

Jan. 5, 1971

L. M. CARREIRA ET AL

3,553,708

APPARATUS AND METHOD EMPLOYING PHOTOELECTROVISCOUS INK

Original Filed Jan. 26, 1966

2 Sheets-Sheet 1

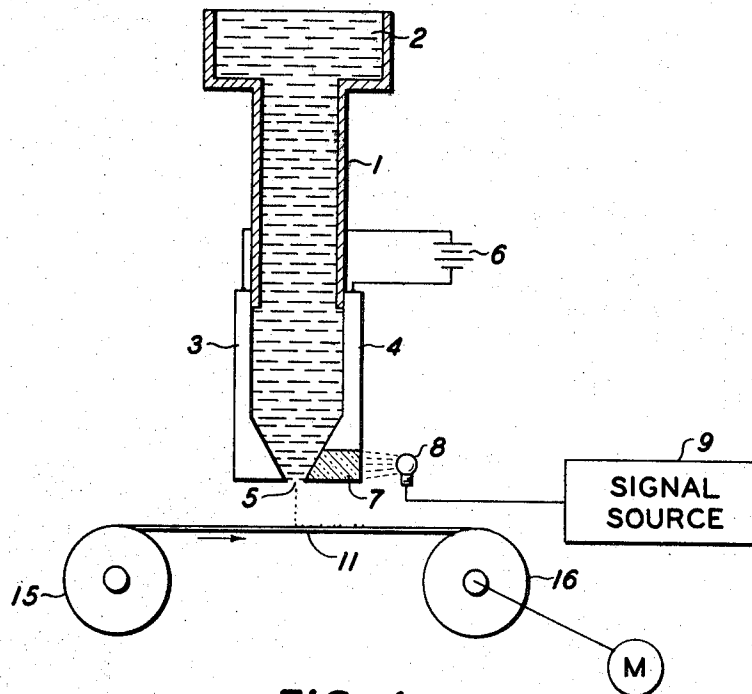


FIG. 1

