

[54] **METHOD AND APPARATUS FOR THERMAL VISCOSITY MODULATING A FLUID STREAM**

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Related U.S. Application Data

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[52] U.S. Cl. **178/6.6 R, 101/335, 346/1, 346/140**

[51] Int. Cl. **G01d 15/18**

[58] Field of Search.... 346/1, 140, 76 R, 74 ES, 75; 178/6.6 R, 96; 219/211

References Cited

UNITED STATES PATENTS

2,633,796	4/1953	Pethick.....	346/74 ES UX
3,134,849	5/1964	Frohbach et al.....	346/140 X
3,161,882	12/1964	Mullin.....	346/74 ES
3,270,637	9/1966	Clark.....	346/140 UX
3,359,566	12/1967	Donalies.....	346/140
3,656,169	4/1972	Kashio.....	346/75
2,487,865	11/1949	Glassey.....	346/76 R
3,480,962	11/1969	Weigl et al.....	346/1
2,556,550	6/1951	Murray.....	346/1

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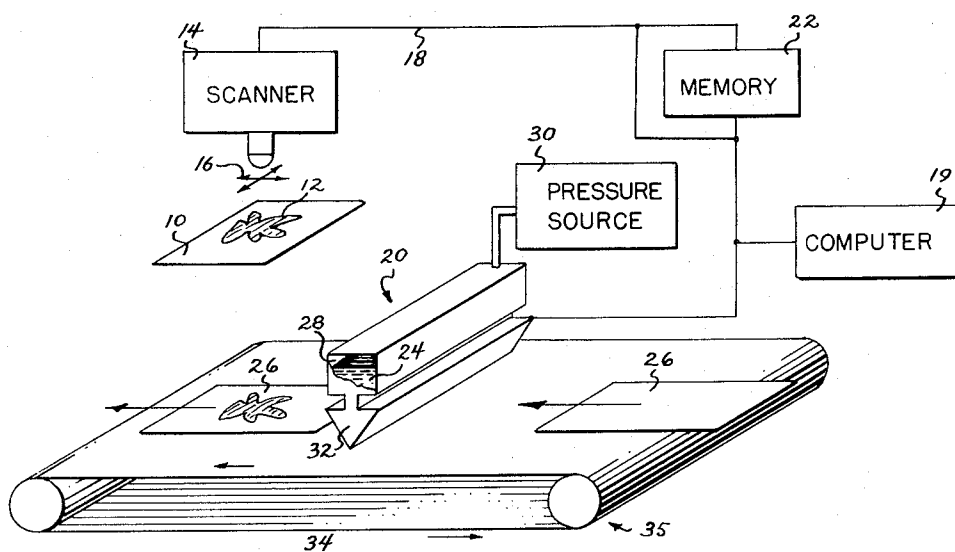
Attorney, Agent, or Firm—Chittick, Pfund, Birch, Samuels & Gauthier

[57]

ABSTRACT

A method and apparatus for thermal viscosity modulating a fluid stream by time varying the temperature of the stream in response to an intelligence signal. The method and apparatus are useful for "printing" or forming an ink image of an original in black and white or color. In the preferred embodiment, a plurality of fluid printing ink streams are thermal viscosity modulated in response to an electrical signal which represents a scanned original. Each fluid ink stream corresponds to a resolution element across the serially or parallel scanned original. The image of the original is formed or "printed" on a suitable fluid receptor, such as paper, by depositing the fluid streams in varying amounts on the receptor according to the viscosity of each of the streams. The thermal viscosity modulation of the fluid stream is accomplished in a preferred embodiment by passing the fluid streams under pressure through capillaries each having a thin film electrical resistor formed on the inner wall thereof. The scanned original electrical signal is impressed across the capillary electrical resistor to heat the fluid ink stream in accordance with the signal. By varying the amount of heat, the viscosity of each stream is modulated as a function of the value of the corresponding resolution element of the original.

