# United States Patent [19]

**Egnaczak**

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[54] **MULTIPLE EXPOSURE METHOD AND APPARATUS**


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[73] Assignee: **Xerox Corporation,** Stamford, Conn.



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**Related U.S. Application Data**

[62] Division of Ser. No. 104,333, Jan. 6, 1971, Pat. No. 3,719,484.

[52] **U.S. Cl.** ..... **355/4**

[51] **Int. Cl.** ..... **G03g 13/10**

[58] **Field of Search** ..... 355/4; 96/1, 1.2, 1.3



[56] **References Cited**

UNITED STATES PATENTS

3,703,335 11/1972 Hoffman ..... 355/4



*Primary Examiner*—John M. Horan

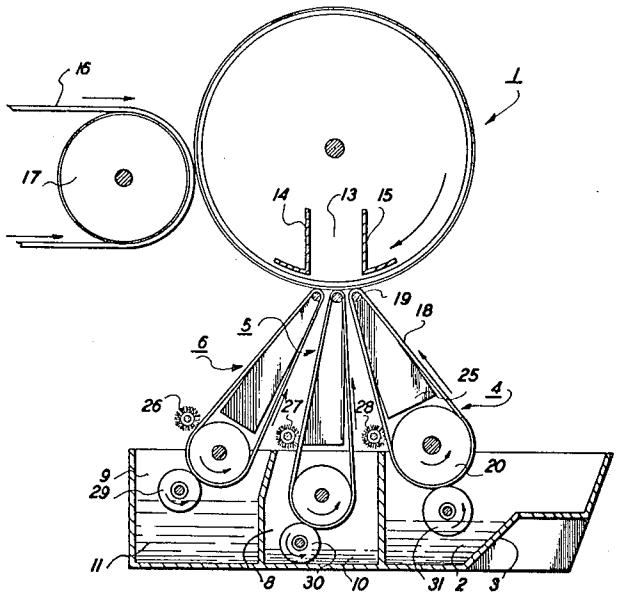
*Attorney, Agent, or Firm*—James J. Ralabate; David C. Petre; Charles E. Smith



[57] **ABSTRACT**

A photoelectrophoretic ink is subjected to light and electric field a plurality of times during a single scanning pass over the ink by a plurality of web electrodes positioned within the boundaries of a narrow slit scanning light image.


