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[54] **LIQUID DEVELOPING APPARATUS FOR DEVELOPING AN ELECTROSTATIC IMAGE**

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[52] **U.S. Cl.**..... **118/637,** 117/37 LE, 118/DIG. 23

[51] **Int. Cl.**..... **G03g 13/00**

[58] **Field of Search**..... 118/637, 602, DIG. 23; 117/37 LE, 93.4 A; 252/62.1; 355/10

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[57] **ABSTRACT**

A liquid developing apparatus for developing an electrostatic image formed on an electrophotographic surface using an aqueous solution as a developing electrode and a developing liquid which has a specific gravity less than that of the aqueous solution and is immiscible therewith. The developing liquid is floated on the aqueous solution and in contact with the electrostatic image surface, and is continuously circulated from a reservoir to the developing area, overflowing or decanting from the body of aqueous solution, and back to the reservoir.

6 Claims, 2 Drawing Figures

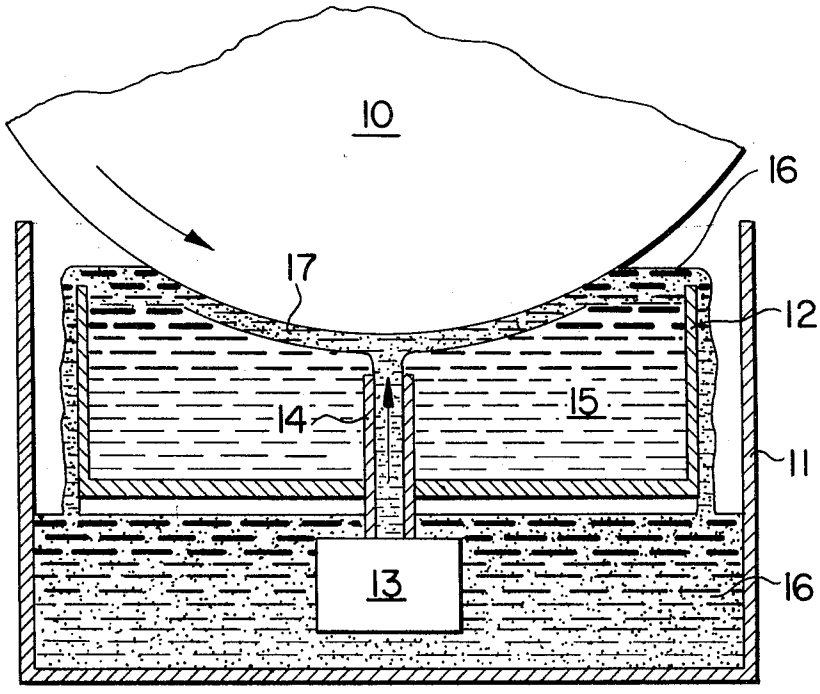


FIG. 1

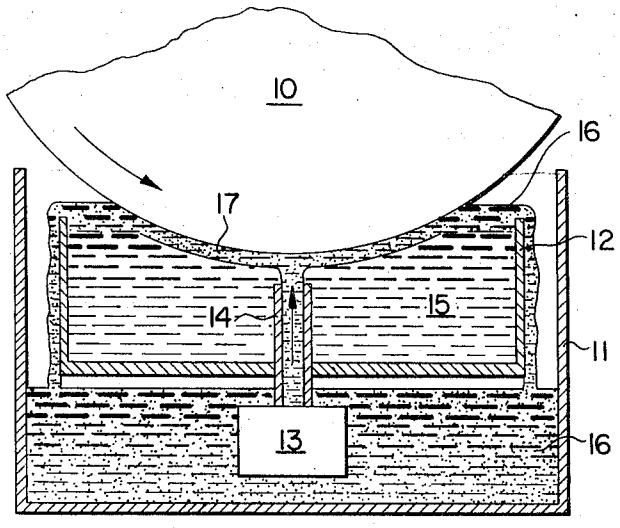
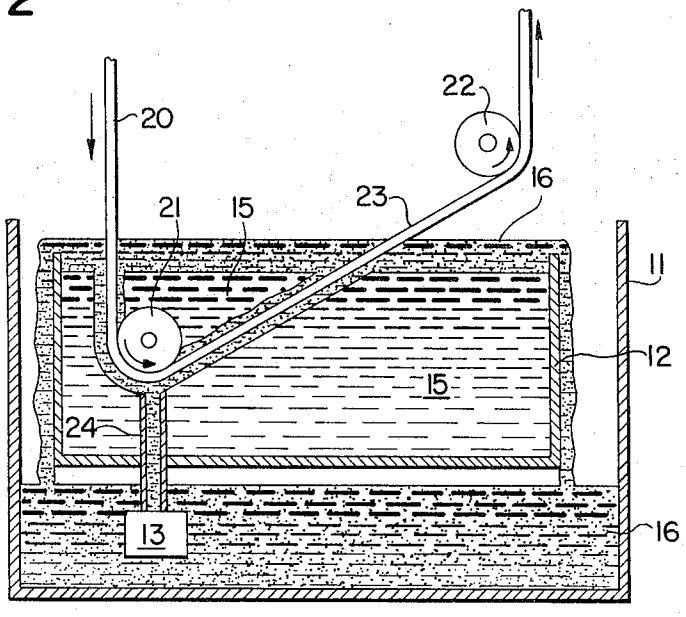


