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[54] LIQUID DEVELOPMENT OF ELECTROSTATIC IMAGES

[75] Inventor: **Heino Kase**, Los Altos, Calif.
[73] Assignee: **Varian Associates**, Palo Alto, Calif.

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[52] **U.S. Cl.** **118/637**; 118/DIG. 23; 355/10; 427/15
[51] **Int. Cl.**^{2} **G03G 15/10**
[58] **Field of Search** .... 355/3 P, 10; 117/37 LE; 118/DIG. 23, 637; 427/15, 16, 17

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Primary Examiner—Mervin Stein
Assistant Examiner—Douglas Salser
Attorney, Agent, or Firm—Stanley Z. Cole; D. R. Pressman; Robert K. Stoddard

[57] **ABSTRACT**

In a liquid development station for developing electrostatic latent charge images on the charge retentive surfaces of recording media, a cylindrical development electrode is mounted for rotation adjacent the charge retentive surface of a recording medium to be developed. The cylindrical development electrode has a rough surface and is rotated with sufficient angular velocity such that the speed of the rough surface is faster than the speed of the moving charge image to be developed. Liquid electrographic toner is supplied to the rough surface of the rotating development electrode so as to be carried by the rotating rough surface into contact with the charge image to be developed.

10 Claims, 2 Drawing Figures

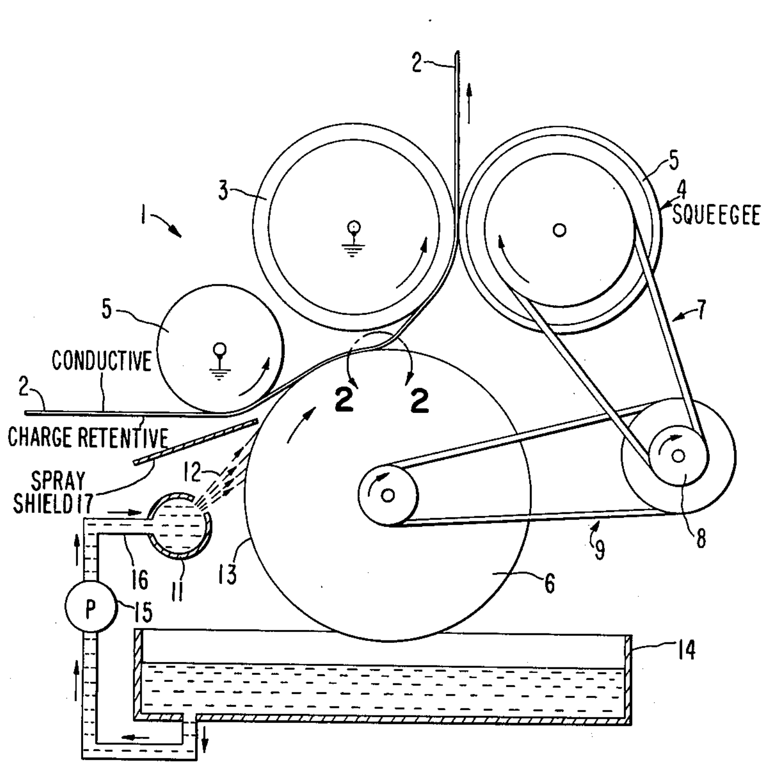
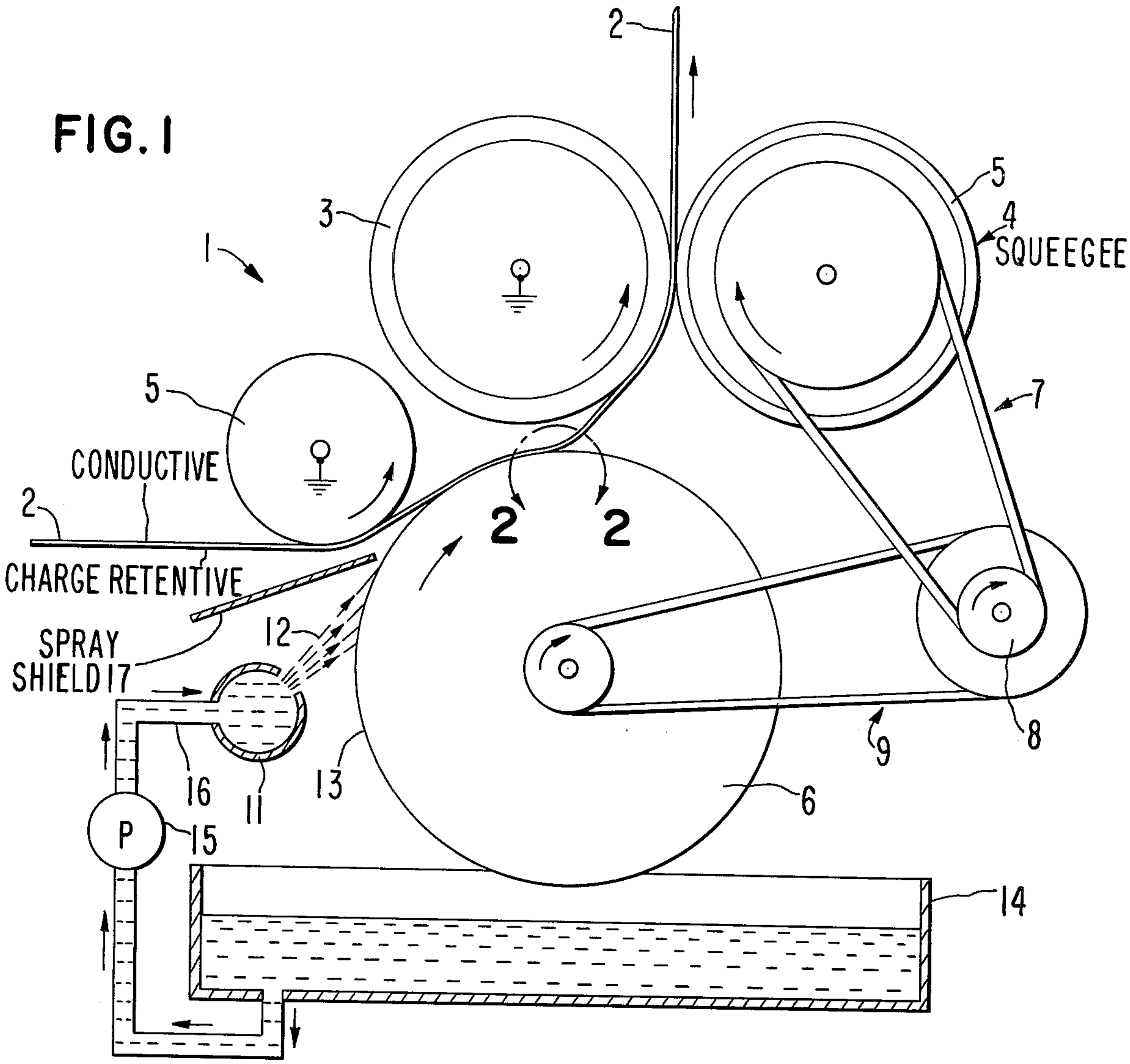