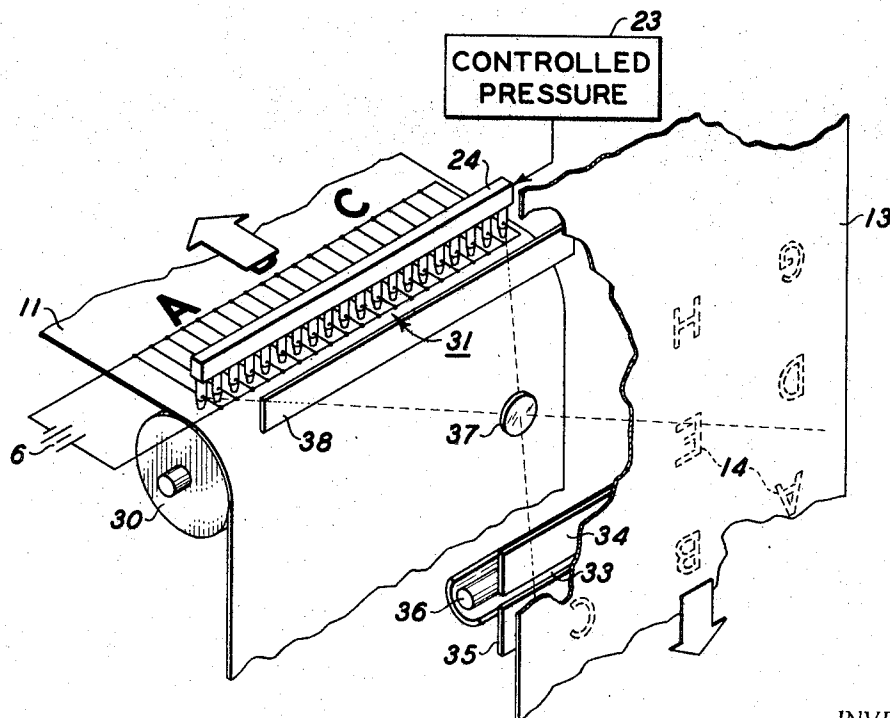
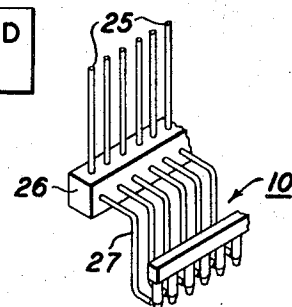
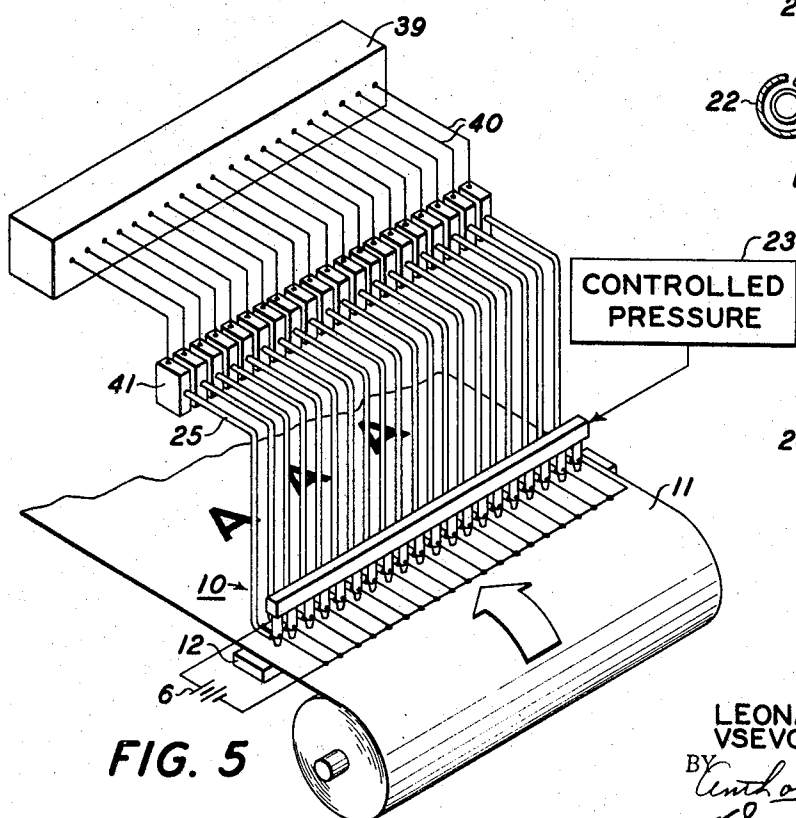
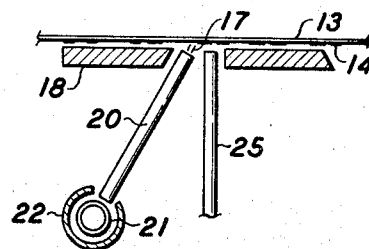
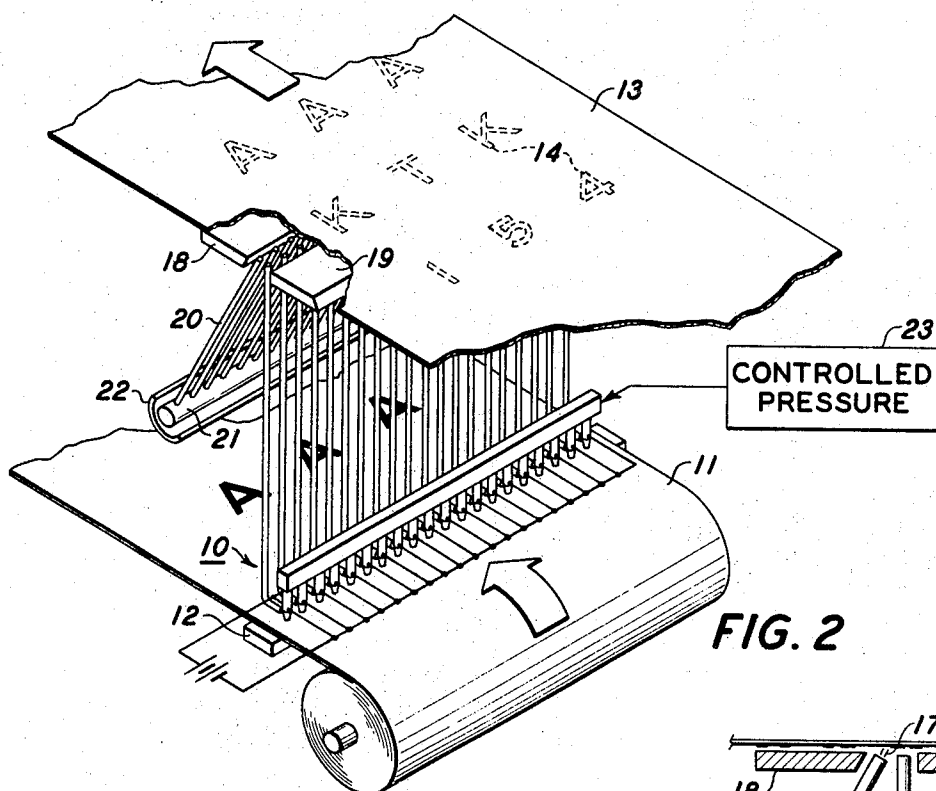


