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Mahoney et al.

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[45] **Nov. 12, 1974**

[54] **MULTI-JET INK PRINTER**

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[52] **U.S. Cl.** **346/140,** 118/625, 118/638, 346/75

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

[58] **Field of Search** 346/140, 75; 118/621, 623, 118/625, 629, 638; 317/3

[56] **References Cited**

UNITED STATES PATENTS

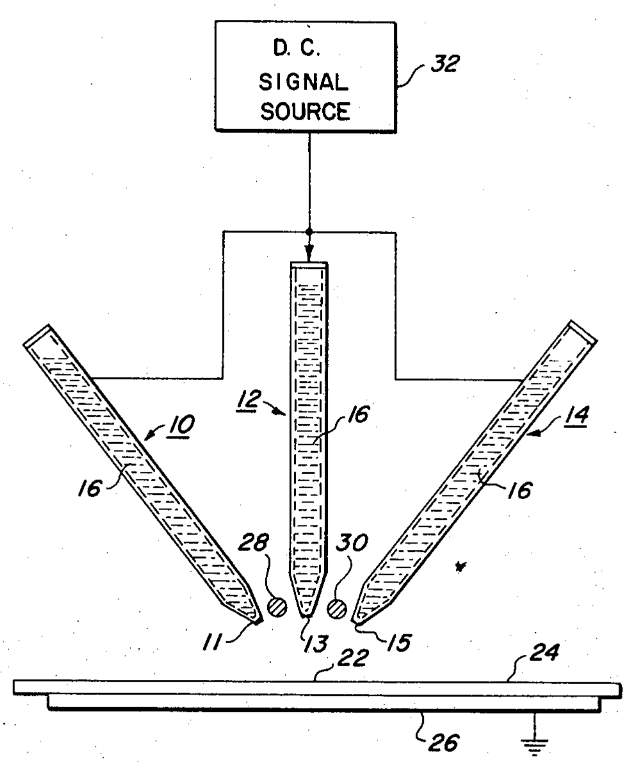
3,052,213	9/1962	Schaffert	118/637
3,341,859	9/1967	Adams	346/140
3,446,183	5/1969	Drum	118/629

Primary Examiner—Joseph W. Hartary

[57] **ABSTRACT**

An ink printer system in which line thickness and line separation are regulated by disposing a plurality of ink nozzles in a converging array and limiting undesirable electrostatic attraction forces active in the system. In one embodiment, an electrode is positioned between each adjacent pair of nozzles of the array with the electrodes being connected to a d.c. source having a value less than the peak value of the voltage pulses applied to the nozzles. In a second embodiment, alternate nozzles of the array receive video pulses of the opposite polarity whereby jets of ink drops having opposite charges are formed by adjacent nozzles of the array.

