

United States Patent

Borelli et al.

[15] 3,701,337

[45] Oct. 31, 1972

[54] PRINTING APPARATUS

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[22] Filed: **Dec. 29, 1969**

[21] Appl. No.: **888,769**

[52] U.S. Cl. **118/637**, 101/DIG. 13, 117/37 LE, 118/DIG. 23

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

[58] Field of Search.....118/637, 637 LX, DIG. 23; 117/37 LX; 101/DIG. 13

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Primary Examiner—Mervin Stein

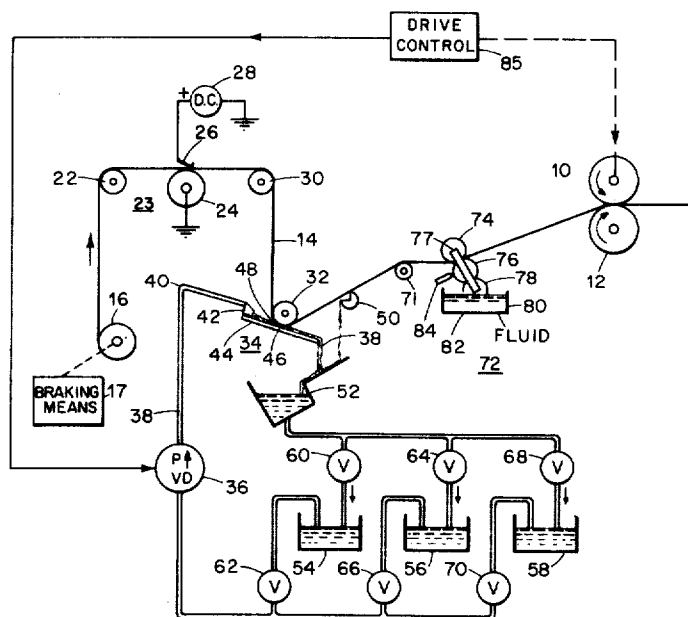
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[57] ABSTRACT

A recording medium is printed upon by exciting it, developing the medium in a toning liquid, and drying it. The toning liquid is applied by passing the medium longitudinally around an arc and pumping the toning liquid to flow so that its surface touches the medium on only one face. The latter preferably is substantially liquid impenetrable.