27 Claims, 8 Drawing Figures



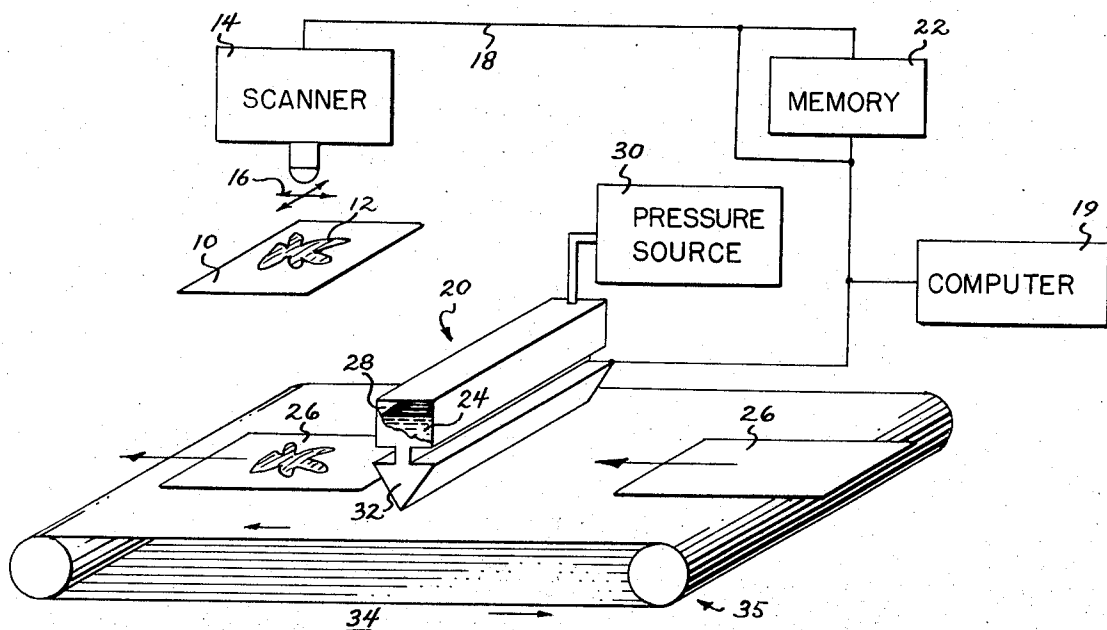
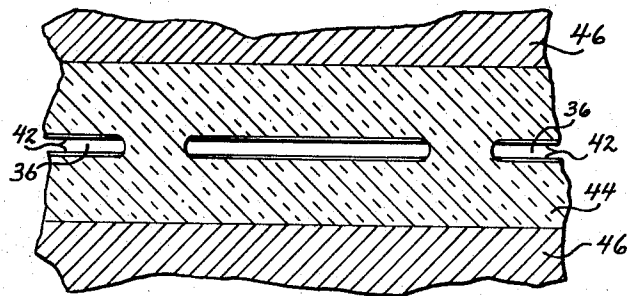
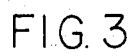
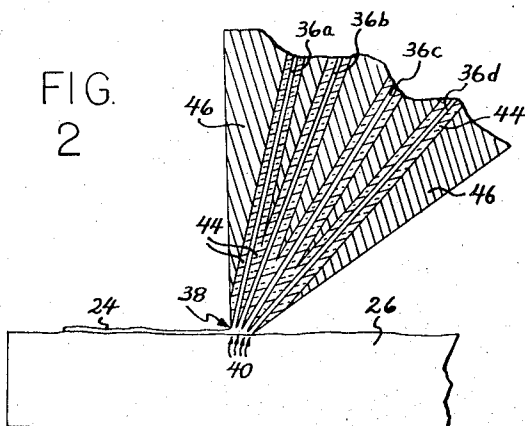


FIG. 1

FIG.
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FIG. 4

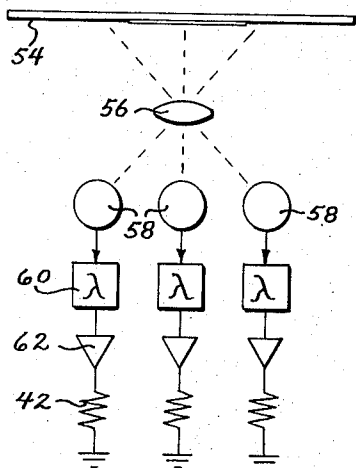
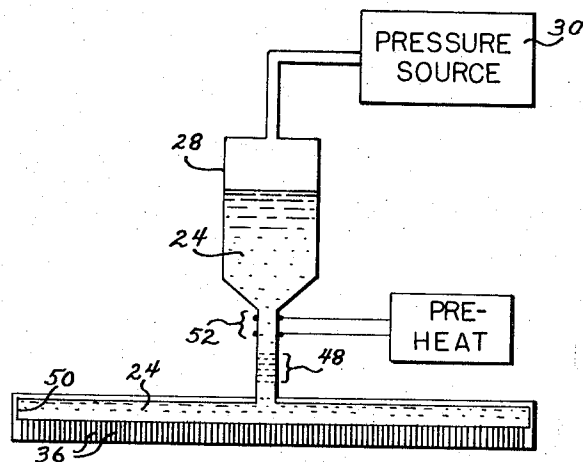