7 Claims, 3 Drawing Figures



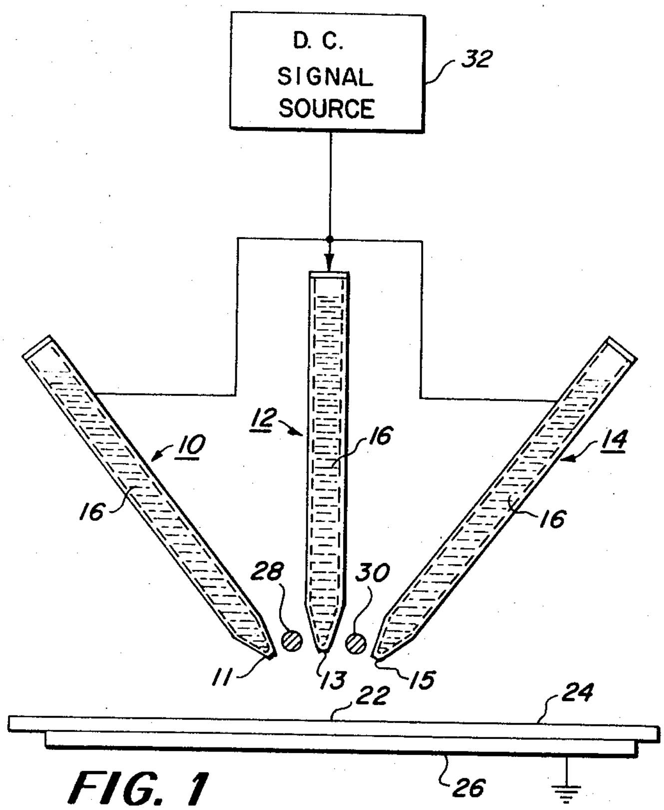

D. C.
SIGNAL
SOURCE
32
12
16
10
14
16
16
28
30
11
13
15
22
24
26

FIG. 1

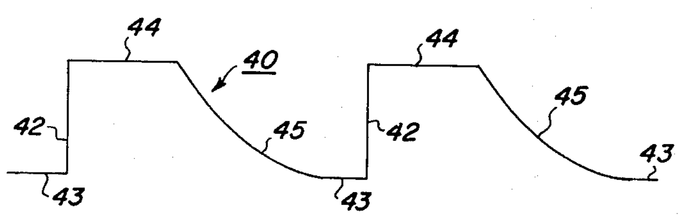

44
40
44
45
42
45
42
45
43
43
43
43

FIG. 2

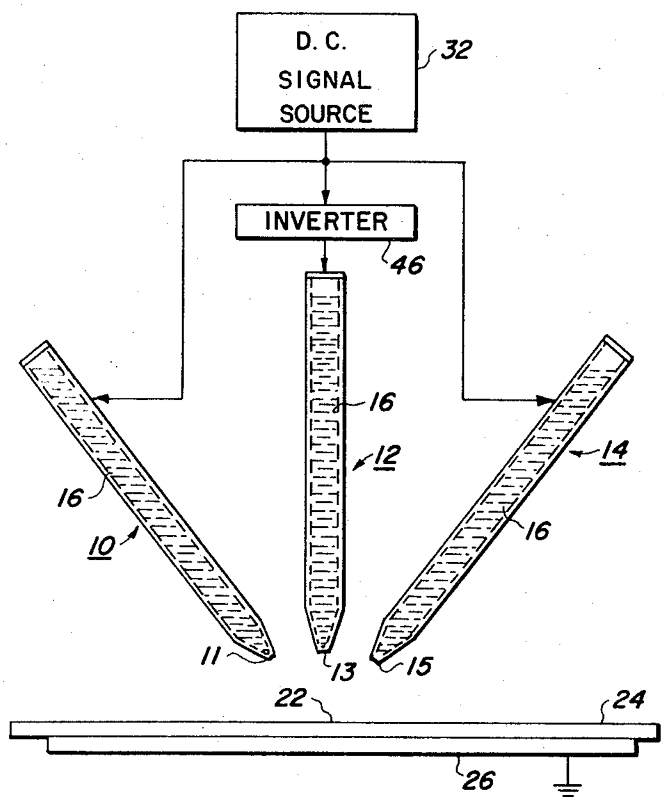

D. C.
SIGNAL
SOURCE
32
INVERTER
46
16
12
14
16
10
16
11
13
15
22
24
26

FIG. 3

MULTI-JET INK PRINTER

BACKGROUND OF THE INVENTION

Prior art devices for recording with liquid ink are generally of three basic types. The first type operates with physical contact between an ink-fed stylus and a recording surface with the stylus being physically removable from the recording surface on receipt of an appropriate signal. Drawbacks of this system include difficulty associated with physical removal of the stylus under varying conditions of operation. At high operating speeds, such as is associated with a fast flow of intelligence, a highly damped, relatively non-elastic mechanical system is required which becomes impractical or impossible to construct.

A second of the prior existing types for liquid ink recording devices is one in which an ink-fed stylus is maintained in constant contact against a recording surface and is moved relative thereto in order to record information. Like the last mentioned type, this provides a continuous mark on the recording surface at all times when the stylus and recording surface are in contact. This type has been largely limited in practical applications to oscillograph use since mechanical complexity has been regarded as too prohibitive to control a continuously marking stylus for the tortuous configurations necessary for modern, sophisticated writing.

The last of the aforementioned types is referred to as "ink spitters" and includes devices in which ink is projected across a gap from a nozzle point to a recording medium. One type of ink spitter is known as a "continuous flow" system in which ink drops are formed continuously in response to pressure and vibration. In the region adjacent to the nozzle there is placed a charging tunnel through which the ink drops are projected and which serves the function of applying charge to selected ink drops in accordance with a desired video signal to be produced. Downstream of the tunnel there is provided a set of deflecting plates which have a potential difference between them. The electric field which is created between the plates acts on the charged drops causing them to be deflected in an amount determined by the amplitude of the applied potential difference. Downstream of the deflection plates, a trough is provided for catching drops which do not have any charge and transferring them to a waste reservoir. There is provided also a writing medium which receives the deflected ink drops, whereby an image representative of the video signals is produced. The writing medium is usually moved in synchronism with the application of the video signals to the drops. In addition to requiring an ink waste reservoir and possibly pumping means for transferring ink from the reservoir to the nozzle, with the inherent possibilities of ink spillage and failure of mechanical parts with such a system, the continuous flow ink spitters may not provide fidelity with the video signal. Obviously, if the video signal is in the process of rising or falling, or is not present at the time the drops separate, the charge on the drops will not be indicative of the video signal. In order to place separate charges on given drops, one must know when drop separation is occuring or the phasing of the drop formation relative to the video signal. In the absence of control of drop separation time, because of unpredictable phase changes in the ink drop formation, the uniformity and the fidelity of the printing are effected adversely.

A second type of "ink spitter" is known as an "on-demand" system in which ink drops are formed selectively in accordance with the video signal, all ink drops formed impinge on the recording medium. Such systems are described in U.S. Pat. Nos. 3,341,859 and 2,143,376. In these systems a conductive bar is placed behind the writing medium with a voltage of one polarity applied to the bar that is insufficient to draw ink from the nozzle. When it is desired to print, square wave or rectangular wave voltage pulses of the other polarity are selectively applied to the nozzle, and the paper is moved. The resulting electrostatic field between the nozzle and the bar will overcome the liquid surface tension and draw ink from the nozzle to the writing medium.

The desirability of an ink system that uses all ink drops for printing is apparent, that is, no ink drop deflection or ink recirculation is required. However, it is often desirable to provide greater ink line thickness than can be produced with a single nozzle. For this purpose it has been found convenient to arrange a plurality of ink nozzles or jets in a converging array (see U.S. Pat. No. 3,373,437). Such an arrangement of jets permits greater spacing between the individual jets than jets arranged in parallel. In such systems, where ink drops are formed by an array of jets, voltage pulses of one polarity are applied simultaneously to selected nozzles and hence a plurality of jets of ink drops having the same charge are produced.

Since the jets of ink drops produced by a converging array of nozzles are of the same polarity, the electrostatic forces on the ink drops near the nozzles causes the jets to diverge while moving toward the writing medium. This repulsion results in an undesirable widening of the line thickness and, in some cases, variable line thicknesses. Furthermore, the electrostatic repulsion makes it difficult to provide two ink lines with a fixed spacing therebetween.

It is therefore an object of the present invention to provide an improved "on-demand" ink printing system.

It is a further object of the present invention to provide an improved "on-demand" ink printing system having an array of nozzles that can produce ink lines of controlled thickness.

It is a further object of the present invention to provide an improved "on-demand" ink printing system having a plurality of nozzles in a converging array.

In accordance with the invention, an ink printing system is provided in which line thickness and line separation are regulated by disposing a plurality of ink nozzles in a converging array and limiting undesirable electrostatic attraction forces acting on the jets of charged ink drops emanating from the nozzles. In one embodiment, an electrode is positioned between each adjacent pair of nozzles of the array with the electrodes being connected to a d.c. source having a value less than the peak value of the voltage pulses applied to the nozzles. The polarity of the d.c. source is generally the same as that of the voltage pulses applied to the nozzles. In a second embodiment, alternate nozzles of the array receive video pulses of the opposite polarity whereby jets of ink drops having opposite charges are formed by adjacent nozzles of the array. With both embodiments undesirable electrostatic interaction forces active in the system are limited, thereby allowing the jets of ink drops to follow a substantially straight-line path from the nozzles to a selected area of the recording medium.

The novel features of the invention are set forth in particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of one embodiment of the ink printing system in accordance with the present invention.