14 Claims, 4 Drawing Figures



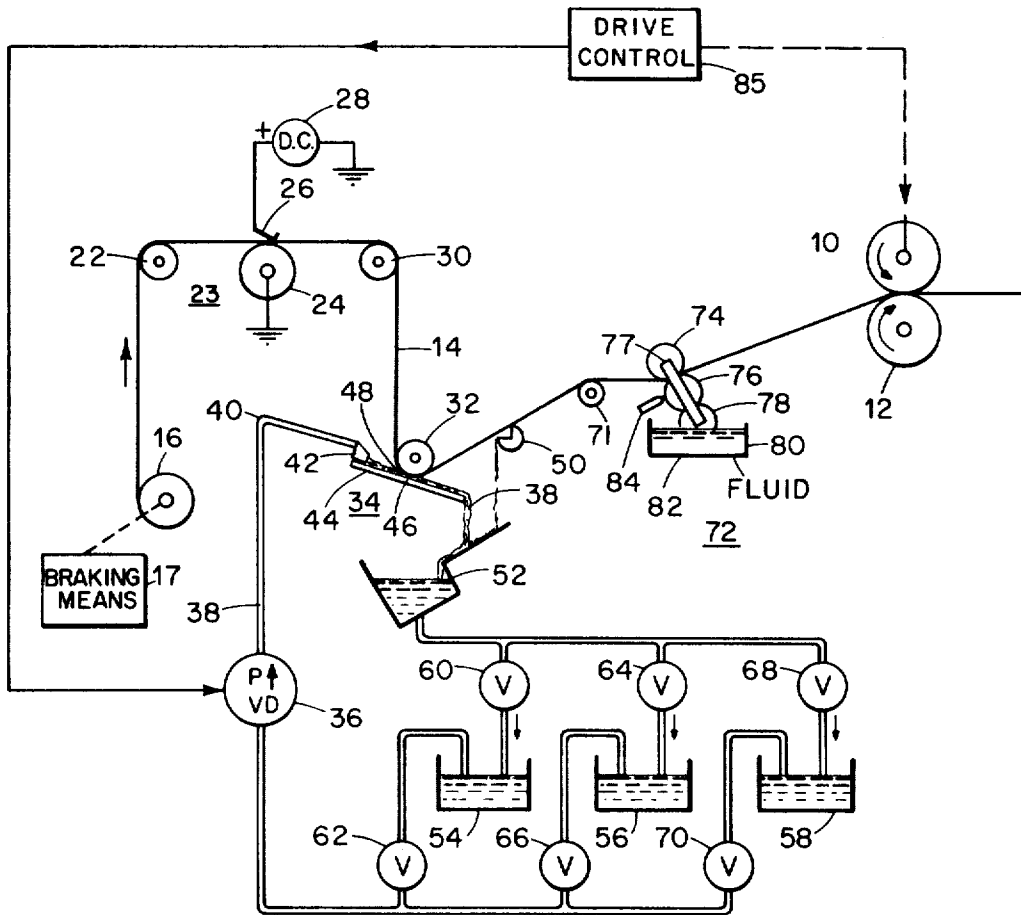


Fig. 1.

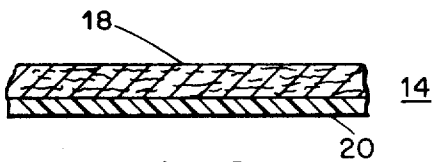


Fig. 2.

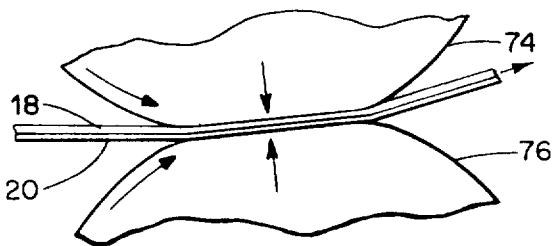


Fig. 4.

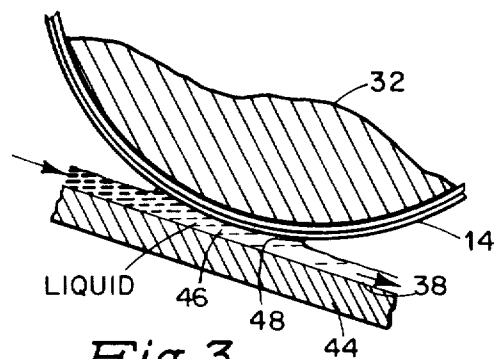


Fig. 3.

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PRINTING APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to methods and means for printing upon a recording medium and particularly to methods and means for printing permanent images electrographically upon a paper medium at high speeds.

Such high speed printing is desirable in environments such as a computer print-out. Generally electrographic printing, is accomplished upon an electrographic paper medium composed of a conductively treated paper base that supports a plastic dielectric coating. The paper medium is positioned between an electrode that contacts the conductive base and a and a second electrode whose surface conforms to the shapes to be printed. A high voltage applied between the two electrodes excites the paper medium and establishes an electrostatic field across the dielectric coating. The coating retains a residual electrostatic field that constitutes a charged latent image of the shapes to be printed.

The latent image is developed by subjecting the paper medium to a toning liquid composed of charged resin particles which are softened by a liquid carrier. The residual electrostatic field at the dielectric surface attracts these particles and holds them. This makes the image visible. The image is then fixed, i.e., made permanent, by drying to removing the liquid carrier. This solidifies the particles and bonds them to the paper. Such drying may be done by heating.

The toning liquid used to develop the latent image consist of these charged toning particles and the solvent liquid carrier. Normally, in the process, large amounts of this carrier liquid are left on and in the paper medium. This liquid is volatile and when the paper is dried for fixing the developed image large amounts of fumes are expelled into the local environment. Large amounts of such fumes are unpleasant and possibly harmful. Attempts to reduce these fumes to acceptable levels by reducing the amount of liquid carrier used to hold the particles have not met with success. Poor images resulted. Moreover, large amounts of liquid require long time periods to vaporize. These place a limit on the printing speed. Where high speed is essential, such as in the read out of a computer, such printing systems have been inadequate.

