ABSTRACT

A developer apparatus is disclosed which comprises a pair of electrically conductive fluid applicators which are separated from one another by a very narrow passageway. A charge-image bearing member passes through the passageway while relatively rapid moving bodies of liquid toner passes over both upper and lower surfaces of the charge-image bearing member. The flow rate of the liquid toner is relatively high so that a very small gap may be employed between the applicators and yet the imaging member will not contact the opposed surfaces of the passageway due to the effect of the moving liquid. The velocity of the liquid toner is also high in order to supply large amounts of toner for developing large solid black areas even though the applicator itself is not very long. Electrical connections are made between the pair of fluid applicators so that they act as development electrodes in eliminating the fringing effect.

15 Claims, 4 Drawing Figures
LIQUID TONER APPLICATOR

BACKGROUND OF THE INVENTION

Field of the Invention
This invention relates to the field of developing apparatus for developing electrostatic images through the use of liquid toners.

U.S. Pat. No. 3,547,076 to Sakiklar illustrates a liquid toner bath having a pair of electrically conductive guide members which also function as development electrodes. In order to obtain the most effective results with regard to reducing the well-known fringing effect, the distance between the electrodes should be made as small as possible and yet the imaging paper cannot contact them. It should be apparent that the spacing between the electrodes of Sakiklar cannot be made in the neighborhood of 50 thousandths of an inch because slight shifting of the electrostatic paper will cause the paper to touch the electrodes and damage the image. In other words, in order to obtain the desired small gap, the arrangement of Sakiklar is impractical.

The patents to Tamai, 3,566,834, and Fauser, 3,311,490, illustrate electrostatic liquid developers which include a development electrode utilized to counteract the fringing effect. The use of such electrodes result in production of better solid black areas as illustrated in FIGS. 3 and 4 of the Fauser reference.

Fauser also teaches introducing liquid toner between the paper bearing the electrostatic charge and a single development electrode. In these patents, the liquid toner, however, is applied only to the side of the paper which bears the charge image. In contrast therewith, I apply liquid toner to both sides of the paper and create a liquid bearing within an extremely narrow gap which results in a number of new and unobvious results. In the '834 and '490 patents, should the bottom side of the paper (not contacting the toner) not be in uniform contact with the bottom plate, nonuniformity will result in the developed images. In contrast with these patents, I apply the liquid toner to both sides of the paper to eliminate this disadvantage. The resulting liquid bearing of the present invention additionally enables me to employ an extremely narrow gap which results in most efficient counteraction of the fringing effect. An extremely narrow gap may be employed in my apparatus since the double side liquid bearing prevents the paper from touching the electrodes even though the gap is extremely thin. Also, in contrast with these references, the apparatus of the present invention pumps the liquid toner through the applicator passageway at a relatively high velocity so that a great deal of toner is available to produce large black areas and yet the applicator need not be very long.

SUMMARY OF THE INVENTION
In accordance with an embodiment of the invention, a pair of electrically conductive fluid applicator means are positioned to provide an extremely narrow passageway therebetween to maximize the development electrode effect. The paper is driven through the gap at a relatively low velocity and upper and lower moving bodies of liquid toner prevent the paper from contacting the applicator surfaces notwithstanding the extremely small gap between the applicator surfaces. The lower moving layer has a sufficiently high velocity to support the paper and to at all times fill the space in the passageway between the lower surface of the paper and the surface of the lower applicator while supplying large quantities of toner within a short time interval to develop large solid black areas where required. The upper moving layer of liquid toner has a sufficient velocity to at all times fill the space in the passageway between the upper surface of the paper and the surface of the upper applicator in order to produce the best solid area images.

DESCRIPTION OF THE DRAWINGS
Other objects, features and advantages of the present invention will become apparent upon reading the following description of an embodiment of the invention taken together with the drawings in which:

FIG. 1 discloses a front view of the developing apparatus;
FIG. 2 illustrates a top view of the apparatus;
FIG. 3 illustrates a side view of a portion of the applicator, said side view showing the relative thickness of the components;
FIG. 4 illustrates a liquid toner inlet gap of FIG. 1 in greater detail.