FIG. **2** shows a waveform that can be supplied to the nozzles of the ink printing systems of FIGS. **1** and **3.**

FIG. **3** is a second embodiment of an ink printing system in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, the apparatus includes a plurality of elongated ink nozzles **10, 12,** and **14** containing a quantity of liquid recording ink **16** which is electrically conductive. Ink **16** may be a pigment-based ink or a dye-based ink having an acceptable specific viscosity, conductivity, and surface tension. The nozzles taper from a large diameter and terminate in short capillary tips **11, 13,** and **15,** respectively. Since the hydrostatic pressure at the nozzle tips is equivalent to only about 1 cm of water, the capillary forces at the capillary tips are not overcome, and hence ink does not normally flow from the nozzles **10, 12,** and **14.** Instead, a convex meniscus forms on the tips of the nozzles. A flow in the form of ink drops of very small cross section is produced only when the meniscus is subjected to the action of an electrostatic field of a certain value. The inner diameter of the tips **11, 13,** and **15** can be rather large, for example, 0.15mm, since the pressure is low. The outer diameter of the tips **11, 13,** and **15** controls the size of the meniscus, and is of the order of 0.25mm. Nozzles **10, 12,** and **14** are positioned in a converging array such that ink drops emanating therefrom are projected toward a common area **22** of a recording medium **24** which passes over a platen **26** which is preferably at ground potential. While it is presently contemplated that the preferred form of the invention would include a circular array of nozzles with uniform spacing between nozzles, it will be appreciated that such uniform spatial relationship of the nozzles is not essential.

If the voltage pulses to each nozzle have the same polarity, the ink drops of the jets flowing from the nozzles will have that polarity, that is, if a positive going voltage pulse is supplied to the nozzles **10, 12,** and **14,** the ink drops of the jets flowing from the nozzles will have a positive charge. As the newly formed charged ink drops leave the nozzles, the electrostatic interaction forces active in the vicinity of the nozzles causes the trajectories of the newly formed ink drops from different nozzles to diverge. This divergence often causes ink drops to bombard the recording medium outside of area **22** of recording medium **24** resulting in an undesirable separating or widening of ink line thickness. Furthermore, if it is desired to form a plurality of individual lines having a desired spacing therebetween within area **22,** each nozzle producing one line, the electrostatic forces on the jets of ink drops may cause the line spacing to increase or vary sporadically.

To overcome the electrostatic interaction forces active in the vicinity of the nozzles **10, 12,** and **14,** an electrode **28** is provided between nozzles **10** and **12** and an electrode **30** is provided between nozzles **12** and **14.** Electrodes **28** and **30** have a d.c. signal supplied thereto which signal has a value between the maximum value of the pulses supplied to the nozzles and the potential of platen **26.** For example, if the voltage pulses supplied to nozzles **10, 12,** and **14,** by source **32** have a maximum positive value of 3–3.5 kilovolts with respect to ground, and the platen **26** is grounded, the d.c. signal supplied to electrodes **28** and **30** would have a positive value of between 2–2.5 kilovolts with respect to ground. If the platen **26** was at a negative potential with respect to ground, the value of the signals applied to the nozzles and the electrodes **28** and **30** could be reduced and, if the negative potential on platen **26** had a sufficient value, the signal applied to electrodes **28** and **30** may be of the opposite polarity as the signal applied to the nozzles. The intermediate electrodes **28** and **30** control electrostatic interaction between adjacent nozzles, and hence control electrostatic forces on newly formed ink drops with the result that the trajectories of the ink drops from the different nozzles do not diverge.

FIG. **2** depicts the pulses of a waveform **40** illustrative of the signal supplied by source **32,** each pulse producing desirably several ink drops. As shown, each pulse has a rapidly rising leading edge **42** which increases to a predetermined level **44** of, for example, 3500 volts with the nozzles and ink specifically mentioned previously, and is maintained at level **44** for a brief period, 100 microseconds being appropriate. Preferably, the trailing edge **45** of each pulse decreases slowly either linearly or exponentially, as shown, to about base level **43.**

FIG. **3** is illustrative of another embodiment of the invention in which divergence of the trajectories of jets of ink drops from different nozzles of any array is controlled without intermediate electrodes. In this embodiment, in which components corresponding to like components of FIG. **1** have the same reference numbers, the waveform supplied to the intermediate nozzle **12** is of the polarity opposite to the polarity of the waveforms supplied to nozzles **10** and **14.** As shown, this can be achieved by means of a conventional inverter circuit **46** disposed in the circuit supplying nozzle **12.** With this system, the ink drops from nozzles **10** and **14,** for example, have a positive polarity, and the ink drops from nozzle **12** have a negative polarity. Since the ink drops of the jet from middle nozzle **12** are of the polarity opposite to those ink drops from the outer nozzles **10** and **14,** repulsion forces between the outer jets is prevented. Thus, ink lines of constant thickness or ink lines of controlled separation can be achieved.

In the system of FIGS. **1** and **3,** the nozzles **10** and **14** are preferably offset at an angle of 15°–30° with center nozzle **12** which is orthogonal to the plane of recording medium **24.** Nozzles **10, 12,** and **14** are preferably a distance of about 0.060 inches from area **22** of recording medium **24.** In the embodiment of FIG. **1,** electrodes **28** and **30** are preferably equidistant from nozzles **10** and **12,** and nozzles **12** and **14,** respectively, and preferably about 0.060 inches from areas **22** of recording medium **24.**

While the invention has been described with reference to preferred embodiments thereof, it will be apparent to those skilled in the art that various changes may be made without departing from the true spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A fluid printer for writing on a record medium comprising:

an array of a plurality of fluid-containing nozzles each having a capillary tip, the array being oriented such that a projection of the longitudinal axes of said nozzles converge toward an area of said record medium,

first means for maintaining the voltage of said record medium at a reference value,

second means for selectively supplying voltage pulses of the same polarity to the fluid contained in said nozzles, said voltage pulses having a peak value different from said reference value,

an electrode disposed between adjacent pairs of said nozzles in the vicinity of said capillary tips of said nozzles, and

third means for applying to said electrodes a voltage intermediate said peak value and said reference value thereby to allow fluid drops from said capillary tips to converge toward said area of said record medium even though the drops have the same polarity due to voltage pulses of the same polarity being applied to the fluid contained in said nozzles.

2. The printer of claim **1** wherein said nozzles are offset to each other at an angle of between **15** and **30** degrees.

3. The printer of claim **2** wherein said peak value of said voltage pulses is in the range of 3,000 to 3,500 volts and said intermediate voltage has a value in the range of 2,000 to 2,500 volts.

4. A fluid printer for writing on a record medium comprising:

an array of a plurality of fluid-containing nozzles each having a capillary tip, the array being oriented such that a projection of the longitudinal axes of said nozzles converge toward an area of said record medium,

first means for maintaining the voltage of said record medium at a reference value,

second means for supplying voltage pulses of opposite polarity to the fluid contained in adjacent of said nozzles to thereby reduce undesirable electrostatic forces between fluid drops issuing from the capillary tips of adjacent nozzles.

5. The printer of claim **4** wherein said nozzles are offset to each other at an angle of between 15° and 30°.

6. A fluid printer for writing on a record medium comprising:

an array of a plurality of fluid-containing nozzles each having a capillary tip, the nozzles of the array being offset to each other at an angle of between 15° and 30° and being oriented such that a projection of the longitudinal axes of said nozzles converge toward an area of said record medium,

first means for maintaining the voltage of said record medium at a reference value,

second means for selectively supplying voltage pulses of the same polarity to the fluid contained in each of said nozzles, said voltage pulses having a peak value different from said reference value,

an electrode disposed between adjacent pairs of said nozzles in the vicinity of the capillary tips of said nozzles, and

third means for supplying to said electrodes a potential having a value between said peak value and said reference value thereby to allow fluid drops from said capillary tips to converge toward said area of said record medium even though the drops have the same polarity due to voltage pulses of the same polarity being applied to the fluid contained in said nozzles.

7. A fluid printer for writing on a record medium comprising:

an array of a plurality of fluid-containing nozzles each having a capillary tip, the nozzles of the array being offset to each other at an angle of between 15° and 30° with the array being oriented such that a projection of the longitudinal axes of said nozzles converge toward a common area of said record medium,

first means for maintaining the voltage of said record medium at a reference value,

a source of voltage pulses,

second means for coupling said source to alternate of said nozzles,

an electrical inverting circuit, and

third means coupling said source through said inverting circuit to the nozzles intermediate said alternate nozzles.

* * * * *