FIG. 2



LIQUID DEVELOPING APPARATUS FOR DEVELOPING AN ELECTROSTATIC IMAGE

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to improved liquid development of electrophotographic latent images, wherein water or an aqueous solution is employed as a developing electrode.

In order to obtain a developed image of high quality in an electrostatic photographic process, a development electrode is usually employed and located closely adjacent to the latent image during the development operation. Liquid development has the advantage that the distance between the latent image and the developing electrode, hereinafter referred to as the electrode distance, can be made less than with other developing methods, such as for example, cascade development, magnetic brush development and powder-cloud development. However, when using a conventional metal plate as the development electrode, it has been difficult to reduce the electrode distance to several hundred microns or less in an automatic processing apparatus because of the likelihood of accidental contact between the development electrode and the image surface.

In order to overcome this problem, it has been suggested that mercury be used as a liquid development electrode. However, because mercury is difficult and dangerous to handle, its use as a liquid development electrode has not been accepted. Water and/or aqueous electrolyte solutions have also been suggested for use as liquid development electrodes, and these are far more practical to use than mercury. When an aqueous electrolytic solution is employed as a development electrode, the development electrode distance may be made very small and uniform, with development electrode distances of several tens of microns or less, e.g., less than about 30 microns. This very small distance between image surface and development electrode is occupied by a thin film of developing solution, in the form of a dielectric liquid vehicle having electrophoretic toner particles dispersed therein. When the electrode distance is very small, as above, the effect of the development electrode becomes very large, whereby the toner particles are quickly consumed by the electrostatic latent image, depleting the developer solution before complete development of the image occurs. One may seek to compensate for this effect by using a developing solution having a very large toner concentration. The employment of a small electrode distance and a developing solution having a large toner concentration causes a substantial increase in image background fog. On the other hand, if the number of toner particles contained in the film is insufficient, a very low density and inadequate image results.

In accordance with the present invention, the foregoing problems are overcome using an aqueous solution as the development electrode, and a developer solution that has a specific gravity less than the aqueous solution and is immiscible therewith. Essentially, a layer of developer solution is floated in a thin film on the surface of the aqueous solution and between the aqueous solution and the electrophotographic surface being developed, to obtain the effect of a closely spaced development electrode. The problem of quick depletion of the developer solution is overcome by constantly circulating the developer solution from a sump or reservoir, to

the interface between the electrophotographic surface and the aqueous solution. As the developer solution collects on the top of the more dense aqueous solution, it overflows from, or decants from the development tank and is returned to the developer solution reservoir.

It is therefore one object of the present invention to provide for the liquid development of electrostatic latent images, using a thin film of dielectric developer solution interposed between the latent image surface and a liquid development electrode.

Another object of the present invention is to provide for the liquid development of electrostatic latent images, using a thin film of dielectric developer solution interposed between the latent image surface and a liquid development electrode, wherein the developer solution is continuously circulated from a reservoir to the interface between the latent image surface and the development electrode, and back to the reservoir.

Still another object of the present invention is to provide for such development wherein the developer solution comprises a dielectric vehicle containing electrophoretic toner particles dispersed therein, and said developer solution has a density less than that of said liquid development electrode and is substantially immiscible therewith.

And a still further object of the present invention is to provide for such development wherein said liquid development electrode is an aqueous electrolytic solution.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings, which are given by way of illustration only and thus are not limitative of the present invention and wherein,

FIG. 1 is a sectional schematic illustration of one embodiment of the present invention wherein the electrophotographic surface is in the form of a drum, and

FIG. 2 is a sectional schematic illustration of another embodiment of the present invention wherein the electrophotographic surface is in the form of a web of indefinite length.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the embodiment of the invention shown in FIG. 1, the development apparatus comprises two tanks, an outer tank **11**, and an inner tank **12** positioned inside the confines of the outer tank and supported in an elevated position above the botton of the outer tank. A pump **13** is provided, shown as positioned within and adjacent the bottom of the outer tank **11**. The effluent from pump **13** is conducted by pipe **14** through the bottom of inner tank **12** and up to a delivery point near but below the top of inner tank **12**.