SUMMARY OF THE INVENTION

The invention obviates these deficiencies. According to a feature of the invention only one face of the medium, preferably the dielectric face, is covered with toning liquid. According to another feature this is done by guiding the medium through a longitudinally curved path, and into a controlled flow of toning liquid that encounters only one face of the medium. Preferably the flow is formed by liquid moving means that discharge a continuous downward laminar flow of the liquid over an inclined surface near the path. Drying means then need eliminate only this liquid. Since only a plastic dielectric face need be wetted by the liquid and liquid is not absorbed by a paper base the amount of volatile fumes are created by drying are substantially reduced.

According to another feature of the invention the flow is tangential to the curved path.

According to another feature of the invention the inclined surface forms a gap with the guide means at the curved path. The size of the gap is sufficiently small so that when the medium moves through the gap, and the liquid flows through the gap, the liquid forms a continuous meniscus over the portion of the curved path closest to the inclined surface.

According to another feature of the invention, control means control the flow of toning liquid over the inclined surface. Preferably, these control means respond to driving means that transport the recording medium.

According to yet another feature of the invention, valve means control the flow of the liquid from one of several reservoirs carrying different colors of the liquid so as to pass one color of liquid over the inclined surface.

According to still another feature of the invention the guide means include a roller extending transversely to the longitudinal direction of the movement of the medium and the driving means apply a longitudinal force on the medium so that there exist a continuous normal force over the arc against the roller. The normal force assures uniform distribution of the flowing liquid. It also prevents any liquid from entering the side of the medium contacting the roller.

According to still another feature of the invention, the gap is sufficiently small so the carrier medium contacts the liquid, but sufficiently large to keep the liquid in contact with only one side of the medium.

According to another feature the guide means and inclined surface are made of conductive materials. These align the residual electrostatic field lines, that form the image on the medium. Preferably, the gap is small enough to make these lines perpendicular to the opposing faces of the guide means and the surface.

According to still another feature of the invention, the liquid moving means include nozzle means for spreading the liquid over the inclined surface to distribute it so as to encounter the entire transverse dimension of the medium at the meniscus in the gap.

According to still another feature of the invention, the gap size is such and the flow such that the moving medium shears a portion of the liquid off the meniscus and the flow replaces the portion to retain the meniscus. Preferably, the flow and movement of the medium are in the same direction.

These and other features of the invention are pointed out in the claims. Other objects and advantages of the invention will become obvious from the following detailed description when read in light of the following drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a printing system embodying features of the invention;

FIG. 2 is a cross-sectional view of the recording medium in FIG. 1;

FIG. 3 is a sectional view of the medium passing through the meniscus in FIG. 1; and

FIG. 4 is a cross-sectional view of the medium passing through the drying rolls of FIG. 1.

DESCRIPTION OF PREFERRED EMBODIMENT

In FIG. 1, a pair of peripherally engaging elastomeric capstan rolls 10 and 12 rotating as shown pinch a web of electrographic paper 14 and draw it from a supply roll 16 upon which the paper is wound. A cross section of the paper 14 appears in FIG. 2. The paper is composed of a conductively treated paper-fibrous base 18 which supports a plastic dielectric coating 20. The paper is rolled on the roll 16 so as to place the coating 20 on the inside. The paper 14 constitutes the recording medium. It is referred to as paper although only a portion is composed of paper fibers. The base 18 may for example be .003 inch thick and the coating .0005 inch thick.

Braking means 17 places the paper 14 under longitudinal tension as the capstan rolls 10 and 12 pull it. This keeps the paper taut. The bearings in roll 16 may exhibit sufficient friction to constitute the braking means 17.

The paper 14 leaving the supply roll 16 passes over an idler roll 22 with the dielectric coating 20 contacting the roll. An excitation station 23 then excites the paper 14. In the excitation station 23 the paper 14 passes between the peripheral surface of an idling image roll 24 which contacts the coating 20 and an electrode 26 which is biased to frictionally contact the conductive base 18. The periphery of the roll 24 maybe etched so as to project outwardly to form the pattern of writing which is to be printed on the paper. It may also be composed of variable projecting types that are controlled by a computer to produce a computer print-out. Essentially the writing makes the image roll 24 a print roll.

