes. But it does so without incurring the disadvantages associated with conventional electrodes, i.e. deposition offset and ghost images. This seems to result from an exchange of toner and dispersant particles on opposite sides of the screen **112**, permitting new toner particles to replenish the depletion region and excess dispersant molecules to escape to other side of the screen. In addition, freedom of toner migration appears to lubricate the electrode **112**, which is fixed in position, so as to avoid the binding problem previously encountered with fixed electrodes in this type of equipment. Finally, the screen **112** appears to focus the field lines and distribute them uniformly over the surface of the image area in such a way that it is particularly effective in eliminating edge effect, and also produces homogeneous blacks in the pigment areas and uniformly clear whites in the non-pigment areas.

In a preferred embodiment of this invention the screen material **112** is formed of individual metal wires having a diameter of 0.0055 inch arranged in a rectangular mesh of between 40 x 40 and 100 x 100 wires per inch. An 80 x 80 mesh screen size has been found to work very well. If the screen opening size falls within the acceptable range, the diameter of the screen wires appears to have relatively little effect on the results obtained.

It will thus be appreciated that in applying a porous development electrode to a liquid toner type of copying process, the present invention for the first time permits this type of process to produce copies which are free of edge effect while simultaneously avoiding the pitfalls of background, ghost imaging, deposition offset, and paper binding. As a result, it is now possible to produce copies of the highest quality by means of a liquid toner process.

The embodiments of the invention in which an exclusive property of privilege is claimed are defined as follows:

1. Photocopy development apparatus comprising:
a tank adapted to hold a liquid toner bath;
means arranged for conveying photocopy paper through said toner bath;
and a porous electrically floating development electrode arranged to be in virtual contact with a surface of said paper as it passes through said toner bath, said electrode having openings therein of a size range corresponding to that for a screen mesh range of 40 x 40 to 100 x 100 wires per inch.

2. Apparatus as in claim **1**, wherein said development electrode comprises a metal screen.

3. Photocopy development apparatus comprising:
a toning station;
means for conveying photocopy paper through said toning station;
an electrically floating development electrode arranged to confront in virtual contact a surface of said photocopy paper as it passes through said toning station;
and means for maintaining a layer of toner fluid between said development electrode and said confronting photocopy paper surface, and for maintaining a replacement supply of toner fluid on the opposite side of said development electrode from said photocopy paper, without imparting to said toner fluid a flow in the direction from said development electrode to said photocopy paper, other than the random motions of individual toner particles;
said development electrode being sufficiently porous to permit said random particle motion to bring about an exchange between toner particles on opposite sides thereof, the opening in said electrode being of a size range corresponding to that for a screen mesh range of 40 x 40 to 100 x 100 wires per inch.

4. Liquid toner photocopy development apparatus comprising a tank for containing a liquid toner bath;

means for conveying photocopy paper through said bath;

a porous development electrode;

and means fabricated of electrically insulating material mounting said development electrode in position to confront in virtual contact said photocopy paper as it passes through said bath and arranged to hold said development electrode out of contact with any electrically conducting material, the opening in said electrode being of a size range corresponding to that for a screen mesh range of 40 x 40 to 100 x 100 wires per inch.

5. Apparatus as in claim 4, wherein said development electrode is arranged to guide said photocopy paper through said bath.

6. Apparatus as in claim 5, wherein said development electrode comprises a screen formed of metal wires.

7. Apparatus as in claim 6, wherein:

said electrode mounting means comprises an element shaped to guide the photocopy paper through said toner bath;

and said screen conforms to the shape of said guide element and is affixed thereto in a position to be interposed between said guide element and said photocopy paper.

8. Apparatus as in claim 7 wherein:

said element comprises spaced guide partitions with convexly curved surfaces cooperating to define a curved paper-guiding form for said screen;

and said screen is curved to fit said form, and secured in place over said convexly curved partion surfaces.

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JAMES KEE CHI, Primary Examiner

U.S. Cl. X.R.

117—17.5; 355—3