FIG. 1


2
1
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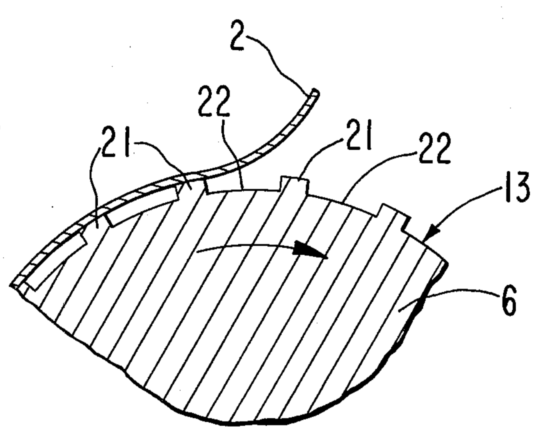
5
4
SQUEEGEE
7
5
CONDUCTIVE
2
2
2
CHARGE RETENTIVE
SPRAY
SHIELD 17
12
8
9
16
11
13
6
P
15
14

FIG. 2


2
22
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6

LIQUID DEVELOPMENT OF ELECTROSTATIC IMAGES

BACKGROUND OF THE INVENTION

The present invention relates in general to liquid development of electrostatic charge images and more particularly to a method and apparatus employing a rotatable development electrode for carrying electrographic toner into contact with the charge images to be developed.

DESCRIPTION OF THE PRIOR ART

Heretofore, electrostatic charge images on the charge retentive surface of the recording web have been developed with liquid electrographic toner. In such systems, the development station included a rotating cylindrical drum-shaped development electrode. The drum-shaped electrode was mounted adjacent the large image bearing surface of the recording medium. The lower portion of the drum dipped into a bath of liquid toner so as to pick up toner on the smooth surface of the drum and carry it into contact with the charge images on the charge retentive surfaces to be developed. The drum was rotated with sufficient angular velocity such that the peripheral speed of the drum exceeded the speed of the web being developed so as to establish a bead of liquid toner between the outer surface of the rotating drum and the charge retentive surface to be developed. Such a development station is disclosed in U.S. Pat. No. 3,367,791 issued Feb. 6, 1968.

While such a development station is suitable for developing images moving at a relatively slow speed it is generally unsatisfactory for developing images on charge retentive surfaces of recording webs traveling at relatively high speeds, such as faster than two inches per second, because the angular and peripheral velocity of the development electrode must be relatively high to provide the necessary amount of toner to the images being developed, particularly when the images include relatively large dark areas which are to be developed with a uniform degree of darkness.

It has also been proposed, in the prior art, to utilize a porous or perforated drum-shaped development electrode with means inside the electrode for forcing electrographic liquid toner through the porous walls of the drum against the charge retentive surface of the recording web to be developed. In one embodiment, the drum was rotated at the same speed as the speed of the recording web being developed. Such a device forms the subject matter of U.S. Pat. No. 3,618,567 issued Nov. 9, 1971 and assigned to the same assignee as the present invention. In another such device, a perforated development electrode drum was rotated at a sufficient angular velocity such that the surface of the drum adjacent the charge retentive surface being developed was approximately up to ten times the speed of the image bearing web being developed. This higher differential speed allowed the drum to disturb the boundary layer of liquid toner which would ordinarily form adjacent the surface of the moving recording web to be developed. This boundary layer interferes with complete development because it soon becomes depleted of the electrographic toning particles. This depleted layer is preferably removed so as to allow fresh electrographic toner to contact the charge image to be developed.

This latter differential speed perforated development electrode forms the subject matter and is claimed in U.S. Patent application 341,658 filed Mar. 15, 1973 as a continuation of the parent application Ser. No. 127,683 filed Mar. 24, 1971 and assigned to the same assignee as the present invention.

While such perforated or porous development electrode drums are capable of developing relatively large areas at relatively high speeds, such as tens of inches per second, they are cumbersome assemblies and are relatively difficult to fabricate and thus are more costly than imperforate drums.

Thus it would be desirable to provide an improved rotatable development electrode which is capable of operating at relatively high web speeds, which is easy to fabricate and assemble, and which does not have to be driven at such high angular velocity as heretofore encountered with smooth imperforate development drums.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved method and apparatus for liquid development of electrostatic charge images.

In one feature of the present invention, the development station includes a cylindrical development electrode having a rough outer surface to be rotated adjacent the charge retentive surface of the recording medium being developed. This rough surface serves to facilitate the carrying of liquid toner to the charge images being developed and to disrupt the boundary layer of liquid toner otherwise tending to form adjacent the charge images to be developed, whereby improved liquid electrographic development is obtained.

In another feature of the present invention, liquid electrographic toner is applied to the rough surface of a cylindrical development electrode by directing a stream of liquid development toner against the outer rough surface of the development electrode. The toner is preferably applied to a region of the rotatable development electrode which is moving toward the charge bearing surface to be developed.

In another feature of the present invention, the outer surface of a cylindrical development electrode includes an array of lands and grooves such lands and grooves being elongated and running transverse to the direction of rotation of the development electrode.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a transverse sectional view of a liquid electrographic development station incorporating features of the present invention, and

FIG. 2 is an enlarged detail view of a portion of the structure of FIG. 1 delineated by line **2—2.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1** there is shown a liquid electrographic development station **1** incorporating features of the present invention. Electrographic recording paper **2** is pulled through the development station **1** by passing through the nip of a pair of rollers **3** and **4.** Roller **4** is a squeegee roller having a compressible layer **5** on the outer surface thereof and such layer being compressed against the other roller 3, as of stainless steel, to provide a frictional drive for the paper web 2 sandwiched between the two rollers 3 and 4. The squeegee roller 4 is driven in the clockwise direction via any one of a number of conventional drive means, such as a gear train or V-belt, not shown.

The electrographic recording paper 2 is threaded between an idler roller 5, as of stainless steel, and a development electrode roller 6, as of aluminum. Rollers 3 and 5 are positioned relative to the development roller 6 so as to cause the electrographic recording web 2 to be pressed into nominal engagement with a portion of the surface of the development electrode 6. A V-belt power take off of the squeegee roller 4 is passed over an idler pulley 8 which in-turn drives the development roller 6 via a second V-belt drive 9. The pulley ratios are chosen so that the peripheral speed of the development electrode 6 is within the range of 2 to 5 times the speed of the electrographic recording web 2 which is to be developed. Any one of a number of drive means, such as gear trains, etc., may be employed as an alternative to the V-belt drives 7 and 9.

Liquid electrographic toner is applied to the development drum via a spray pipe 11 which directs a stream 12 of liquid toner against the outer cylindrical surface 13 of the development electrode 6 in a region where the direction of movement of the development electrode 6 is toward the electrographic web 2 to be developed. The liquid electrographic toner comprises a dielectric liquid vehicle having a suspension of charged pigmented toner particles therein. The toner is drawn from a reservoir 14 and supplied to the spray pipe 11 via a pump 15 and conduit 16. A spray shield 17 is interposed between the spray pipe 11 and the electrographic web 2 to prevent unwanted spraying of the electrographic toner directly onto the web 2.

The electrographic recording web 2 includes a conductive paper backing having a dielectric insulative layer coated thereon to form a charge retentive surface. Charge images to be developed are deposited upon the charge retentive surface and carried by the web 2 into the development station 1. The charge retentive layer is disposed facing the development drum 6. Rollers 3 and 5 make electrical contact to the conductive side of the web and the development electrode drum 6 may be operated at a floating potential relative to the potentials applied to rollers 3 and 5 or the development drum 6 may be operated at a suitable development potential relative to the potentials applied to rollers 3 and 5.

Referring now to FIG. 2 there is shown the surface detail of the development electrode drum 6. The outer surface 13 of the drum 6 is rough, and in a preferred embodiment comprises an array of relatively thin longitudinally directed lands 21 separated by wider groove portions 22. In a typical example, the lands 21 have a height of approximately 0.050 inch relative to the bottom of the groove portions 22. In operation, the land portions 21 serve as wipers for wiping the depleted boundary layer of toner from the charge retentive surface of the recording web 2. The groove regions 22 between adjacent lands 21 serve to carry fresh toner into contact with the charge images to be developed on the recording web 2.

In addition, the bottom surface of the grooves 22 serves the function of the development electrode, namely, to provide a conductive surface operating at a different potential than that of the charge images to be developed so that the field lines will extend between the charge images and the adjacent surface of the development electrode 6. In this manner the electric fields in the electrographic toner region between the development electrode 6 and the charge retentive surface are relatively high to expedite transfer of toner particles from the electrographic toner liquid to the charge images to be developed. In a preferred embodiment, the groove portions 22 are within 0.100 inch or less of the charge image being developed. The land regions 21 should be relatively narrow relative to the groove region 22 so that nominal contact is established between the upper surfaces of the lands 22 and the charge retentive surface so as to efficiently disrupt the boundary layer of depleted toner adjacent the web 2.

In addition, the lands 21 should have a slight pitch relative to the axis of revolution of the development electrode 6 so that the paper web 2, particularly in the case of a fan-fold electrographic web, does not get caught and torn by the more rapidly moving peripheral surface of the development electrode 6. The spiral pitch of the lands is sufficient if the pitch has advanced by one angular land period over the length of the development electrode 6. Furthermore, the surface 13 of the development electrode should be free of surface detail which is invariant in the direction of rotation of the development electrode to prevent streaking and patterning of the developed image.

As an alternative to a surface roughness detail consisting of lands and grooves, the surface of the development electrode may be roughened by sand blasting, photoetching, or knurling. Generally speaking, the rough surface 13 should have surface detail thereon having mean peak-to-peak amplitude variations of between 0.005 and 0.100 inch. In each case the rough surface can be conceived of as comprising a plurality of discrete projecting surface portions (i.e., "high points") mutually separated from one another by a plurality of recessive surface portions (i.e. "low points").

In an alternative embodiment of the present invention, the development electrode drive can be arranged for driving the development electrode in a direction counter to the direction of movement of the electrographic web 2. In such an embodiment, the V-belt take off drive 7 is moved to the back up roller 3 so as to drive the development electrode 6 in the counterclockwise direction. In this latter embodiment, the spray pipe 12 is preferably moved to a region adjacent the first quadrant of the development electrode so that the electrographic toner is sprayed onto the roughened surface of the surface 13 of the drum in a region moving toward the charge retentive surface to be developed.

Although the surface roughening feature of the development electrode is, in a preferred embodiment, applied to an imperforate development electrode drum 6 this is not a requirement. It may be also used to advantage with perforated or porous development electrode drums wherein the electrographic toner is pumped through the perforated wall of the development drum into contact with the charge retentive surface of the recording medium to be developed. In the case of the perforated development electrode drum, the lands function in the same manner as previously described with regard to the embodiment of FIG. 1 wherein the lands 21 serve to disrupt the boundary layer of depleted toner adjacent the charge retentive surface of the recording web 2.

The differential speed between the speed of the recording web **2** and that of the periphery of the development electrode **6** is preferably at least twice the speed of the web **2**.

An advantage of the spray method of supplying liquid toner to the development electrode, as contrasted with the method of dipping the lower part of the rotating drum in liquid toner, is that the spray tends to scrub away depleted toner from the surface of the drum due to its turbulent impact with the drum.

What is claimed is:

1. In an apparatus for developing electrostatic images on a charge retentive surface:

development electrode means having a rough cylindrical surface comprising a plurality of discrete projecting surface portions, separated from one another by a plurality of recessive surface portions;

means for mounting said development electrode means for rotation about its axis of revolution;

means for passing the charge retentive surface of a recording medium, for bearing latent charge images thereon to be developed, adjacent said rough surface of said development electrode and contiguous with said projecting surface portions thereof;

means for rotating said development electrode means with an angular velocity such that said rough surface of said development electrode moves at a different speed than that of the adjacent charge retentive surface to be developed; and

means for supplying liquid electrographic development toner, having electroscopic toner particles suspended in a dielectric liquid, to the rough surface of said development electrode so that the toner liquid is carried into contact with the charge images on the charge retentive surface to be developed for developing same, said liquid toner being carried within said recessive surface portions, said projecting surface portions serving to wipe liquid toner from said charge retentive surface, whereby said charge-retentive surface undergoes a plurality of successive development operations, each of said operations being followed by a wiping operation.

2. The apparatus of claim **1** wherein said means for supplying liquid toner to said rough surface of said de-

velopment electrode comprises, means for directing a stream of liquid toner onto the outer rotating rough surface of said development electrode.

3. The apparatus of claim **2** wherein said toner supplying means is disposed for directing the stream of liquid toner onto the rotating surface of said development electrode in a region thereof which is moving toward the charge image bearing surface to be developed.

4. The apparatus of claim **1** wherein said rough surface of said development electrode is made of an electrically conductive material, and wherein said means for passing the charge retentive surface to be developed adjacent said rough surface of said development electrode includes means for passing said charge retentive surface within 0.100 inch of the recessive surface portions of said development electrode.

5. The apparatus of claim **1** wherein said rough surface of said development electrode comprises an array of elongated land regions separated by elongated groove regions, said land and groove regions being elongated in a direction transverse to the direction of rotation of said development electrode.

6. The apparatus of claim **5** wherein said array of land and groove regions spiral about the axis of revolution of said development electrode.

7. The apparatus of claim **5** wherein said groove regions are wider than the intervening land regions.

8. The apparatus of claim **1** wherein said rough surface of said development electrode is free of surface detail which is invariant in the direction of rotation of said development electrode to prevent streaking of the developed image.

9. The apparatus of claim **1** wherein said rough surface of said development electrode is essentially imperforate so that essentially all the liquid toner supplied to the charge retentive surface to be developed by said development electrode is carried thereto by the outside rough surface of said development electrode.

10. The apparatus of claim **1** wherein said rough surface of said development electrode has surface detail thereon having mean peak-to-peak amplitude variations of between 0.005 and 0.100 inch.

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