**7 Claims, 4 Drawing Figures**



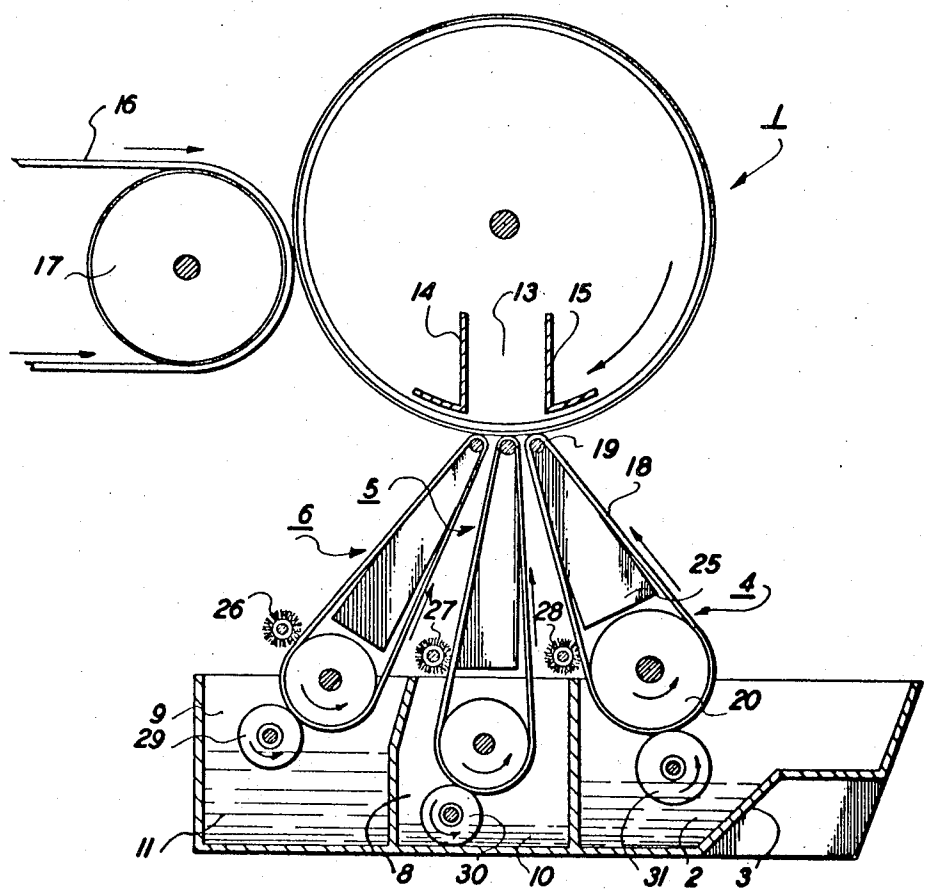

16
17
1
14
13
15
19
18
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9
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11
8
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10
31
2
3

FIG. 1

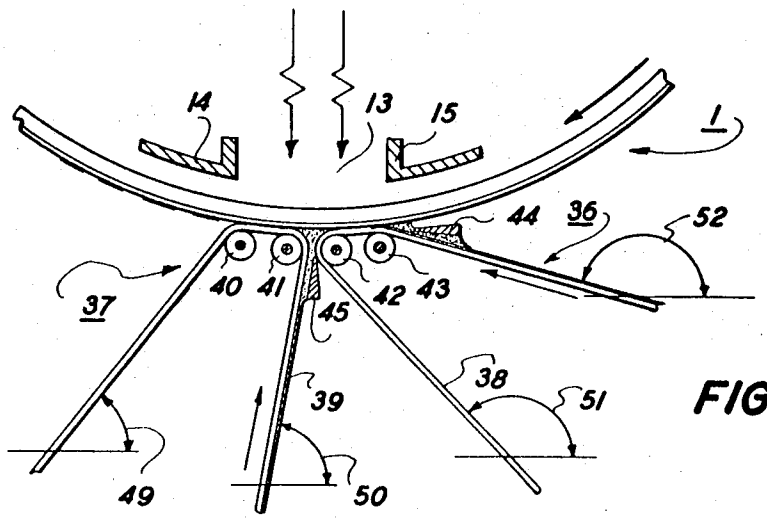

14
13
15
1
44
36
52
37
40
41
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43
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38
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39
49
50