FIG. 5A

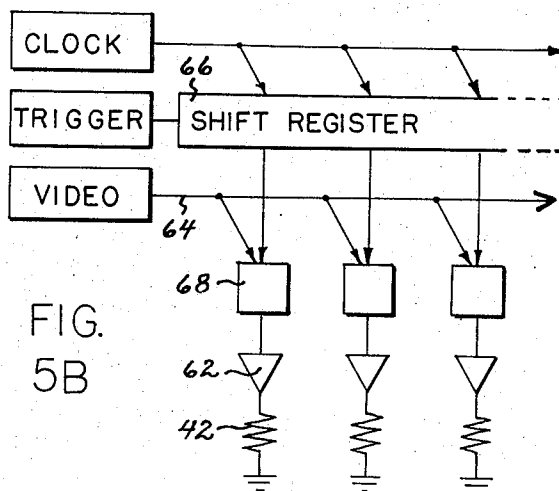


FIG. 5B

FIG. 7

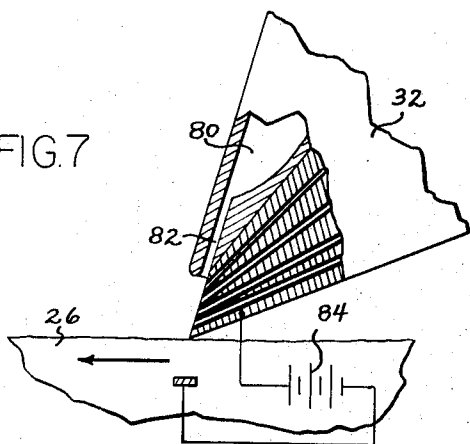
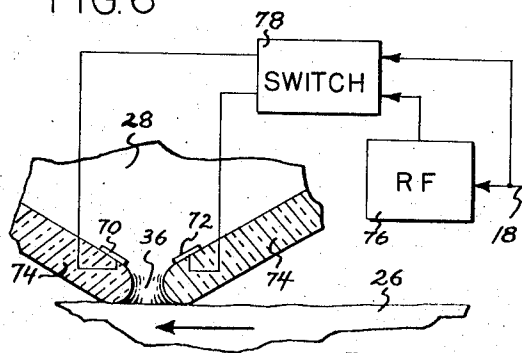


FIG. 6



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METHOD AND APPARATUS FOR THERMAL VISCOSITY MODULATING A FLUID STREAM

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-Part application of my application Ser. No. 46,935, filed June 17, 1970 for METHOD AND APPARATUS FOR ELECTRONIC LITHOGRAPHY now U.S. Pat. No. 3,741,118.

BACKGROUND OF THE INVENTION

The present invention relates to viscosity modulation of a fluid stream and, more particularly, to a method and apparatus for electronic printing utilizing a thermal viscosity modulation of the printing fluid.

The printing industry today uses a number of printing techniques, the major types of which include lithography, letterpress, and gravure. Lithography is a printing technique which employs a plate on which the areas corresponding to the inked areas of the image have different properties than the other areas. An aqueous-based "fountain solution" is applied to the plate and adheres only to the non-ink areas. An oil-based ink is then applied to the plate. The ink is repelled by the fountain solution and adheres only to the ink-receptive areas of the plate. The plate is then brought into contact with the paper (direct lithography) or with a resilient rubber blanket which in turn prints on the paper (offset lithography).

The second technique, letterpress, utilizes a plate on which areas corresponding to the inked section of the image are raised. When the ink is applied to the plate, the ink adheres to the raised portions only. The image is then printed by bringing the paper into contact with the inked plate.

The gravure technique employs a plate on which areas corresponding to the inked section of the image are indented. The printing ink is applied to the plate and then the plate is wiped with a "doctor blade" leaving printing ink only in the indented portions. When the paper is brought into contact with the plate, it absorbs the ink from the indented portions.

The printing processes described above all require that a plate be prepared prior to the printing process which contains in some permanent form the image to be printed. In practice, such plates are used on presses repeatedly so as to rapidly produce many copies of the same image. However, it is not possible to introduce a new image without interrupting the printing process to change the plate. This is not only costly from an equipment standpoint, but it is also expensive in terms of the "down time" for the printing press.

Recent advances in technology have produced a number of "copying" techniques. The various electrostatic processes, including xerographic copying, employ techniques which do not involve a permanent plate, but instead create a charged pattern on a photoconductor, such as, zinc oxide or selenium, to which a powdered ink selectively adheres. The photoconductor is either on an intermediary, e.g., drum, or the paper itself. Unfortunately, the electrostatic processes have several limitations: the electrostatic ink is much more expensive than printer's ink; the quality is noticeably inferior to conventional printing; and, the process is unacceptable for photographic work.

Photography or chemical imaging is a technique in which the variations involve light-sensitive chemical reactions, heat sensitive chemical reactions, possible intermediary images, developing reagents, chemical image transfers and the like. The per-print cost is relatively high and the processes are generally slow and inconvenient. However, the quality is good; especially when silver chemistry is employed.