The space in tank 11 below the bottom of inner tank 12 contains a reservoir of developer solution 16, which is usually composed of a dielectric vehicle with very small electrophoretic toner particles suspended therein, as is well known in the art. Inner tank 12 is nearly filled with a body of aqueous electrolyte solution 15, such as a saline solution. The two liquid solutions are selected to be immiscible with the developer solution 16 having a substantially lesser density than the aqueous solution 15, for reasons that will become apparent hereinafter. Under these circumstances, when pump 13 is operated, developer solution 16 from the reservoir is directed through pipe 14 and is discharged near the surface of the body of aqueous solution 15. The lighter developer solution 16 floats to the top of the body of aqueous solution 15, forms a layer on top of it, and when tank 12 becomes filled to the top developer solution 16 overflows from the lip of tank 12 and returns to the reservoir at the bottom of tank 11. This action continues so long as pump 13 is operated, causing a continuous circulation of developer solution from the reservoir, to the top of tank 12, and then back to the reservoir. Using a small opening or slit for the fluid egress from the top of pipe 14 would inhibit any downward flow of aqueous solution 15 into the pipe.

In the FIG. 1 embodiment, the electrophotographic element is shown as a drum 10, which conventionally may comprise a metallic electrically conducting cylinder having an outer layer formed of a photoconductive material, such as selenium. The drum 10 is positioned to be partially immersed in the contents of inner tank 12, and thus rotated through the development apparatus. Any electrostatic latent image present on the photoconductive surface of drum 10 is exposed to the development solution 16, and by the combined action of the force of the electrostatic image and the aqueous solution 15 functioning as a development electrode, the latent image on drum 10 is developed.

As shown in the drawing, as the drum is rotated and the developer solution 16 is circulated by pump 13, a thin film 17 of developer solution is caused to flow continually from pipe 14, over the immersed surface of drum 10, over the top edge or lip of tank 12, and back to the reservoir at the bottom of tank 11. In this manner, one can obtain a very close and uniform positioning of the image surface on drum 10 with the development electrode formed by the juxtaposed surface of the body of aqueous solution 15. At the same time, because of the continuous circulation of developer liquid, the toner content of thin film 17 is never fully depleted, for it is continuously being renewed.

The embodiment of the invention shown in FIG. 2 is essentially very similar to that shown in FIG. 1, and corresponding parts have been similarly designated. The present embodiment illustrates the development of an electrophotographic web 20 of indefinite length, instead of the drum configuration of FIG. 1. Web 20 is fed into the inner tank 12 and around guide roll 21, thence back out of the tank and around guide roll 22. Guide roll 21 is located over the delivery opening of pipe 24 (corresponding to pipe 14 in FIG. 1), resulting in a flow of a thin film of developer solution along the immersed portion of web 20. The operation of this embodiment will be quite apparent from the previous description of the FIG. 1 embodiment.

By virtue of the apparatus of the present invention, developed image with little or no edge effect can be obtained. In addition, a sufficiently high density for the image can be obtained with little or no background fog, without using a developer liquid having an excessively high toner concentration. Furthermore, the apparatus of the present invention can be handled with extreme safety as no dangerous liquids, such as mercury, are employed.

The invention being thus described, it will be obvious to one skilled in the art that the same may be varied in many ways. Such variations are not to be regarded as departures from the spirit and scope of the invention, and all modifications as are embraced by the appended claims are intended as within the purview of the present invention.

What is claimed is:

1. A liquid developing apparatus for electrostatic latent images which comprises a first tank having an open end portion and containing a body of electrically conducting liquid adapted to function as a development electrode, and a second tank having an open end portion and containing a body of liquid developer for electrostatic latent images, said first tank being disposed within said second tank and defining an annular channel therebetween, an element having an electrostatic latent image carrying surface extending into the open end portions of said first and second tanks and extending into said first tank, means for directing said electrostatic latent image carrying surface through said open end portions, and means for directing a flow of said developer liquid from the second tank and forming a thin film of developer between said surface and said conducting liquid.

2. The apparatus of claim 1, wherein the flow directing means comprises pump means disposed in the second tank and conduit means providing sealing communication from said pump means through the first tank to a zone in close proximity to the electrostatic latent image carrying surface.

3. The apparatus of claim 1, wherein said developer has a lower specific gravity than said conducting liquid and is immiscible therewith.

4. The apparatus of claim 1, wherein the annular channel between the first and second tank provides communication between said tanks so that the second tank can receive the developer flowing over the upper edge of the first tank.

5. The apparatus of claim 1, wherein the electrostatic latent image carrying surface is a drum.

6. The apparatus of claim 1, wherein the electrostatic latent image carrying surface is a web and guide roller means are provided for conveying said web into and out of the first tank.

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