FIG. 2

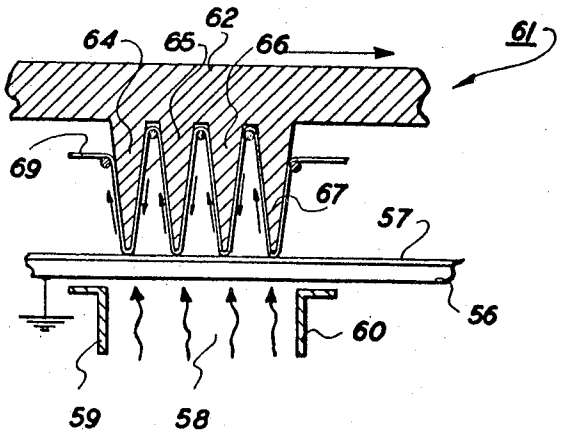



FIG. 3

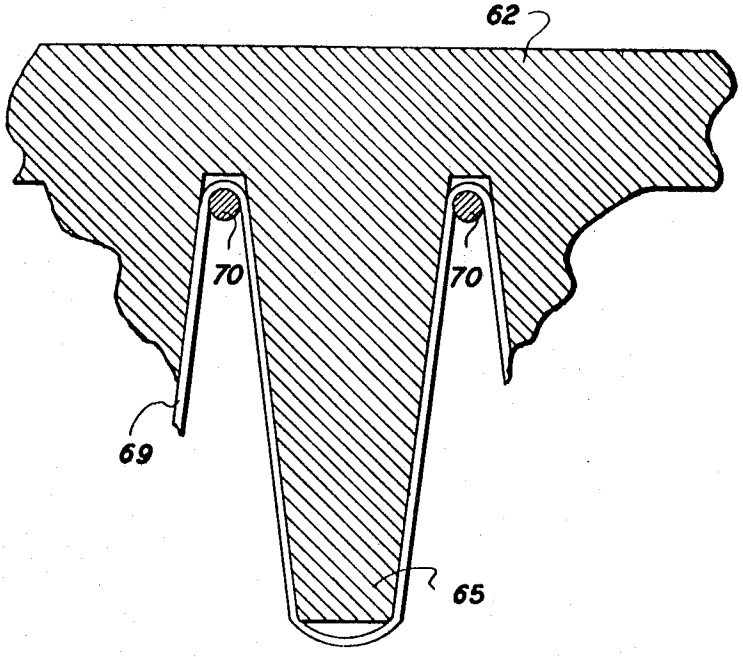



FIG. 4

# MULTIPLE EXPOSURE METHOD AND APPARATUS

This is a division of application Ser. No. 104,333, filed Jan. 6, 1971, now U.S. Pat. No. 3,719,484.

## BACKGROUND OF THE INVENTION

This invention relates to imaging systems and, in particular, to photoelectrophoretic imaging systems and apparatus.

Images are formed in the photoelectrophoretic process by exposing a photoelectrophoretic ink to electromagnetic radiation (hereafter referred to as light) and electric field. The ink is made of electrically photosensitive particles bearing a net electrical charge suspended in an electrically insulating liquid. Inks having different color particles are capable of producing full color images with conventional full color inks using cyan, magenta and yellow particles. An extensive description of the photoelectrophoretic process, materials and apparatus is given in U.S. Pat. Nos. 3,384,488; 3,384,565; 3,384,566; and 3,393,933, the disclosures of which are incorporated herein by reference. Briefly, the photosensitive particles are attracted to a transparent electrode by an electric field established between it and another electrode forming a dense layer of ink particles. This layer of particles is exposed to a pattern of liqht causing the light struck photosensitive particles to change charge polarity driving them from the transparent electrode. The ink particles remaining on the transparent electrode comprise a positive image of the light pattern and the exposed ink particles driven away comprise a negative image. The image and color quality of ink images produced from a polychromatic ink are improved by repeating the exposure and the application of electric field. In simple system configurations using flat plate transparent electrodes traversed by roller electrodes, the multiple exposure and application of field is not a particularly difficult requirement to meet. However, in more sophisticated systems wherein full frame light patterns are not used, the methods and apparatus for re-exposing an ink image become relatively complex.

Accordingly, it is an object of the present invention to simplify the optics required for performing multiple exposures of a photoelectrophoretic ink.

More broadly, it is an object of this invention to improve the photoelectrophoretic imaging process.

Another object of the invention is to devise novel methods and apparatus for subjecting photoelectrophoretic ink and ink images to electric fields.

A specific object of the present invention is to devise methods and apparatus for performing multiple applications of light and field during a single scanning pass.

Another object of the invention is to devise method and apparatus for inhibiting corona currents between closely spaced electrodes.

These and other objects of the instant invention are accomplished by positioning a plurality of web electrodes into a very narrow exposure region. The electrodes and exposure region are moved relative to a transparent electrode to form a full frame image on the transparent electrode in a line by line fashion during a single scanning pass. Exposure is made by projecting a light pattern through a narrow slit and through the transparent electrode to the photoelectrophoretic ink. The web electrodes include small rollers or squeegees



positioned within the width of the exposure region as defined by the slit. Each roller has a web passed around it to carry away exposed particles driven toward it from the transparent electrode. A liquid is usually applied to each web that is the same or similar to the electrically insulating liquid carrier in the ink. The dielectric properties of the liquid suppress corona currents in the vicinity outside the nips formed between the web and transparent electrodes.

## DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will be apparent from a further reading of the description and from drawings which are:

FIG. **1** is a schematic, side elevation view of a photoelectrophoretic imaging system having a transparent drum electrode and continuous web electrodes according to the present invention.

FIG. **2** is a schematic, partial side elevation view of the exposure section of FIG. **1** having a modified web electrode structure.

FIG. **3** is a schematic, partial side elevation view of a photoelectrophoretic imaging system having a transparent flat plate electrode and consumable web and squeege electrodes according to the present invention.

FIG. **4** is a schematic, enlarged, partial view of a squeege electrode shown in FIG. **3.**

## DESCRIPTION OF THE EMBODIMENTS

Polychromatic imaging systems of the present type normally include slit scan exposure optics for projecting a light pattern to the nip, i.e., interface, between two electrodes. The electrodes have large potential differences applied between them to establish a field sufficiently high for imaging. The slit scan optics is even used in systems having flat electrode shapes if images are made from opaque originals. The slit scan optics are used in the latter system because the light intensity required to flood a narrow strip is far less than that needed for full frame image projection. Furthermore because image quality and color are improved with multiple exposures to light and field, the color system often includes means for projecting two or more slit scan images to two or more nips. An alternative to the simultaneous projection of multiple slit images is to recycle the scanning apparatus to make several scanning passes over an ink image. The present photoelectrophoretic system solves these and other problems by accomplishing a multiple exposure to light and field with a single scanning pass of a slit image.

FIG. **1** illustrates the web electrodes of the present invention and how several of them are positioned within the scanning region to allow multiple imaging, i.e., multiple exposure to light and field, during a single scanning pass. The relative size of some of the elements are exaggerated to clarify their function. The drum **1** is a transparent electrode on which color ink images are formed from the photoelectrophoretic ink **2** contained in trough **3.** The ink is applied to first imaging electrode **4** which carries the ink to the nip between it and the drum for the first exposure to light and field. A second and third exposure to light and field is made as the ink image on the drum moves past the second **5** and third **6** imaging electrodes. The troughts **8** and **9** contain electrically insulating liquids **10** and **11** (normally the same as the insulating liquid of ink **2**) which are carried to the nips between electrodes **5** and **6** and the drum to

assist the migration of ink particles from the drum to an imaging electrode. The liquids **10** and **11** also act to suppress corona currents in regions of high field outside the nips.

A narrow image pattern is projected to the ink **2** by appropriate optical apparatus through the aperture or slit **13** formed between light stops **14** and **15.** The width of the slit **13** substantially defines the imaging region which is small compared to the circumference of the drum **1.** For example, when the circumference of drum **1** is in the order of 24–30 inches, the width of the aperture is in the order of ½ to 2 inches, meaning that the exposed arc of the drum is relatively flat and any optical distortion due to curvature is negligible. Also, the width of the aperture is adequate for positioning at least two imaging electrodes opposite to it.

The ink image formed on the drum during a single rotation or scanning pass is transferred to a web **16** between the transfer electrode **17** and drum **1.** The transfer electrode has a potential coupled to it to establish an electric field polarity to pull the ink particles comprising the image toward the web. The transferred image may be permanently fixed to the web by appropriate means.

The drum **1** is a complete 360° or partial transparent glass cylinder having a transparent conductive material (e.g., tin oxide) on its outside periphery. Conventionally, the conductive layer on the drum is electrically grounded with potentials substantially above and below ground being coupled to the imaging, transfer and other (e.g., a cleaning member) electrodes.

The imaging electrodes **4, 5** and **6** are substantially identical, thereby requiring a detailed description of only one of them. The first imaging electrode **4** includes a thin conductive web **18** formed into a continuous loop supported between rollers **19** and **20.** Roller **20** is coupled to an appropriate mechanical energy source in order to rotate the web synchronously with the drum so as to establish a near zero relative velocity between the web and drum. Roller **20** is also coupled to an appropriate electrical energy source that maintains the web at a high potential. Web **18** has an insulating outer surface facing drum **1** to prevent shorting the potentials coupled to the drum and web. The thickness of the insulating material is preferably small for high field in the nip between the web and drum and for high dielectric strength. The metal web may be comparatively larger for yielding mechanical strength to the web. Generally, the total web thickness is in the order of 1/32 to 1/64 inch and, consequently, is negligible compared to the width of aperture **13.**