Although each of the "printing" or imaging techniques discussed above is suitable for certain applications, the technical limitations and economic tradeoffs of each technique substantially preclude the use of a single technique in a broad range of imaging applications. It is, accordingly, a general object of the present invention to provide a new method and apparatus for "printing" or imaging which obviates many of the technical limitations of the existing techniques and which provides competitively acceptable economic tradeoffs.

It is a specific object of the present invention to provide a method and apparatus for modulating a fluid stream with an intelligence signal.

It is another specific object of the present invention to provide a method and apparatus for printing an image of high quality at low cost and at high speeds.

It is still another object of the invention to provide a method and apparatus for printing a visible image from an image in scanned electronic form.

It is a further object of the present invention to provide a method and apparatus for printing which utilizes thermal viscosity modulation of a stream of printing ink.

It is still a further object of the present invention to provide a method and apparatus for printing which prints the same or different images in continuous sequence.

It is a feature of the invention that the above objects can be achieved without sacrificing the quality of the final printed image while at the same time providing a competitive cost per-print/quality ratio.

These objects and other objects and features of the present invention will best be understood from a detailed description of a preferred embodiment thereof selected for purposes of illustration and shown in the accompanying drawings in which:

FIG. 1 is a diagrammatic view in partial perspective and block diagram form illustrating the "printing" or imaging system of the present invention;

FIG. 2 is an enlarged detailed view showing the tip of the printing head in relation to the ink receiving paper;

FIG. 3 is a greatly enlarged view of a representative cross-section taken through the tip of the printing head showing the capillary cross section;

FIG. 4 is a simplified diagrammatic view of the ink distribution system; and,

FIGS. 5A and 5B are block diagrams of the circuitry employed in thermal viscosity modulating the stream of printing ink through the printing head tip capillaries.

FIG. 6 is an alternative construction of the printing head illustrating the use of conductive or electromagnetic radiation heating of the printing ink; and,

FIG. 7 is still another alternative construction showing an "air brush" transfer system and electrostatic means to facilitate ink transfer.

Turning now to the drawings and particularly to FIG. 1 thereof, there is shown in diagrammatic view and partial perspective and block diagram form a "printing" or imaging system constructed in accordance with the

present invention. An original 10, such as a document or photograph, having an image or indicia 12 thereon is scanned by a conventional scanner 14, such as, a flying spot scanner. The scanning action is indicated diagrammatically in FIG. 1 by the two arrows identified by the reference numeral 16. Other known scanning techniques also can be used including parallel wire, "TV" and "facsimile" scanning of the original.

The output signal from the scanner 14 on line 18 comprises an electrical signal having a characteristic which varies in accordance with the light value of each element of the scanned original 10. The scanned electrical signal on output line 18 constitutes an "intelligence" signal since it represents in electrical form the intelligence information of the scanned original 10. Alternatively, the "intelligence" signal can be directly generated by a computer 19.

The electrical intelligence signal on line 18 can be used directly to actuate a printing head assembly 20, as will be described in detail below, or it can be stored in a suitable memory 22 for subsequent utilization. In broad terms, the printing head assembly 20 comprises a means for depositing a modulated fluid stream upon a suitable fluid receptor. Expressed in printing technology, the printing head assembly 20 controls the deposition of a printing ink 24 upon an ink receptor 26, such as, paper, or an intermediate ink transfer medium. The printing ink is contained in an ink reservoir 28 under pressure from a pressure source 30. The ink reservoir is fluidly coupled to a printing head 32. The ink or fluid 24 is discharged in a modulated stream from the printing head in accordance with the intelligence signal from scanner 14. The apparatus for modulating the ink stream with the intelligence signal will be discussed below in connection with FIGS. 2 through 5.

Vertical scanning, in the sense of TV signal scan, is provided at printing station 34 by the relative movement of the printing head assembly 20 and the ink receptor 26. For the purposes of illustration, this relative movement is provided by a conventional belt-drive system, indicated generally by the reference numeral 35. Other variations in the means for producing relative motion between the ink receptor and the printing head assembly can be employed depending upon the desired machine configuration. For example, the printing head assembly can be moved across the ink receptor. Similarly, a drum transport mechanism can be used to move the ink receptor passed the printing head assembly printing station 34.

Looking at FIG. 2, there is shown in cross-section and greatly enlarged, a portion of the printing head 32. The printing head or "doctor" by analogy with the use of that term in the gravure printing process, can be considered as a knife blade extending across the width of the paper and angled "with" the moving ink receptor 26. The printing ink 24 is delivered from the ink reservoir 26 through a plurality of capillaries 36 which terminate at the printing head edge 38 in a corresponding plurality of capillary orifices 40.