FIG. 6

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2. Sheets-Sheet 2



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RECORDING APPARATUS AND METHOD EMPLOYING PHOTOELECTROVISCOUS INK

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Continuation of application Ser. No. 523,189, Jan. 26, 1966. This application Feb. 21, 1968, Ser. No. 707,331

Int. Cl. G01d 5/26, 5/16

U.S. Cl. 346—1

10 Claims

ABSTRACT OF THE DISCLOSURE

A method and apparatus for image recording by the use of a photoelectroviscous fluid formed of a select dielectric liquid containing organic photoconductive pigments is disclosed. The fluid is maintained under pressure at an electrode aperture to which a constant field is applied and the flow of the fluid through the aperture onto a recording surface is controlled in response to a light signal applied thereto.

This is a continuation of application Ser. No. 523,189, filed Jan. 26, 1966, and now abandoned.

This invention relates to a system for image recording and more particularly to method and apparatus for imaging with a photoelectroviscous fluid in response to light modulated signals.

It has been shown by Willis M. Winslow that the apparent viscosity of certain liquids can be markedly altered by applying an electric voltage or electric field to these materials. (Journal of Applied Physics 20, 1137 (1949), U.S. Pats. 2,417,850; 2,661,596; 2,661,825; 2,663,809; 3,047,507.) Generally speaking, these liquids comprise a suspension of micron sized solid particles in a liquid carrier. It is desirable to have a certain amount of water present as an adsorbed layer on the particles, and various other materials are known to be desirable additives.

The effect of an electric voltage on these liquids may be termed the "electroviscous" or lectroviscosity effect and the liquids themselves are termed electroviscous liquids. The phenomenon is generally defined as the increase in torque necessary to maintain a given rate of shear of various liquids or suspensions under the influence of an electric field. This increase in torque is usually measured by a device called a Brookfield viscometer which includes a rotating flat disc (spindle) in a fluid at a constant angular velocity and measures the torque necessary to overcome the viscous resistance of the fluid. As shown, for example, by Winslow the viscosity of electroviscous liquids can be varied in accordance with the particular ingredients and proportions employed as well as by voltage. A viscosity of about 1000 poises, in the absence of any voltage, has been found to be particularly desirable. When a voltage is applied to the electroviscous fluid, it has been found that the liquid does not actually undergo a change in viscosity in the strict sense, but instead, the liquid jells or becomes grease-like. This indicates that the liquid, when a voltage is applied, will not flow at all unless a certain minimum force is applied which force is actually related to the applied voltage. This aspect of the electroviscous effect was not previously known but is very beneficial for the present invention in which the flow is controlled by the use of fluids having photoconductive sensitivity. The Winslow patents and publications noted above include numerous formulas for electroviscous liquids certain of which when modified as hereinafter described may be used in connection with the present invention.

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The use of electroviscous fluids for image recording is disclosed in copending application, Ser. No. 313,675 filed Oct. 3, 1963 in the name of Clark, now Pat. No. 3,270,637, and is incorporated herein by reference. The present invention is likewise concerned with image recording, and therefore it is desirable that the liquids employed have a dark or readily visible color effected by the use of dyes or other suitable coloring matter. Other types of homogeneous liquids also exhibit an electroviscous effect and when appropriately modified are useful in the present invention. These include where suitable; solutions of metal soaps in non-polar hydrocarbons; mixtures of mutually soluble substances which can exist as solid or liquid solutions at different temperatures and which may exist in the liquid crystalline state in liquid solutions; solutions of paraffin sulfates which form micelles; and liquid crystals, i.e. elongated molecules which contain one or more polar groups and which form nematic, smectic, or cholesteric phases. Further information on non-particulate electroviscous materials may be found in the literature, e.g. Bjornstahl and Snellman, Kolloid Zeitschrift, vol. 78, p. 258; Bjornstahl and Snellman, Kolloid Zeitschrift, vol. 86, p. 223 (1939); Michailoff and Zwetkoff, Acts Physicochimica U.R.S.S., vol. 10, p. 415 (1939).

Now in accordance with the instant invention there has been discovered that certain insulating oils or other dielectric liquids disclosed above and as will be further described, when containing quantities of photosensitive materials will display a change in electroviscous effect in response to actinic radiation. By applying radiation as signals representing intelligence information to the fluid under pressure and in the presence of an applied field, the flow thereof can be correspondingly controlled to effect image recording onto a recording media as in a facsimile system.

It is therefore an object of this invention to provide a novel recording system for image recording of information intelligence.

It is a further object to provide novel method and apparatus for image recording by means of electroviscous liquids selectively flow responsive to applied signals of information intelligence in the form of actinic radiation.

It is a still further object of the invention to provide novel compositions of electroviscous liquids having photoconductive properties as to display a change in electroviscous effect in response to applied actinic radiation.

Further objects and features of the invention will become apparent upon reading the following description in conjunction with the drawings wherein:

FIG. 1 is a sectional elevation of a simplified apparatus embodiment in accordance with the invention;

FIG. 2 is a schematic isometric view of an apparatus embodiment in accordance herewith to effect a facsimile reproduction from an original document;

FIG. 3 is an enlarged side elevation of the document scanning mechanism employed in FIG. 2;

FIG. 4 is a schematic apparatus variation of FIG. 2 for effecting a reversed optical signal;

FIG. 5 is a schematic isometric view of an apparatus embodiment for reproducing from a source of intelligence voltage signals; and

FIG. 6 is a schematic isometric of alternate apparatus for direct scanning of an image document.

Essential to the invention hereof is the fluid or ink composition which as light sensitivity to the extent that the composition by virtue of its fluid properties or the properties of contained particles changes its viscosity when a field is applied in the presence of light. Thus, as will be understood from the description below, the ink composition in the preferred arrangement is contained under pressure between electrodes to which an electrical field is

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applied. The pressure is sufficient to effect flow in the absence of a light signal. That is, in the absence of a light signal the composition has sufficiently low viscosity to flow past the electrodes onto a closely spaced recipient surface. Application to the ink fluid of a light signal, representative of intelligence to be recorded, irrespective of its origin whether it be a transduced computer output, the images from the surface of a scanned document, or the like, causes the fluid viscosity to be changed sufficient to arrest flow. This changed viscosity, effected intermittently in correlation to information being recorded, enables controlled flow onto a closely spaced recording member on which a reproduction is formed. The period of flow interruption corresponds accurately to the duration of the applied radiation such that flow is resumed or restored when the radiation signal is removed. Accordingly, the ink composition as above stated should preferably be colored, or contain a color former or otherwise be capable of marking a receiving sheet. It should likewise contain quantities of photosensitive materials whereby its viscosity can be selectively controlled in response to an applied signal of actinic radiation. The viscosity varying agent may comprise any suitable photosensitive material. Typical photosensitive materials include Monastral Green B, C.I. No. 74260, a phthalocyanine pigment available from E. I. du Pont de Nemours & Co.; Indofast Yellow Toner, C.I. No. 70600, flavanthrone, available from Harmon Color; Quindo Magenta RV-6803, a substituted quinacridone, available from Harmon Color; Algol Yellow GC, C.I. No. 67300, 1,2,5,6-di-(C,C'-diphenyl)thiazole-anthraquinone, available from General Dye Stuffs; Indofast Brilliant Scarlet Toner, C.I. No. 71140, 3,4,9,10-bis (n,N'-(p-methoxyphenyl)-imido)-perylene, available from Harmon Color; Skyline Blue B-4712, C.I. 74160, copper phthalocyanine available from Harmon Color; Monolite Fast Blue GS, a mixture of alpha and beta phthalocyanine, available from Arnold Hoffman Co.; Phosphor 2225, a mixed cadmium sulfide-zinc sulfide phosphor available from New Jersey Zinc; Phosphor 511, zinc oxide, available from E. I. du Pont de Nemours & Co.; 1,1'-diethyl-2,2'-carbocyanine iodide; Permanent Violet Toner, C.I. 42535, Phosphotungstomolybdic acid lake of methyl violet available from Collway Co.; and mixtures thereof.

The carrier liquid may comprise any suitable dielectric liquid. The photosensitive material may be dispersed in finely divided form in the carrier liquid in any suitable concentration; typically about 5 to 20 percent by weight may be used. Typical dielectric liquids include mineral oil, normal heptane, normal hexane, kerosene, petroleum ethers and mixtures thereof; also, paraffin, chlorinated hydrocarbons, and fluorinated hydrocarbons may be used where suitable.

Referring now to FIG. 1 there is illustrated an apparatus embodiment of the invention in its simplest form. As there shown, the apparatus comprises a reservoir 1 containing and providing vertical head to a quantity of pigment containing electroviscous liquid ink 2 as described above. The lower portion of the reservoir is formed of two spaced apart electrodes 3 and 4 defining an aperture 5 of about 8 to 12 mils and to which a constant electric field is applied from a potential source 6. The lowermost portion of one of the electrodes extending along the slit aperture includes a transparent or translucent section 7 formed preferably of electrically conduction material or having an electrically conductive coating in contact with the ink. Commercially available NESA glass comprising a transparent tin oxide coating or glass is suitable for this purpose.

Aligned with the glass section 7 is a light source 8 which is energized selectively from a signal source 9. Source 9 can represent a variety of inputs as from a facsimile system, computer or the like and is operative to control liquid flow by viscosity changes in the ink in response to the applied radiation to which the ink is sen-

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sitive. Depending upon the choice of liquid and pigment combination the ink viscosity will either increase or decrease in response to radiation such that in its latter condition it flows through aperture 5 onto a recording web 11 advancing from a supply reel 15 to a take up reel 16. The signal from source 9 should correspond to the liquid response to result in a right reading or reverse reading image on the web as desired. That is, if flow is arresting in response to radiation and a right reading image is desired, the signal should ordinarily energize the light source during an absence of transmitted information to be recorded and be deenergized when information is to be recorded. This will result, for example, on colored ink depositing onto a white paper web to correspond with usually encountered positive type original documents.

The operative mechanism of the suspended pigment particles in the insulating liquid is not fully understood, but is believed at least in part to result from the responsive formation of loosely bound agglomerates of the photoconductive pigment particles in regions of high field density and illumination at the aperture. Hydrostatic pressures for inducing flow are not critical and will of course vary with the materials used and the flow rate required. That is, depending upon operative conditions as will be understood, the ink should flow with sufficient density of deposit to form a legible indicia onto a recording member. At the same time flow should be arrested and resumed in response to the applied and discontinuance of the light signal within a fraction of a second to ensure a good quality reproduction without blurring.

The voltage applied from potential source 6 in part controls the flow of the ink and may be either AC or DC. AC voltage is preferred in that the use of a DC field tends to increase the danger of field breakdown giving poorer control to the ink flow at the aperture. A suitable range of AC voltage is from 600-1000 volts. Any minimum voltage should be sufficient to yield a controllable field satisfactory for the materials employed, while the maximum voltage is ordinarily that at which a field breakdown occurs. When using AC voltage it has been found generally that frequencies exceeding 10^4 cycles/second causes a loss of flow control of the ink at the aperture.

Likewise the light intensity and wavelength at source 8 will be a function of response sensitivities of the materials employed. With an ink formed of a suspension of monastral green (5% by weight) in mineral oil and a potential of 600 volts AC applied between the electrodes, a 150-watt incandescent projection bulb 8 when energized at a distance of 10 inches arrested the ink flow. When the bulb was deenergized, the ink flow resumed resulting in a pattern on a recording web corresponding to the on-off operational pattern of the light source. A similar result was obtained with a suspension of Skyline Blue B-4712 (20% by weight) and mineral oil when subjected to a 1000-volt AC potential. With a suspension of Permanent Violet toner (11% by weight) in mineral oil an analogous result was obtained with 600 volts AC applied and a 500-watt projection lamp at about a 12-inch distance.

Referring now to FIGS. 2 and 3, there is illustrated an array of linearly aligned closely adjacent recording capillaries or pens 10 each similar to that described above and terminating contiguously spaced to the surface of a continuously advancing recording member 11 on which the ink is to be selectively deposited. Extending beneath the recording member parallel and at least coextensive with the array of recording pens is a platen 12 which supports the web member 11 as it passes below the pen array. A uniform hydrostatic pressure is applied from a source 23 to an ink manifold 24 supplying ink to each of the individual pens.

The signal for controlling ink deposition from the individual recording pens in accordance with this embodiment emanates from a moving original document 13 containing images 14 which are caused to move past a scanning slit 17 extending laterally thereacross and defined by spaced

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apart plates 18 and 19. As the document advances across the slit, the images surface thereof is continuously illuminated by a plurality of closely adjacent fiber optic light pipes 20 receiving light from transversely extending lamp member 21 partially enclosed by shield member 22.

The illuminated surface of the document is reflected into a plurality of corresponding fiber optic light pipes 25 which extend from close proximity to the document surface into an emission position relative to the discharge end of each of the pens as described above. Accordingly, as the illuminated document advances, each incremental area thereof is scanned by a light pipe 25. With an ink composition responding to light with increased electroviscosity, the absence of sensing an image 14 produces a light signal transmitted to the corresponding pen flow causing ink interruption to prevent deposition onto the recording member 11. On the other hand, on sensing an image 14, there is a discontinuance of light transmission through the respective optics such that the ink in the corresponding pen will flow onto the recording member. As can be appreciated, each of the recording pens in the array are closely juxtaposed to each other as are their individual corresponding light pipes 25 to provide optimum and maximum coverage of the document surface as well as the printout onto the recording member 11.

Because of direct signal transmission by which an absence of image on document 13 causes ink deposition from a corresponding recording pen 10 onto recording member 11, there generally results a positive reproduction printout, i.e., image areas 14 will be represented by an ink deposition on recording member 11 and vice versa. One method of effecting a reverse reproduction of the original is to employ a black surfaced recording member 11 with a white ink contained in the capillaries.

An alternative and preferable method for rectifying the signal in order to result in a positive-to-negative, or reverse reproduction is illustrated in FIG. 4. In accordance therewith, the emission end of the fiber optics 25 are connected to an intermediate electronic light inverter 26, the output of which is connected via fiber optic light pipes 27 to the recording pens as above. By this means a light input signal to the inverter will result in an absence of a light signal to the corresponding pen, whereas an absence of signal into the inverter will produce a light output signal thereto. This therefore results in a faithful positive-to-negative reproduction of the document surface containing image areas 14 and permits the use of conventional while papers with colored inks in effecting this result.

Recording is effected in FIG. 5 similarly as above and differs from the previous embodiments in that the originating signal source can be other than optical. As here shown, the signal source 39 can be the output of various electronic or sonar devices such as a computer, sound recording, or the like. The output of the source includes a plurality of individual leads 40 corresponding to the respective recording pens in the array and each of the leads is connected to apply a signal to the transducer 41 whereat the voltage signal from the source is converted to a light output signal connected to light pipes 25. Thereafter, the apparatus is operable as before.

In FIG. 6 the use of light pipes is omitted and the recording member 11 advances continuously over a roller support 30. An electrical bias is connected via potential source 6 to an array of recording pens 31 to which ink is supplied from a manifold reservoir 24. An original copy sheet 13 is caused to continuously advance past an exposure slit 33 formed between transverse plates 34 and 35 and at which illumination from lamp 36 illuminates the advancing portions of the copy surface. Instead of the fiber optic members employed as in the embodiment of FIG. 2, the image 14 thereon in passing slit 33 is optically projected by means of objective lens 37 onto the array of recording pens 31 to effect a response similar to that described above. An opaque bar 38 extends transversely across the surface of the moving recording member to

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prevent stray light from impinging on the recording pens as might be caused by unwanted reflection. By means hereof, the optical image projection of the incremental areas of the original passing over exposure slit 33 selectively affects each of the pens 31 in the array to cause ink deposition selectively in response to received illumination as before.

By the above description there is disclosed novel method and apparatus for a liquid ink recording system discriminately responsive to a received optical signal for the selective deposition of ink onto a recording sheet. In accordance herewith, the ink composition is characterized by having photosensitive sensitivity such as photoconductivity while in an applied electric field that becomes electroviscously changeable upon exposure to actinic radiation to which its photosensitive component is sensitive. By containing quantities of this ink under pressure in a plurality of closely spaced capillary recording pens, each of the pens subjected to a constantly applied electrical field can be rendered discriminately responsive to controlled ink flow onto a recording member on receipt of an optical signal representative of intelligence to be recorded. The apparatus can be adapted for either positive-to-positive or reversal reproduction and can be operable with optical signals having optical origin or whatever origin is known to those skilled in the art. While many light sensitive materials have been specifically mentioned for use in the photoviscous inks, where desired, other viscosity varying materials may also be used. Typically, photochromic materials such as pyrospirans may be used.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the drawings and specification shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method of controlling the flow of a photoelectroviscous recording ink for the recording of optical intelligence information comprising the steps of:

- (a) supplying under pressure a photoelectroviscous ink to an aperture in closely spaced proximity to a recording surface so that said photoelectroviscous ink may flow through said aperture to said recording surface in the absence of actinic radiation.
- (b) creating an electric field across said aperture and through said photoelectroviscous ink in the region proximate said aperture, and
- (c) selectively arresting the flow of said photoelectroviscous ink through said aperture by exposing said ink most closely adjacent said recording surface to actinic radiation to which said ink is photosensitive, said radiation being in the form of an optical signal representative of intelligence to be transmitted.

2. A method of controlling the flow of a photoelectroviscous recording ink at an aperture for the recording of optical intelligence information comprising the steps of:

- (a) supplying a photoelectroviscous ink to a discharge aperture defined by an opposed pair of electrodes, said aperture being in closely spaced proximity to a recording surface;
- (b) applying sufficient pressure to said photoelectroviscous ink to cause it to flow through said discharge aperture;
- (c) applying an electrical potential across said pair of opposed electrodes defining said discharge aperture to create an electric field in said photoelectroviscous ink across said discharge aperture; and
- (d) selectively exposing said photoelectroviscous ink in the region of said discharge aperture to radiation to which said ink is photosensitive to alter the fluid viscosity of said photoelectroviscous ink to modulate said photoelectroviscous ink flow therefrom onto said recording surface in response to radiation received

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directly from an optical signal representative of the intelligence to be transmitted.

3. A facsimile recording apparatus comprising in combination:

- (a) a container containing a pressurized quantity of photoelectroviscous ink having photoconductive properties and including opposed electrodes defining an ink discharge aperture in said container, said electrodes terminating on the same side of and adjacent the surface of a recording member on which a recording is to be made;
- (b) electrical potential means connected to apply an electric field between said opposed electrodes at said ink discharge aperture; and
- (c) means for transmitting radiation intelligence to the ink to said discharge aperture whereby the fluid viscosity of the photoelectroviscous ink is altered to control the flow of said photoelectroviscous ink from said discharge aperture so that the period of flow interruption corresponds to the duration of the applied optical radiation.

4. Apparatus according to claim 3 in which there is included an array of said containers and means to effect relative movement between the recording member and said container array.

5. Apparatus according to claim 4 in which said means for transmitting radiation intelligence to the ink at said discharge aperture to effect a controlled ink flow from said container onto said recording member correlated to the radiation transmitted includes means to project a continuous image pattern of light and shadow from an original document across said array of said containers.

6. Apparatus according to claim 4 in which said transmitting means includes a plurality of light fibers each aligned to separately transmit radiation to a different container of said array.

7. Apparatus according to claim 4 in which there is included a signal source to emit voltage signals of intelligence to be recorded and means to transduce said voltage signals to radiation signals to be transmitted by said transmitting means.

8. Apparatus according to claim 4 in which there is

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included means to scan the image surface of an image bearing document to form the intelligence input to said transmitting means.

9. Apparatus according to claim 8 in which there is included light-inverter means intermediate said scan means and said transmitting means to invert the radiation signal input to said transmitting means.

10. A recording apparatus comprising in combination:

- (a) electrode means comprising at least two electrodes defining an aperture in part, said electrodes residing on the same side of and adjacent the surface on which a recording is to be made;
- (b) electrical potential means connected to apply an electric field between said electrodes;
- (c) photoelectroviscous inking means including a photoelectroviscous ink having photoconductive properties, said photoelectroviscous ink being within the electric field of said electrodes in at least the region of said electrodes most closely adjacent to said surface on which the recording is to be made and means to exert pressure on said photoelectroviscous ink; and
- (d) optical control means for transmitting radiation intelligence to said photoelectroviscous ink in the region of said electrodes most closely adjacent to said surface on which the recording is to be made whereby the fluid viscosity of the photoelectroviscous ink is altered to control the flow of said photoelectroviscous ink from said electrode means to the recording surface so that the period of flow interruption corresponds to the duration of the applied optical radiation.

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U.S. Cl. X.R.

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