A 700 volt direct current source 28 applies an excitation voltage between the electrode 26 and the image roll 24 which is grounded. This forms an electrostatic field across the coating 20 at those portions of the periphery on the roll 24 that project and contact the layer 20 and the conductive base 18. The image roll 24 rotates as the paper 14 passes between it and the electrode 26. The roll 24 and the electrode 26 are slightly less wide than the width of the paper 14. The coating 20 retains across it a residual electrostatic field corresponding to the exciting field and the image on the periphery of the image roll 24. This constitutes a latent image.

The paper 14 emerging from between the roll 24 and electrode 26 passes over an exit idler roll 30 and around a steel toning roll 32 of a developing or toning station 34. The roll 32 guides the paper and is preferably as narrow or slightly narrower than the paper. The plastic coating 20 of the paper 14 faces outwardly of the toning roll 32. Since the capstan rolls 10 and 12 draw the paper 14 against the restraining force at the supply roll 16, the longitudinal forces on the paper produce radial forces directed inwardly to the axis of the roll 32. This assures substantially firm contact between the roll 32 and the base 18 of the paper 14.

During this process the dielectric coating 20 of the paper 14 continues to retain across its thickness the latent electrostatic field that constitutes the latent image of the projections on the periphery of the image roll 24. In order to develop this latent image, a pump 36 drives a toning liquid. The latter comprises a high resistance carrier such as kerosene, which has a re-

sistance of 10^{16} ohms per cubic centimeter, and a suspension of charged colored thermoplastic resin particles which form the printing material. The pump 36 drives this fluid 38 through a flexible pipe 40 to a fan nozzle 42. The latter spreads the fluid laterally over a flat steel inclined plate 44 to form a shallow laminar liquid flow. The plate is as narrow or narrower than the width of the paper. The plate 44 is spaced from the freely turning toning roll 32 so as to form a gap 46 between the coating 20 and the plate 44 of from .005 to .020 inch. When the liquid 38 flows through the gap 46, it contacts the coating 20 and forms a meniscus 48. The meniscus appears more particularly in FIG. 3 which shows an enlarged cross section of the roll 32, the paper 14, the plate 44, the meniscus 48 and the liquid 38 in FIG. 1.

As stated the toning liquid 38 flows by gravity to the toning area where it contacts the paper 14 due to the closeness of the roller 32 and the flat plate 44. As the liquid 38 contacts the paper 14, the meniscus 48 is formed at the coating 20. The meniscus is formed and kept intact by the forces of adhesion between the molecules of the flowing liquid 38 and the coating 20 of the paper 14. It extends transversely across the roll 32 and clings peripherally from one side of the gap, at its narrowest portion, to the other. The gap 46 is sufficiently small to form such a meniscus but large enough to allow some passage of toning liquid 38.

The thermoplastic resin particles suspended in the kerosene of the liquid 38 are charged and adhere to the portions of the surface 20 which are oppositely charged. This makes the image visible. As the paper 14 is drawn away from the capstan rolls 10 and 12 it shears off the top portion of the meniscus 48 and retains a portion of the liquid and the thermoplastic resin particles. The flow that supports the meniscus is maintained by the constant pumping action of the pump 36. The flow is adjusted so the paper 14 just contacts or "kisses" the liquid. This helps assure even distribution of the liquid and a distribution of the particles that depends almost exclusively on the electrostatic field. A uniformly developed image results.

The particles continue to adhere to the now wet surface of the coating 20. A wiper 50 in the shape of a longitudinally notched rod removes some of the liquid 38 on the dielectric coating. The remaining liquid 38 flowing out of the meniscus 48 is caught in a trough 52 and fed back to a selected one of three reservoirs 54, 56 and 58 containing toner liquid of different colors.

The liquid 38 in each reservoir 54, 56 and 58 has suspended therein thermoplastic resin particles of different colors so as to print in different colors. Six pairs of electrically actuated flow valves 60, 62, 64, 66, 68, and 70 select which of the fluids 38 are drawn by the pump 36 from their respective reservoirs. The valves 60-70 are arranged so that two pairs are closed and one pair open to fluid flow.

The tightness of the paper about the roll 32 helps assure uniform distribution of liquid over the coating 20. It also keeps liquid 38 from the meniscus 48 from entering between the roll 32 and base 18 of the paper 14. Such entry would cause the base to absorb a good deal of the liquid and make drying difficult. The particles in the liquid on the coating are concentrated in those areas carrying the electrostatic field.