The ink dispensing capillaries 36 deposit the ink onto the paper 26 in the pattern of the original image 12. The number of capillaries depends upon the desired resolution, the number of colors and the width of the paper 26. At the present time, printing practice uses resolutions or "screens" in the range of 60-200 elements per inch and one to four colors except in specialized circumstances. For a standard 8½ inch wide page,

150 screen, and "process" color (four colors), the printing head 32 and 5,100 capillaries. Under other circumstances, the number of capillaries 36 could be under 100 or over 10,000.

In the greatly enlarged side view of FIG. 2, four color capillaries 36a, 36b, 36c and 36d are shown for each single picture element. These four color capillaries, respectively, are fluidly connected to separate pressurized ink reservoirs containing yellow, blue, magenta, and black ink.

For purposes of illustration, only one such ink reservoir has been shown in FIG. 1. The four capillary orifices 40 are positioned as close as possible to each other and to the forward or downstream edge of the doctor blade in order to prevent the wet ink from being smeared by the doctor blade.

It has already been mentioned that the ink flow through the capillaries is modulated in accordance with the scanned intelligence signal from either scanner 14, memory 22, or computer 19. The intelligence information is impressed upon or modulates the printing ink 24 by thermal viscosity modulation. Thermal viscosity modulation of the printing ink is accomplished by selectively heating the printing ink in each capillary tube. Heat is applied to the ink by the wall of the capillary which is partially or totally covered by a thin film resistor 42. The electrical signal which represents the desired image is impressed after the suitable amplification or other processing across the resistor 42 causing ohmic heating thereof. Since both the thin film resistor 42 and the ink itself have a relatively small thermal mass, the heat generated produces a rapid temperature change in the moving ink. Preferably, the entire length of the capillary tube is heated in unison thereby causing the microscopic column of ink to suddenly accelerate due to viscosity modulation.

Looking at FIG. 3, which is a view in cross-section of a capillary tube taken perpendicularly to the direction of ink flow, it can be seen that the capillary tube 36 has an elongated rather than circular configuration. This shape is desirable in order to decrease the time required to thermal viscosity modulate the flowing ink. With this structural configuration, it is possible to obtain very rapid changes in temperature of the ink in the capillaries using frequencies in the audio range.

The thermal mechanisms of the system are relatively straight forward. The flow rate through the capillary tube, ignoring end effects, is given by

$$F = P/\eta G$$

where η is the viscosity, p is the pressure difference, G is a factor of dimension cm^3 representing the geometry of the capillary, and F is the flow rate in volume/time if the viscosity is absolute (poises), or mass/time if the viscosity is kinematic (stokes).

The η of liquids decreases markedly when they are heated. For many oils, viscosity can be varied by a factor of over 1,000 by varying the temperature. Even water is six times thicker near freezing than near boiling. By using a suitable vehicle for the ink, it is possible to produce a thousand times more flow through a hot capillary than through a cold capillary with a continuous range in between. Current printing practice indicates that a flow ratio of approximately 100:1 is required for quality work. The ink flow can be shut off completely by turning off the pressure or by lowering the capillary temperature to virtual solidification of the

ink. However, for purposes of illustration in the present invention, it is assumed that "white" is an invisibly small ink flow, but not zero.

A variety of suitable vehicles can be used for the ink. Successful tests have been conducted using AMCD Copy Duplicator CD-118 ink sold by the Copy Duplicator Division of the AM Corporation, 1,200 Babbitt Road, Cleveland, Ohio. The ink vehicle, and the ink as a whole, should have a wide dynamic range of viscosity as a function of temperature. Many oils, including some presently or previously used as vehicles in conventional printing inks have the desired characteristics. These oils include mineral oils, castor oil and linseed oil. It is also possible, of course, to use a water vehicle albeit with a much more limited dynamic range of viscosity as a function of temperature.

Each thin film resistive element 42 is surrounded by an electrical insulator 44 and a heat sink 46 which provide the dominate mode of heat loss, as well as, electrical insulation and mechanical strength. The heat sink 46 is maintained at or below the lowest temperature desired and preferably is constructed from a metal and is shared by all of the capillaries 36. A separate fluid cooling system (not shown) can be employed to remove heat from the heat sink 46 if the signal power levels produce more heat than can be dissipated by the heat sink.

The insulator 44 conducts heat from the capillary to the heat sink and has a preselected thickness or thermal resistance which is compatible with the other physical parameters of the system. The choice of various physical parameters determines the time response of the printing or imaging system. For faster time response, the capillaries are narrower, the pressure is higher, the insulator thinner and more power is dissipated by the thin film resistor 42 and absorbed by the heat sink. For a slower response, these parameters are less restrictive.