A roller **19** is a small diameter roller journaled for rotation at the tip of a support block **25** that has a cylindrical recess for supporting the roller. The small roller is not coupled to a power source but is rotated by the movement of a web **18.** The diameter of a small roller **19** is generally of the order of ⅛ to ¼ inch for the 24–30 inch drum mentioned earlier. With spacings of approximately ⅛ inch between electrodes **4** and **5** and between electrodes **5** and **6,** the three electrodes, considering web thickness, roller diameter and electrode spacing, occupy a region approximately one inch wide.

The web configuration for the three imaging electrodes **4, 5** and **6** is significant because the webs carry away migrated ink particles to convenient locations for cleaning and wetting. The webs of the three electrodes converge to close spacing at the imaging region adjacent aperture **13** but they diverge to large spacings to permit cleaning and wetting at the troughs **3, 8** and **9.** The brushes **26, 27** and **28** represent appropriate cleaning apparatus for removing ink particles from the surface of the electrodes. The cleaning function can be eliminated if consumable webs are used in place of the continuous webs. The wetting rollers **29, 30** and **31** represent appropriate apparatus for applying the liquids **10, 11** and **2,** respectively, to the three electrodes **4, 5** and **6.**

An alternative embodiment to that shown in FIG. **1** is to have inking apparatus similar to wetting roller **31** and trough **3** positioned to apply ink **2** directly to the drum **1** at a location counterclockwise from the aperture **13** but before the transfer roller **17.** This configuration is helpful for simplifying the apparatus for cleaning the surface of electrode **4** because more space is available when the inking apparatus is not present.

Another alternative embodiment to that shown in FIG. **1** is to employ corotrons (electrostatic charging devices of the type described in U.S. Pat. No. 2,836,725) to establish the electric fields. The conductive webs **18** on the electrode **4, 5** and **6** are coupled to ground as well as the drum **1** and the corotrons are spaced from a web to deposit charge on the insulating surface of the web before it enters the nip. The charge is attracted to the grounded web whether an ink **2** or liquid **10** or **11** is on an electrode and is deposited in quantities such that the field in the nip is adequate for imaging to take place. This method of establishing the field is advantageous in that the thickness of the web can be greater for mechanical strength without fear of lowering field strength in the nip for practical potentials.

FIG. **2** illustrates a modified web electrode structure for a system like that shown in FIG. **1.** Here only two electrodes are illustrated but more could be used. The idea in this embodiment is to expand the width of each individual nip between an imaging electrode and the drum. Imaging electrodes **36** and **37** are composed of webs **38** and **39** similar to a web **18** being supported by a drive roller like a roller **20** but by two small idle rollers (rollers **40–43**) instead of a small roller **19.**

FIG. **2** illustrates another modification other than the additional number of small rollers **40–43.** The other modification includes the meniscus forming dielectric wedge shaped members **44** and **45.** The wedges are closely spaced from webs **38** and **39** to cause ink or liquid to form a meniscus that prevents air breakdown. The potentials coupled to the webs are sufficient to cause corona currents in regions between the webs and drum where separated by air or other ambient gas. The wedges are high dielectric constant materials that enable the majority of the field to be applied across it rather than the surrounding air. In addition, since the liquid fills the gap between the wedge and the web, air is excluded in regions outside the nip where the web and drum are closely spaced. At further spacings between the web and drum the field strength is insufficient to cause significant corona currents. The corona currents are undesirable at the entrance to an imaging electrode nip because it tends to reduce field strength, imparts undesirable polarities to the ink particles and other reasons. The wedge **45** between webs **38** and **39** is used principally to insure the space between rollers **41** and **42** is filled with liquid and/or ink. The webs are generally at the same potentials so the field is very low

or zero in the spaces between the web **38** and **39** but the field is high in the space between rollers **41** and **42** close to the drum **1.**