The steel roll 32 and the steel plate 44 are in close proximity across the gap. In the vicinity of the gap they thus tend to align the residual electrostatic field across the dielectric 20 to be substantially perpendicular to the dielectric. Such alignment prevents fringing. It assures a sharp visible image. It prevents fuzziness that fringing may introduce. The smaller the gap the sharper the image.

An idler roll 70 directs the paper into a drying apparatus 71 where the image is fixed. In this drying apparatus the paper passes between an elastomeric back-up roll 74 that contacts the base of the paper 14 and a second elastomeric absorption roll 76 that contacts the wet toner-carrying coating 20 of the paper 14. Both of the rolls idle and move with paper 14. Mountings 77 that support rolls 74 and 76 bias the rolls to apply pressure against the paper 14.

As the paper passes through the rolls 74 and 76 compress not only the paper but a portion of the peripheral surface of the elastomeric material. The elastomeric material of the absorption roll 76 is such as to be absorbent of the liquid 38. As the roll 76 has its periphery compressed near the engagement point with the roll 74, any air in the absorptive surface or any other fluid in the absorptive surface is squeezed out. As the paper passes through and emerges between the pinch of the rolls, the portion of the roll 76 that has been compressed begins to expand and absorb the kerosene carrier in the liquid 38 on the surface of the coating 20 of the paper 14. Those particles which are attracted by their electrophoretic condition to the charged portions of the coating 20 remain on and in the crevices of the coating 20.

The concentration of charged particles near the charged portions of the coating 20 develops the printing to create the visible image. The removal of the surrounding liquid 38 produces printing upon the paper 14 and fixes the paper. However, the concentration when squeezed may also transfer a portion of the image onto the roll 76. This may then be transferred to a successive portion of the moving paper. To prevent this, a rotating cleaning brush 78 that dips into a cleaning fluid 80 of a trough 82 applies the cleaning fluid to the surface of the elastomer roller 76. This removes any image.

A scraper 84 compresses the surface of the roll 76 after its contact with the brush 78. The scraper 84 squeezes the surface of the elastomeric roll between itself and the axis of the roll. This squeezes out any toning liquid or cleaning fluid that may exist in the absorptive pores of the roll 76. At the same time it scrapes the toning liquid and cleaning fluid that was on the surface of the roll and that which was squeezed out of the roll. This substantially dries the paper 14. The paper then passes between the capstan rolls 10 and 12 and out to a utilizing station. The scraper avoids the effect of a squeeze roller which would, as it turns, reapply the liquid squeezed out.

A drive control 85 that senses the speed of the capstan rolls 10 controls the flow of the pump 36 so that more or less fluid 38 can pass out the nozzle 42 in dependence upon the speed of the paper 14. In that manner, if the paper speed 14 at the gap 46 is so fast as to shear off large amounts of liquid in the meniscus 48 in a short period of time, sufficient fluid is provided to replace the liquid in the meniscus. This permits a varia-

ble speed printer that can achieve high speeds. The high speeds are rendered possible because large amounts of liquid can be concentrated along a thin line across the moving paper. The line can be constantly replenished.

By virtue of the invention a controlled amount of toning liquid 38 is supplied to only one surface of the paper 14 at any one time. The amount of liquid applied can be controlled by controlling the flow down the plate 44 on the basis of the speed with which the paper moves and shears off the liquid. Moreover, because the roll 32 is round and because the capstan rolls 10 and 12 and the braking means 17 place a longitudinal force on the carrier, a normal force exist throughout the arc over which the paper contacts the guide roll 32. This force causes the paper to hug the guide roll 32 across the arc. Thus, even distribution of liquid is encouraged. Also, liquid is discouraged from entering the portion between the toning roll 32 and the dielectric 20 and wetting the fibrous base 18 of the paper 14. This limits the absorption of liquid. It prevents needless vapors.

The steel roll 32 and plate 44 separated by a narrow gap 46 assure a sharp developed image by aligning the electrostatic field lines perpendicularly to the surface of dielectric 20 at the gap 46.