Referring now to FIG. 4, there is shown in simplified diagrammatic view an ink distribution system for the present invention. As mentioned previously, the ink reservoir 28 is pressurized by a pressure source 30. The printing ink 24 in reservoir 28 passes through a ink filtration system indicated generally at 48, in order to remove any particulate matter which might clog the printing head capillaries. The filtered ink passes into a final ink chamber 50 and then down into each of the capillaries 36. If desired, the printing ink 24 can be preheated by passing the ink through an electrically powered preheating station 52. The use of the preheating technique minimizes or substantially eliminates "end effects" in the capillaries.

The circuitry employed in the thermal viscosity modulation of the stream of printing ink through the printing head tip capillaries is shown in block diagram form in FIGS. 5A and 5B. Referring first to FIG. 5A, there is shown the circuitry for a one dimensional scan. By optical means which are not part of the invention, a line 54 of the original image 12 is color separated into the three primary colors. Conventional devices such as dichroic mirrors, color filters or prisms can be employed to achieve the color separation of the image. The color separate image of the line 54 is focused by an optical system, indicated representationally and identified by the reference numeral 56, onto a linear arrangement of photocells 58 which transduce the line image into electrical signals. Although the electronics for only one primary color is shown in FIG. 5A, it should be under-

stood that the same circuitry is repeated for the two other primary colors. The fourth color, black, does not require photocells 58, since its value can be calculated from the other colors, but may have them for reasons well-known in the television art.

Color matrixing and gamma adjustment are performed electrically by conventional circuits identified by the reference numeral 60. When the proper signal has been derived, it is amplified by power amplifiers 62 which drive the capillary ohmic heaters 42. It will be appreciated that while not explicitly shown, there is a polarity inversion involved in the system since the resistors 42 are powered for "black" and unpowered for "white."

The circuit shown in FIG. 5B depicts in block diagram form the electronics for a two dimensional scan. The image information is supplied as a scanned electronic signal such as a television signal. In general, the parameters of the scanned electronic signal, such as frame-rate, number of lines, differ markedly from a standard television signal and the signal is non-interlaced. The signal can be generated in a number of ways either directly by electronic equipment such as a computer, or from video-tape or by a camera using electronic or mechanical scanning with or without image storage (integration) and with a scanned or unscanned light source. Conventional camera technology and electronic signal generation and processing are employed in the present invention and need not be described in detail. It is sufficient to note that some of the currently available camera technique which can be employed to produce the scanned electronic signal include: image orthicon, vidicon, flying-spot scanner, rotating mirrors, rotating prisms, scanned laser light source and dichroic mirror color separation.

The "television" or signal parameters are selected for the speed, aspect ratio, and resolution desired. Compared to standard 525 line television signals, representative values for printing three $8\frac{1}{2} \times 11$ inch copies per second at 150-screen resolution are: 1/10 the frame rate; 10 times the resolved picture elements; and the same bandwidth.

In the case of color printing, the colors in the original are separated and matrixed electronically to produce separate television signals for each color ink used in the printing process. In addition, gray-scale (gamma) correction to the television signal is done before it is fed to the printing unit. As shown in FIG. 5B, the "television" signal for the color in question comes in on a "video bus" 64 extending across the width of the printing head 32. The signal is then descanned by well known circuit techniques such as, a shift register sampler comprising shift register 66 and samplers 68. Amplifiers and resistors 62 and 42 respectively, perform the same function as in connection with FIG. 5A. Interconnections between the colors for matrixing purposes are not required, but the shift register 66 may be shared by all colors.

It will be appreciated that the electronic configuration shown in FIG. 5B has the advantage that the image can be manipulated or stored for subsequent usage while in electronic form. Manipulations include transmission, storage, collating, masking, mixing, negative, contrast enhance, color correction and other specialized alterations such as sequence numbering of printed forms. These manipulations of the electronic signal are

performed by conventional and well-known signal processing circuits or by computer.

FIG. 6 illustrates in diagrammatic form two alternative constructions of the printing head, which utilize conductive heating or electromagnetic radiation absorptive heating of the printing ink. Two electrodes 70 and 72 are positioned within the ink reservoir 28 at the entry to capillary 36, which capillary is formed in an electrical insulator 74. If electrically conductive printing ink is employed, the intelligence signal modulated current flow through the ink between electrodes 70 and 72 produces the desired thermal viscosity modulation. Suitable power amplification can be provided in this mode of operation.

Electromagnetic radiation heating of the printing ink is another method which can be utilized to achieve thermal viscosity modulation of the printing ink. In this case, the intelligence signal on line 18 (or from computer 19) modulates a source 76 of radio frequency energy. The modulated rf is applied to the capillary electrodes 70 and 72 through switch means 78.