The electrode configuration of FIG. **2** offers great versitility for varying the angles **49–52** that the webs make with the drum, as compared to a horizontal reference line. The large angle **52** of web **38** as it enters the nip enables wedge **44** to be removed because the web and drum approach each other gradually. The air space at the entrance can be filled with a liquid for small spacings so that significant corona currents do not occur. On the other hand, angle **49** may be any desired angle that leads to gradual or abrupt separation between web **39** and drum **1** because the photoelectrophoretic process is not normally adversely affected by corona current generated at the exit to electrode nips. The angles **50** and **51** are generally selected for convenience and for insuring the presence of a liquid in the region close to drum **1** between rollers **41** and **42.**

The velocity at which the slit image, projected through aperture **13,** is moved past electrodes **4, 5** and **6** in FIG. **1** and electrodes **36** and **37** in FIG. **2,** is selected to be substantially equal to the velocity of a point on the periphery of the drum **1.**

FIG. **3** illustrates a photoelectrophoretic system wherein a flat transparent conductive electrode **56** has a slit image projected through it to the photoelectrophoretic ink **57.** The aperture **58** formed between light stops **59** and **60** defines the width of the slit image which is preferably on the order of ½ to 2 inches. The squeege electrode assembly **62** includes a conductive body **63** and two or more (here four) squeegee blades **64–66** all spaced to fit within the imaging region defined by aperture **58.** The insulating web **69** is woven around the squeegee blades **64–66** and pulled over the blades at a velocity that is substantially equal and opposite to the translational velocity of the assembly relative to the transparent electrode **56.** The plate **56** is grounded and a high potential is coupled to the conductive body of assembly **62** giving rise to high electric fields in the nips between the tips of the squeege blades and the transparent electrode.

An insulating liquid similar to that in ink **57** is applied to the web **69** before it enters the nips of the various blades to assist the migration of ink particles, minimize air breakdown and otherwise assist the multiple exposure process for the production of high quality images.

FIG. **4** is an enlarged view of squeege blade **65** which is typical of the other blades. The web **69** is wrapped around idle rollers **70** to reduce the mechanical drag on the web. The tip of each blade may include a compliant conductive member **70** such as conductive rubber to enable the web to be pushed closely to the transparent electrode generally uniformly along the length of the blade.

Whereas specific embodiments of the present invention have been given, it is apparent that modifications conventional to photoelectrophoretic imaging systems may be made without departing from the scope of the invention. The principal concept of this invention is the use of web electrodes in closely spaced regions to accomplish multiple exposures to light and field during a single scanning pass.

What is claimed is:

**1.** In an imaging system of the type wherein full frame images are formed from polychromatic photoelectrophoretic ink by scanning said ink with an electric field established in the nip between imaging and transparent electrodes and with a narrow slit light image, the improvement comprising

a plurality of closely spaced imaging electrodes positioned within the boundaries of said slit light image wherein each image electrode includes a web forming a nip with the transparent electrode and

drive means for moving said webs relative to said transparent electrode in a manner to establish a substantially zero relative velocity between them in the nip during a scanning pass,

whereby said ink is exposed to a light image and subjected to electric field a plurality of times during a single scanning pass.

**2.** The apparatus of claim **1** wherein said imaging electrode webs are wrapped around a small diameter roller to form the nip with the transparent electrode.

**3.** The apparatus of claim **1** wherein said transparent electrode includes at least a section of a cylinder.

**4.** The apparatus of claim **1** wherein said transparent electrode includes a flat plate and said slit light image is formed with apparatus including means to flood with light a narrow region of a full frame opaque original.

**5.** The apparatus of claim **1** further including means for coating an imaging electrode web with an electrically insulating liquid prior to entering said nip.

**6.** The apparatus of claim **1** wherein said imaging electrodes include continuous loop webs supported between small and large diameter rollers with the small diameter roller, web thickness and electrode spacing being substantially equal to or less than the width of said slit light image.

**7.** The apparatus of claim **6** wherein said drive means includes means for coupling a mechanical power source to said large roller for rotating the web around the large and small rollers.

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