It should be noted that the thickness of the paper 14 is somewhat exaggerated for clarity throughout the drawings.

The diameter of the roll 32 is between ½ inch and 3 inches and preferably 1 inch. Other sizes may of course be used.

While an embodiment of the invention has been described in detail it will be obvious to those skilled in the art that the invention may be otherwise embodied within its spirit and scope.

What is claimed is:

1. Apparatus for printing on a flat flexible recording medium having opposing faces, comprising:

- A. driving means for moving the medium along a given path;
- B. excitation means in the path of the recording medium for exciting the medium according to the image to be printed;
- C. developing means in the path of the recording medium for applying a toning liquid to one face of the excited recording medium; and
- D. fixing means in the path of the recording medium after said developing means for fixing the image and removing excess liquid from the recording medium;
- E. said developing means including:

- a. guide means for longitudinally guiding the moving recording medium along a continuously curved course such that the medium intersects the moving liquid at only one of its surfaces, and
- b. flow producing means for forming a laminar flow of toning liquid having a substantially flat surface, said flow producing means including liquid slide means for forming an inclined upper surface spaced from said guide means so as to form a gap between the curved course and the slide means, and liquid moving means including a flat nozzle means for spreading the liquid over the surface of the slide means so as to make the liquid flow gravitationally through the gap, the

size of the gap being sufficiently small so that when the recording medium is moved through the gap the liquid forms a continuous meniscus at the medium gap, the liquid encountering a continuous band across the medium at the meniscus.

2. An apparatus as in claim 1 wherein

A. said flow producing means includes control means for controlling the flow of toning liquid.

3. An apparatus as in claim 1 wherein

A. said flow producing means includes control means responsive to said driving means for controlling the flow of liquid over said surface.

4. An apparatus as in claim 1 wherein

A. said liquid moving means includes a plurality of reservoirs of liquid of different colors and means for controlling the flow of said liquids so as to selectively pass one color of liquid over said slide means.

5. An apparatus as in claim 1 wherein

A. said driving means move the medium longitudinally;

B. said guide means include a roller extending transversely to the longitudinal direction of the movement of the flexible recording medium and cooperating with said drive means to hold said recording medium taut over an arc of said roller and thereby to apply a normal force continuously over said arc with said recording medium.

6. An apparatus as in claim 1 wherein

A. said driving means include a capstan for driving said recording medium in a continuous longitudinal path through said excitation means, said developing means and said drying means, and

B. said driving means further include braking means for restraining movement of the recording medium so as to hold it taut.

7. An apparatus as in claim 4 wherein

A. said driving means move said recording medium along a continuous longitudinal path through said sensitizing means, said developing means, and said drying means and so the recording medium extends simultaneously through said sensitizing means, said developing means and said drying means.

8. An apparatus as in claim 1 wherein

A. the gap between said guide means and said slide means is sufficiently small so the recording medium contacts the liquid and wherein

B. said gap is sufficiently large so as to keep the liquid in contact with only one side of the recording medium.

9. An apparatus as in claim 1 wherein

A. trough means for collecting liquid passing down said slide means,

B. reservoir means for receiving liquid from said trough means, and

C. pump means for pumping the liquid to the upper surface of said slide means;

D. whereby said liquid flows down said slide means.

10. Apparatus for printing on a flat flexible recording medium having opposing faces comprising;

A. driving means for moving the medium along a given path;

B. excitation means in the path of the recording medium for exciting the medium according to the image to be printed;

C. developing means in the path of the recording medium for applying a toning liquid to one face of the excited recording medium;

D. fixing means in the path of the recording medium after said developing means for fixing the image and removing excess liquid from the recording medium;

E. said developing means including:

a. flow producing means for forming a laminar flow of toning liquid having a substantially flat surface, and

b. guide means for longitudinally guiding the moving recording medium along a continuously curved course that intersects the moving liquid at only one of its surfaces; and

F. said liquid removing means including

a. first and second engaging means for engaging opposite faces of the recording medium between them,

b. at least one of said engaging means having an externally curved surface so as to permit rolling engagement between said engagement means when the recording medium is moved between them,

c. said first engaging means having a compressible porous absorbent surface and said second engaging means having a surface,

d. pressure means for pressing the moving recording medium between said engagement means so that as said recording medium advances longitudinally said engagement means squeeze continuously successive portions of the recording medium and the absorbent surface and then release the recording medium and the absorbent surface so that said absorbent surface absorbs liquid on said recording medium,

e. and compression means for compressing the previously squeezed portion of the absorbent surface and scraping it so as to remove the liquid therefrom and scrape it away.

11. An apparatus as in claim 10 wherein

said engagement means each include rotatable roll means adapted to engage opposite faces of the same portion of the recording medium and squeeze the recording medium between them.

12. Apparatus for printing on a flat flexible recording medium having opposing faces comprising;

A. driving means for moving the medium along a given path;

B. excitation means in the path of the recording medium for exciting the medium according to the image to be printed;

C. developing means in the path of the recording medium for applying a toning liquid to one face of the excited recording medium;

D. fixing means in the path of the recording medium after said developing means for fixing the image and removing excess liquid from the recording medium;

E. said developing means including

a. flow producing means for forming a laminar flow of toning liquid having a substantially flat surface; and

- b. guide means for longitudinally guiding the moving recording medium along a continuously curved course that intersects the moving liquid at only one of its surfaces; and
- F. said fixing means including a pair of elastomeric rolls having absorptive surfaces for removing excess liquid;
- G. said recording medium passing between said rolls, means for electrostatically squeezing said rolls so as to squeeze the recording medium between them;
- H. and scraping means for compressing the surface of one of said rolls and scraping away the liquid at said roll.
13. Apparatus for printing on a flat flexible recording medium having opposing faces comprising
- A. driving means for moving the medium along a given path;
- B. excitation means in the path of the recording medium for electrostatically exciting the medium according to the image to be printed;
- C. developing means in the path of the recording medium for applying a toning liquid to one face of the excited recording medium;
- D. fixing means in the path of the recording medium after said developing means for fixing the image and removing excess liquid from the recording medium;
- E. said developing means including
- a. flow producing means for forming a laminar flow of toning liquid having a substantially flat surface, and
- b. guide means for longitudinally guiding the moving recording medium along a continuously curved course that intersects the moving liquid at only one of its surfaces; and
- F. said flow producing means including
- a. liquid slide means for forming an inclined upper surface spaced from said guide means so as to form a gap between the curved path and the surface of said slide means, and
- b. liquid moving means for passing the toning liquid over the surface of said slide means so as to make the liquid flow gravitationally through the gap,
- c. the size of said gap being sufficiently small so that when the recording medium is moved through the gap and the liquid flows through the gap the liquid forms a continuous meniscus at the medium in the gap;
- G. said guide means including a conductive roller ex-

- tending axially across the longitudinal direction of movement of the medium; and
- H. said liquid slide means being conductive and spaced from said roller closely enough to align the electrostatic field lines of the excited medium perpendicularly to the medium.
14. An apparatus for printing
- A. a continuous sheet of flexible recording medium composed of a conductively treated fiber base and a single dielectric coating;
- B. driving means for drawing the continuous flexible recording medium and keeping it taut;
- C. electrical excitation means for applying an electrostatic field across the coating in the form of the image to be printed;
- D. developing means for applying a toning liquid having charged particles to the coating on said recording medium;
- E. drying means for removing excess liquid from the recording medium and allowing the charged particles to remain at the electrostatically charged portions of the recording medium;
- F. said developing means including
- a. a roll in the path of said recording medium and co-operating with said driving means to apply a normal force against the base of said recording medium and about an arc of said roll;
- b. liquid slide means forming an inclined plane parallel to the axis of said roll, said axis being transverse to the direction of said movement of the recording medium;
- c. pump means for pumping liquid to the top of said slide means;
- d. nozzle means at the top of said slide means for directing said liquid over a wide path of the surface of said slide means;
- e. said slide means being spaced from said roll so that said liquid encounters the coating of said recording medium as the recording medium moves around said roll and forms a meniscus at said roll;
- f. trough means for collecting the liquid flowing from said slide means;
- g. a plurality of reservoirs holding a plurality of colors of toning liquid; and
- h. valve means connecting said trough means to said reservoirs and said reservoirs to said pump means so as selectively to select one of the reservoirs into the said pump means whereby one of several colors of toning liquid may be used for toning said recording medium.

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