In order to obtain a smoother transfer of the ink from the capillary orifices to the ink receptor 26, the preferred printing system utilizes an "air brush" and electrostatic transfer techniques. Looking at FIG. 7, there is shown in simplified form both the "air brush" and electrostatic transfer systems. The air brush system comprises a source 80 of pressurized gas, such as air, and an outlet nozzle 82 positioned above the capillary orifices. The high velocity air stream exiting from nozzle 82 forces the discharged ink from the capillaries downwardly onto the paper ink receptor 26. The printing head is positioned with little or no gap between the head and the ink receptor. It will be appreciated that the air brush structure shown in FIG. 7 comprises what is known in the art as "focused" air brush.

Electrostatic ink transfer techniques can also be employed either alone or in combination with the air brush system shown in FIG. 7 or the simple friction transfer system depicted in FIG. 2. A high voltage potential either DC or rapidly pulsed is applied between the ink receptor 26 and the printing head 32. For purposes of illustration, the source of the high voltage potential is illustrated in FIG. 7 as a conventional battery 84. However, it will be appreciated that other conventional sources of a steady state or pulse DC potential can be employed.

Having described in detail a preferred embodiment of my invention, it will be appreciated that the invention can be used in a number of applications. Typically, such applications include photocopying, printing, computer printout, soft copy output with a non-drying ink printed on an endless belt of washable material, facsimile, photographic printing, direct photography, typewriter, and telegraphic printers.

What I claim is:

1. A method for thermal viscosity modulating a fluid stream with an intelligence signal comprising the steps of:

1. passing the fluid stream through a modulation station using a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the fluid stream to modulate the flow of said fluid stream; and,
2. time varying the temperature of at least a portion of the fluid stream at the modulation station in response to the intelligence signal whereby said sig-

nal is impressed upon said fluid stream in the form of thermally produced variations in the viscosity of the fluid stream which correspondingly alter the flow of the fluid stream.

2. The method of claim 1 wherein the intelligence signal is an electrical current and the temperature of said fluid stream is time varied at the modulation station by passing the electrical current through a resistive element that is located at said modulation station and in thermally conductive contact with said fluid stream.

3. The method of claim 1 wherein said fluid is electrically conductive and said intelligence signal is an electrical current which is passed through said fluid stream at said modulation station.

4. The method of claim 1 wherein said intelligence signal comprises electromagnetic radiation which is absorbed by said fluid stream at said modulation station.

5. The method of claim 1 wherein said viscosity modulated fluid stream is deposited upon a fluid receptor.

6. A method of printing an image comprising the steps of:

1. generating an electrical signal which represents the image in scanned form;
2. passing at least one stream of printing ink through a modulation station using a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the fluid stream to modulate the flow of said fluid stream;
3. time varying the temperature of at least a portion of the printing ink stream at the modulation station in response to the electrical signal whereby said signal representation of the scanned image is impressed upon the printing ink stream in the form of thermally produced variations in the viscosity of the ink stream which correspondingly alter the flow of the ink stream; and,
4. depositing at least a portion of said thermal viscosity modulated printing ink stream upon an ink receptor in accordance with the scanned form of said image.

7. The method of claim 6 wherein said electrical signal is generated by scanning an original which contains said image.

8. The method of claim 6 wherein said electrical signal is computer generated.

9. The method of claim 6 further characterized by:

1. introducing said modulated ink stream into a rapidly flowing stream of gas; and,
2. directing the ink carrying gas stream against said ink receptor whereby the thermal viscosity modulated ink is deposited on said ink receptor.

10. The method of claim 6 further characterized by establishing an electric potential between said modulation station and said ink receptor.

11. An apparatus for printing an image comprising:

1. means for generating an electrical signal which represents the image in scanned form;
2. printing ink reservoir means;
3. means for pressurizing said reservoir means, said pressurized ink reservoir means being a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the ink to modulate the flow of said ink;
4. means defining at least one capillary tube, said tube being fluidly coupled at one end to said ink

reservoir means and open at the other end to form an ink discharge orifice;

5. ohmic heating means positioned for thermal coupling to the ink passing through said capillary tube;

6. means for applying said electrical signal to said ohmic heating means whereby said electrical signal is impressed upon said ink in the form of thermally produced variations in the viscosity of the ink which correspondingly alter the flow of the ink; and,

7. means for producing relative motion between an ink receptor and the discharge orifice of said capillary tube corresponding to the scanned form of said image.

12. The printing apparatus of claim 11 wherein said capillary tube defining means defines a plurality of capillary tubes which represent one horizontal scan of said image and wherein said means for producing relative motion produces a relative motion corresponding to the vertical scan of said image.

13. The printing apparatus of claim 11 wherein said means for generating an electrical signal comprises an optical scanner.

14. The printing apparatus of claim 11 wherein said means for generating an electrical signal comprises a computer.

15. The printing apparatus of claim 11 further characterized by focused air brush means positioned to direct the thermal viscosity modulated ink exiting from the ink discharge orifice onto said ink receptor.

16. The printing apparatus of claim 11 further characterized by means for establishing an electrostatic potential between said capillary and said ink receptor.