DESCRIPTION OF THE PREFERRED EMBODIMENT
Referring now to FIG. 1, the applicator comprises a first metallic plate 1 and a second metallic plate 2, the plates having opposed conductive surfaces 3 and 4 which form a gap or passageway through which the paper to be developed 6 (typically ZNO coated) and the liquid toner passes. A pair of drive rollers 7 and 8 are positioned adjacent to the entrance 9 of the applicator and a pair of squeeze rollers 11 and 12 are positioned adjacent the exit of the applicator. Drive means (not shown) are coupled to rollers 7, 8, 11 and 12 to cause them to drive paper 6 through the gap. A pump 13 causes liquid toner to pass through inlet gaps 14 and 16. Liquid toner thereafter passes from right to left through the gap and thereafter is deposited into sump 17 which is connected to pump 13 by means not shown.

The flow rate of the pump is selected so that particularly preferred liquid toner fluid velocities are set up within the applicator. The flow rate should be sufficient to cause the space between paper 6 and the upper applicator surface 4 to be filled with fluid, so that a reliable, uniform liquid and electric contact is maintained between the applicator surface and the paper and the above-mentioned problem of prior art relating to nonuniform contact between the paper and the bottom plate is substantially eliminated. The flow rate of the upper and lower moving layers of liquid toner is also considerably greater than the paper velocity. This results in a liquid bearing which, due to the relatively high velocity of the liquid with respect to the paper, prevents the paper from contacting opposing surfaces 3 and 4 of the applicator. The relatively high velocity of the fluid also results in the application of large quantities of toner to large solid areas to be developed black; large quantities of toner are applied without utilizing an applicator having considerable length to increase the developing time for a particular desired "thru-put" velocity.

An additional advantage of maintaining the fluid velocity at a relatively high rate is that casual background deposition of toner is reduced as it tends to be swept away by the moving liquid. The applicator is tipped
3,791,345

with respect to the horizontal as indicated, which aids in the flow of fluid through the applicator. Slits 14 and 16 are made quite narrow in order to increase the velocity of the liquid toner as it enters the applicator. Electrically conductive plates 1 and 2 are electrically coupled by means of conductor 5 (FIG. 3) which in general would take the form of bolts or other metallic devices for coupling the plates together. Of course, an actual electric wire could be utilized to maintain the plates at the same electrical potential. The plates could alternatively be electrically insulated from each other and biased at different potentials. I have found that a bias potential of 20 volts will reduce background toning without adversely affecting the image.

FIG. 2 illustrates a plane view of one of the applicators. Conduits 15 and 15' are coupled to pump 13 and deliver the liquid toner under pressure to one of the aforementioned slits such as 16. Entrance roller 7 and exit roller 11 are also illustrated. The configurations of the conduits for supplying liquid to the slits are not particularly critical and form no part of the present invention.

FIG. 3 illustrates a side view of the gap portion of the applicator. In the most preferred embodiment, constructed and tested, the distance between opposed surfaces 3 and 4 was 0.060 inches where paper having a thickness of 0.007 inches was developed. See FIG. 3 which is drawn to scale. As an added precaution against the paper contacting the upper surfaces 3, nonconductive nylon threads 21 were positioned against upper surface 3, these threads having a diameter of 0.020 inches. The threads were separated from each other by a distance of three-fourths of an inch. Slits 14 and 16 were one-sixteenths of an inch by 12 inches. The flow rate was adjusted to produce a toner velocity of about 30 inches per second, and the paper velocity was about 4 inches per second. Excellent results were obtained by varying the paper velocity plus or minus 20 percent and likewise excellent results were obtained by reducing the liquid toner velocity down to 15 inches per second, although satisfactory results were produced upon the further reduction of the fluid velocity down to about 5 inches per second. In like manner, the gap width could be varied between 0.030 inches and 0.080 inches although a gap width of 0.060 inches seemed to yield the best results. The velocity of the upper fluid body may be made considerably less than the velocity of the lower one since it is only necessary for the upper body to fill the space between the top side of the paper and upper applicator surface 3. Generally, as a practical matter, both layers would have about the same velocity.

FIG. 4 illustrates in further detail a typical slit configuration. The slit is formed by a blade-like member 41 placed adjacent a second member 42 as shown. The applicators are 12½ inches wide and about 6 inches in length. Hunt "Lith Set" brand toner was employed in the applicator although many available types of liquid toner may be used. The ZnO paper used was manufactured by Mead Paper Co. Inc. although others may also be employed.

In FIG. 3, a D.C. voltage source 10 could be coupled to the conductive surfaces 3 and 4 or, in the alternative, the conductive surfaces could be directly connected by a conductor. Ganged switches 20 and 20' could be utilized, if desired, to carry out this function.

Although the present invention has been described with reference to a single illustrative embodiment thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of the present invention.

1. An improved developing apparatus for developing an electrostatic image present upon an imaging member by applying a liquid toner thereto, comprising:
   a. a pair of spaced fluid applicator means having opposed electrically conductive surfaces for providing a passageway therebetween;
   b. means for positioning said imaging member between the opposed surfaces of said pair of fluid applicator means;
   c. fluid supply means for introducing said liquid toner into said passageway and for forming a first moving body of liquid toner in contact with the image bearing surface of said imaging member and for forming a second moving body of liquid toner in contact with the other surface of said imaging member, the velocity of said first moving body of liquid toner being sufficiently higher than the velocity of said imaging member to maintain said passageway full of liquid toner and to prevent said imaging member from contacting the opposing surfaces of said pair of fluid applicator means; and
   d. voltage reference means coupled to said pair of fluid applicator means for establishing a given voltage relationship between said pair of fluid applicator means.

2. The developing apparatus of claim 1 wherein the distance between said opposed surfaces of said pair of spaced fluid applicator means is between 0.03 inches and 0.08 inches.

3. The apparatus of claim 2 wherein said distance between said opposed surfaces is about 0.06 inches.

4. The developing apparatus of claim 2 further including elongated electrically nonconductive guide members positioned adjacent one surface of said pair of fluid applicator means for further insuring that said imaging member does not make contact with said one surface of said pair of fluid applicator means.

5. The developing apparatus as set forth in claim 1 wherein said fluid supply means includes means for supplying said liquid toner to said applicator at a flow rate for producing a velocity of the first moving body of liquid toner that is above 5 inches per second greater than the velocity of the imaging member.

6. The developing apparatus as set forth in claim 5 wherein said velocity of said first body of liquid toner is between 15 inches and 30 inches per second greater than the velocity of said imaging member.

7. The developing apparatus as set forth in claim 6 wherein the velocity of said first body of liquid toner is about 22 inches per second greater than the velocity of said imaging member.

8. The developing apparatus as set forth in claim 2 wherein said fluid supply means includes means for supplying said liquid toner to said applicator at a flow rate for producing a velocity of the first moving body of liquid toner that is above 5 inches per second greater than the velocity of the imaging member.

9. The developing apparatus as set forth in claim 8 wherein said velocity of said first body of liquid toner
is between 15 inches and 30 inches per second greater than the velocity of said imaging member.

10. The developing apparatus as set forth in claim 9 wherein the velocity of said first body of liquid toner is about 21 inches per second greater than the velocity of said imaging member.

11. The developing apparatus as set forth in claim 3 wherein the velocity of said first body of liquid toner is about 21 inches per second greater than the velocity of said imaging member.

12. An improved developing apparatus for developing an electrostatic image present upon an imaging member by applying a liquid toner thereto, comprising:

   a. a pair of spaced fluid applicator means having opposed electrically conductive surfaces for providing a passageway therebetween;
   b. transport means for transporting said imaging member through said passageway at a first velocity;
   c. fluid supply means for introducing said liquid toner into said passageway and for forming a first moving body of liquid toner in contact with the image bearing surface of said imaging member, which is moving at a second velocity, said second velocity being substantially greater than said first velocity in order to supply large amounts of toner to the imaging member as it passes through said developing apparatus, said fluid supply means further including inlet means for introducing a second moving body of liquid toner in contact with the opposite side of said imaging member in sufficient supply for preventing said imaging member from contacting said opposed surfaces of said applicators; and
   d. voltage reference means coupled to said pair of said fluid applicator means for establishing a given voltage relationship between said pair of fluid applicator means.

13. The developing apparatus as set forth in claim 12 wherein said transport means feeds said imaging member through said applicator at a velocity between 3 and 5 inches per second and wherein said second velocity of said first moving layer of liquid toner is between 15 and 30 inches per second, and wherein the distance between the opposed surfaces of said pair of said spaced fluid applicator means is between 40 and 60 thousands of an inch.

14. The developing apparatus as set forth in claim 13 wherein said first velocity is about 4 inches per second, said second velocity is about 30 inches per second and wherein the distance between the opposed surface of said fluid applicator means is about 60 thousands of an inch.

15. The developing apparatus as set forth in claim 14 further including elongated electrically nonconductive guide members positioned adjacent one surface of said pair of fluid applicator means for further insuring that said imaging member does not make contact with said one surface, the thickness of said guide members being about 20 thousands of an inch thick.

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