17. The apparatus of claim 11 further comprising heat sink means thermally coupled to the printing ink within said capillary.

18. A method of printing an image comprising the steps of:

1. generating an electrical signal which represents the image in scanned form;

2. passing at least one stream of printing ink through a modulation station using a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the printing ink stream to modulate the flow of said printing ink stream;

3. time varying the temperature of at least a portion of the printing ink stream at the modulation station in response to the electrical signal whereby said signal representation of the scanned image is impressed upon the printing ink stream in the form of thermally produced variations in the viscosity of the ink stream which correspondingly alter the flow of the ink stream; and,

4. entraining the thermal viscosity flow modulated printing ink stream in a gas stream and, thereafter

5. depositing the entrained printing ink stream on an ink receptor in accordance with the scanned form of said image.

19. An apparatus for printing an image comprising:

1. means for generating an electrical signal which represents the image in scanned form;

2. printing ink reservoir means;

3. means for pressurizing said reservoir means, said pressurized ink reservoir means being a motive source having sufficient mechanical admittance to

permit thermally produced variations in the viscosity of the ink to modulate the flow of said ink;

4. means defining at least one capillary tube, said tube being fluidly coupled at one end to said ink reservoir means and open at the other end to form an ink discharge orifice;

5. electrical signal responsive heating means positioned for thermal coupling to the ink passing through said capillary tube;

6. means for applying said electrical signal to said heating means whereby said electrical signal is impressed upon said ink which correspondingly alter the flow of the ink; and,

7. means for producing relative motion between an ink receptor and the discharge orifice of said capillary tube corresponding to the scanned form of said image.

20. The apparatus of claim 19 further comprising focused airbrush means positioned to direct the thermal viscosity modulated ink exiting from the ink discharge orifice onto said ink receptor.

21. The apparatus of claim 19 further comprising heat sink means thermally coupled to the printing ink within said capillary.

22. An apparatus for printing an image comprising:

1. means for generating an electrical signal which represents the image in scanned form;

2. printing ink reservoir means, said pressurized ink reservoir means being a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the ink to modulate the flow of said ink;

3. means defining a printing ink modulation station having an inlet and an outlet with the inlet being fluidly coupled to said printing ink reservoir means;

4. means with appreciable mechanical admittance for causing the ink to pass through said printing ink modulation station;

5. electrical signal responsive heating means positioned for thermal coupling to the printing ink passing through said printing ink modulation station;

6. means for applying said electrical signal to said heating means whereby said electrical signal is impressed upon said printing ink in the form of thermally produced variations in the viscosity of the ink which correspondingly alter the flow of the printing ink; and,

7. means for producing relative motion between an ink receptor and the outlet of said printing ink modulation station corresponding to the scanned form of said image.

23. The apparatus of claim 22 further comprising focused airbrush means positioned to direct the thermal viscosity modulated ink exiting from the outlet of said printing ink modulation station onto said ink receptor.

24. The apparatus of claim 22 further comprising heat sink means thermally coupled to the printing ink at said printing ink modulation station.

25. An apparatus for printing an image comprising:

1. means for generating an electrical signal which represents the image in scanned form;

2. printing ink reservoir means, said pressurized ink reservoir means being a motive source having sufficient mechanical admittance to permit thermally produced variations in the viscosity of the ink to modulate the flow of said ink;

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3. means defining a printing ink modulation station having an inlet and an outlet with the ink being fluidly coupled to said printing ink reservoir means;
4. means with appreciable mechanical admittance for causing the ink to pass through said printing ink modulation station;
5. means for impressing said electrical signal upon the printing ink in the form of thermally produced variations in the viscosity of the ink which correspondingly alter the flow of the ink; and,
6. means for producing relative motion between an ink receptor and the outlet of said printing ink

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modulation station corresponding to the scanned form of said image.

26. The apparatus of claim 25 further comprising heat sink means thermally coupled to the printing ink at said printing ink modulation station.

27. The apparatus of claim 25 further comprising means for entraining the thermal viscosity modulated printing ink in a gas stream with said entrained printing ink being deposited upon said ink receptor in accordance with the scanned form of said image.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,790,703

Dated February 5, 1974

Inventor(s) Adam Loran Carley

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 54, "dystem" should be --system--.

Column 4, line 2, "and" should be --has--.

Column 4, line 4, "100" should be --1000--.

Column 8, line 5, "the" second occurrence should be --said--.

Column 8, line 55, "electric" should be --electrostatic--.

Column 10, line 28 delete "pressurized".

Column 10, line 63 delete "pressurized".

Column 10, line 11, after "said ink" insert -- in the form of thermally produced variations in the viscosity of the ink--.

Column 11, line 2, "ink" should be --inlet--.

Signed and sealed this 26th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents