United States Patent

Skala

[15] **3,693,179**

[45] **Sept. 19, 1972**

[54] **PRINTING BY SELECTIVE INK EJECTION FROM CAPILLARIES**

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[22] Filed: **Sept. 3, 1970**

[21] Appl. No.: **69,248**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 801,647, Feb. 24, 1969, Pat. No. 3,582,954.

[52] **U.S. Cl.** **346/1,** 346/140

[51] **Int. Cl.** **G01d 15/16**

[58] **Field of Search** 346/1, 75, 140; 101/1

[56] **References Cited**

UNITED STATES PATENTS

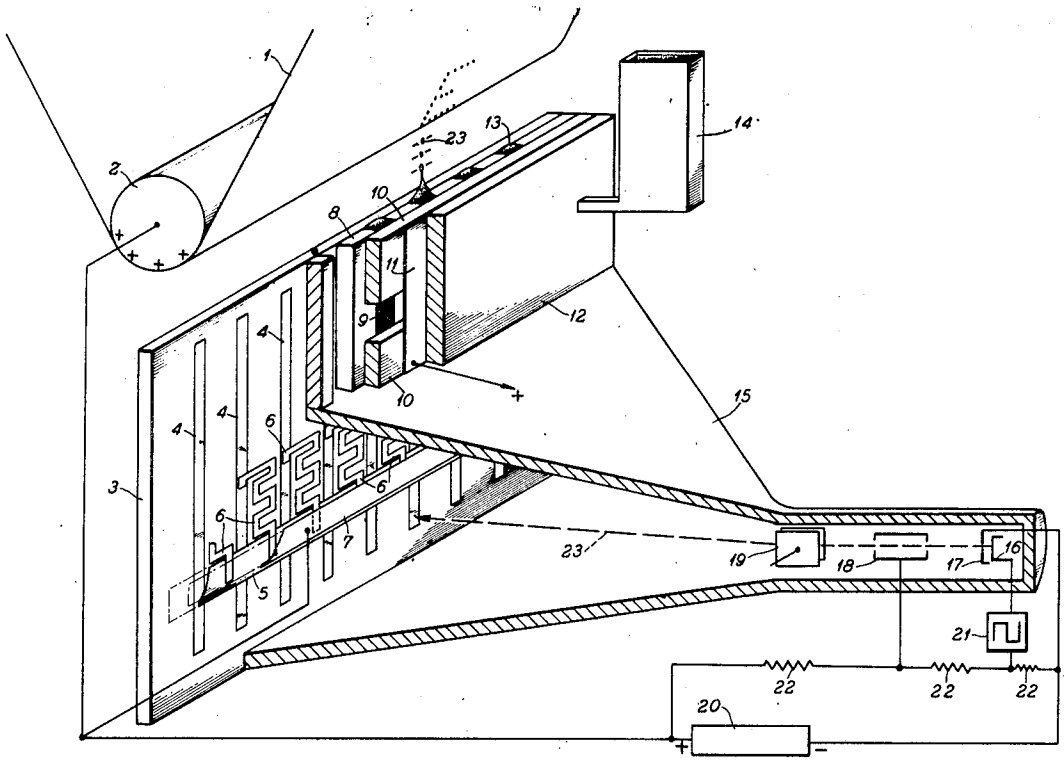
2,556,550	6/1951	Murray	101/426
3,480,962	11/1969	Weigl et al	346/1
3,553,719	1/1971	Miyazaki	346/140
3,582,954	6/1971	Skala	346/1

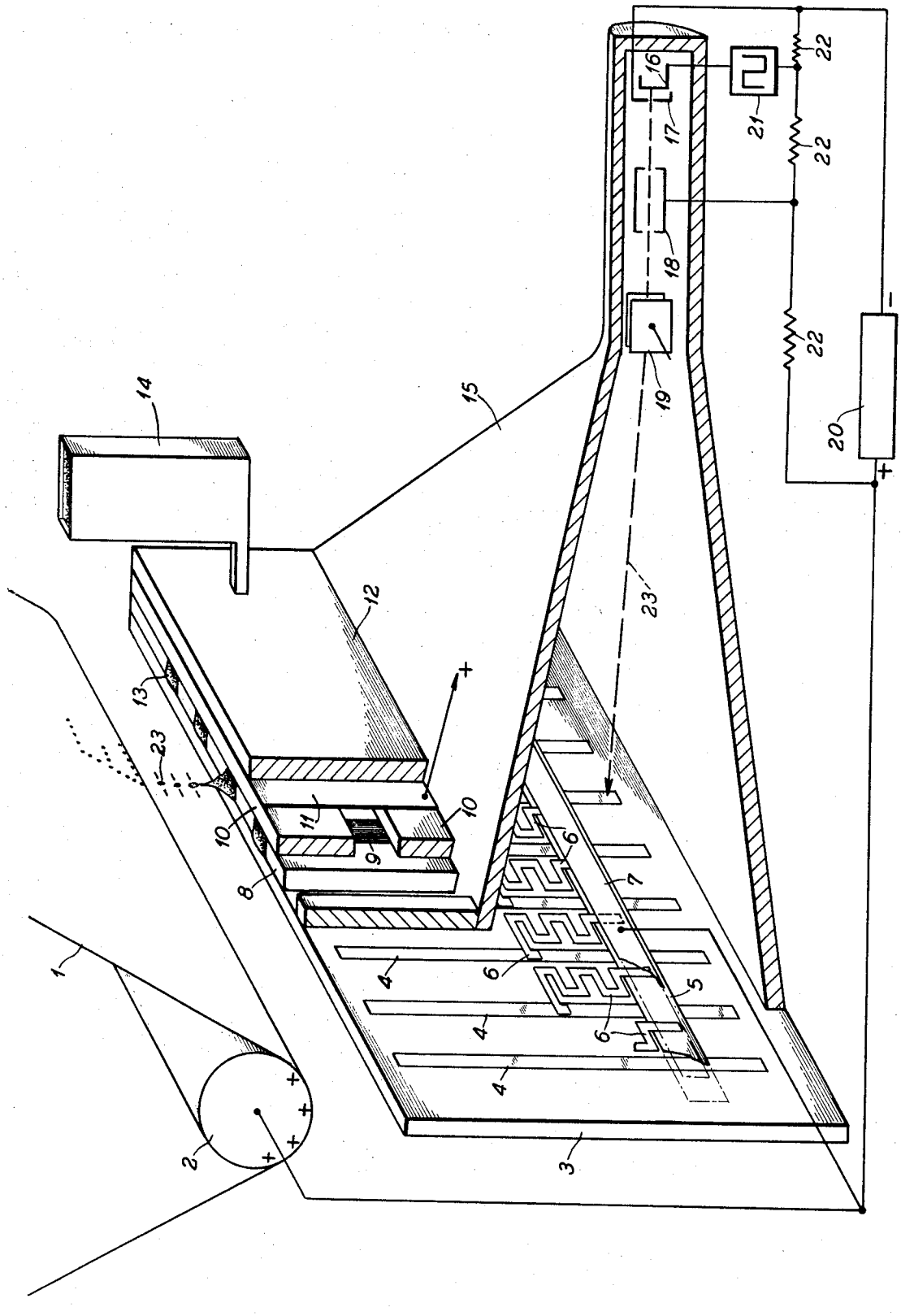
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[57] **ABSTRACT**

A printing method and apparatus in which a plurality of capillaries eject ink selectively. Ink is moved to the capillary surface and is further acted upon by a force external to the capillaries, the combination of forces being sufficient to remove ink from said capillary and to deposit it upon an ink receiving surface.

2 Claims, 1 Drawing Figure




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PRINTING BY SELECTIVE INK EJECTION FROM CAPILLARIES

This invention relates to a method and apparatus for producing ink droplet illustrations on a receiving surface. This application is a continuation-in-part of U.S. application, Ser. No. 801,647, filed Feb. 24, 1969 by the same applicant now U.S. Pat. No. 3,582,954.

Conventional publication requires a complex system of preparation of reproduction masters, printing facilities, and distribution means. Despite continued improvements in the processing of information by computer assisted preparation of text and illustrations, intrinsic system inefficiencies remain.

Several approaches which have attracted interest overcome these inefficiencies by transmitting information and recording this information directly on a subscribers apparatus. Among these approaches are the xerographic systems which convert electrical signals to an optical image and record this image by well known electrostatic means. Another method produces a stream of charged liquid ink droplets and electrostatically deflects these droplets to form characters on a receiving surface as shown in the Winston patent, U.S. Pat. No. 3,060,429. Of more particular interest are the methods which print by selectively ejecting ink droplets from capillaries, particularly from a plurality of such capillaries in accordance with a program so that the plurality of dots deposited on a printing surface such as paper assumes intelligible forms. Several methods have been proposed which eject ink droplets by a force internal to a capillary. Reference may be made, for example, to U.S. Letters Pat. No. 3,211,088 issued to M. Naiman on Oct. 12, 1965. In the Naiman patent a pressure producing transducer, such as a piezoelectric crystal is actuated to cause a shock wave to propagate through a passageway having the configuration of an exponential horn. The ink is ejected out of such passageways as droplets and deposited on paper to form letters.

It will be understood that a row of such passageways or capillaries can be moved across the surface of a sheet of paper while droplets are ejected in a predetermined manner from capillaries to form letters on the moving surface. It will be realized that a single letter may comprise an array of deposited droplets so that the visual perception is that of a solid block letter; and it is further realized that such droplets may follow the line of the letter to present a visual appearance of the individual droplets.

Such a means of printing has attractions but presents problems at most of the steps or with most of the features associated with such means. Attention is required to such steps and features, particularly, delivering ink to the capillaries, manipulating the ink within the capillaries for ejection, ejecting the ink, and directing the ink to a printing surface such as paper. It is desirable to improve these features and steps so that the system of printing by ink droplet ejection capillaries will be made more attractive to users.

It is accordingly a general object of this invention to provide a novel and improved system for transmission of graphic information and its reception and processing on a receiving surface.

Another object is to provide an improved system which can be utilized to transmit information in an improved manner to users such as subscribers who can receive and process such information on conveniently accessible apparatus. In such a system, distribution of information is immediate to the subscriber, and particular features of the information may be selected by the subscriber. Likewise, a large geographic area may be serviced by such a system in which information is electronically distributed throughout a wide geographic area, and is received by a subscribers processing apparatus to obtain a graphically useful form.

Another object is to provide a method and apparatus by which ink is ejected under the control of electric signals in an improved manner to print on ordinary pulp paper, thereby eliminating any requirements of specially sensitized surfaces or the like.

Yet another object of this invention is to provide a method and apparatus whereby ink droplets are ejected in an improved manner from small dimension capillaries whereby the normally encountered surface forces retarding the formation and release of the small ink droplets are overcome to obtain the desired resolution and deposition of such droplets on paper.

Other characteristics, advantages, and objects of this invention will become apparent from the following detailed description, including drawings wherein:

The FIGURE of the drawing is a highly diagrammatic illustration of an apparatus useful in the practice of the method.

The present invention provides a means of forming an image from patterns of dots on a contrasting background. Dots of constant size may be deposited at regularly spaced coordinates. Letter characters may be provided as a plurality of closely spaced dots separated by areas without dots. Pictures may be provided by a plurality of dots spaced at varying intervals. The pattern of the deposited dots are preferably obtained from a row of aligned capillaries positioned in depositing relationship next to a printing surface such as a sheet of paper. Relative movement is provided between the sheet of paper and the row of capillaries so that the graphic information is sequentially deposited on the area of the paper. The final pattern of the dots is a composite of the respective rows of dots, each row being deposited sequentially.

The following use and operation relative to the embodiment to be later dbscribed, includes representative operational ranges. A resolution of 140 dots per inch corresponds to conventional gravure quality. This represents an information density of about 7,000,000 bits for a typical newspaper page. A typical page has about 3,000 words plus illustrations and drawings. With a printing time of one minute per page, the bandwith of the transmitted signal is about 10^5 Hz for monochrome. The printing cycle rate is about 50 rows of dots per second or 20 milliseconds per cycle. Accordingly, the capillary dimensions are about 0.003 inches in diameter on about 0.007 inch centers.

The behavior of fluids in small capillaries is determined to a large extent by their surface energy. In the printing cycle, the ink emerges from the capillary under the force of an electrostatic field. As it begins to protrude, an opposing force of surface tension develops and increases to a maximum when a hemispherical surface develops. Surface tension thus provides a stable

range in which forces bringing the ink outward are balanced by the opposing inward force of surface tension. A similar balance of forces occurs when the ink is withdrawn to the bottom of the capillaries to return them to the same state.

An important feature of the invention is the use of selective capillary tubes so that they form an array of such tubes. Such selected ink-loaded tubes may be used for transferring ink to the paper, or the like. The ink may be ejected from preselected tubes by the step of accelerating movement of the capillary assembly in a direction away from the proximate printing surface, or by utilizing an electrostatic force, or both. An electrostatic field may be created between the printing surface and the surface of the capillary assembly to induce the transfer of ink to the receiving surface. This electrostatic field also tends to prevent loss of resolution of the droplets as they travel from the capillary tubes to the printing surface.

The printing system illustrated in the drawing includes a sheet of ordinary paper **1** moving across a metal guide roll **2**. The guide roll is positioned adjacent to the capillary array of the printing unit shown in the drawing. The unit includes a substrate **3** which is an electrical insulator having on its surface a plurality of metal film actuating electrodes, indicated at **4**. A strip of dielectric film **5** is positioned over the electrodes. A plurality of film resistors **6** contacts each electrode and overlying metal strip **7**. A plurality of rectangular bars **8**, formed from an insulating material, are positioned between the electrodes. An ink channel **9** is defined between two insulating bars **10**. A metal strip **11** has an electrical connection to a positive voltage source. A cover strip or plate **12** for the unit has a passageway (not shown) through which outlet of ink reservoir passes to supply the ink channel **9**. A typical capillary, such as **13**, is formed by bars **8**, **10** and substrate **3**.

An electron tube envelope **15** is bonded to a lower portion of the printing unit, and such envelope has beam forming components which include cathode **61** and a control electrode **17**. Screen grid focusing and accelerating electrodes are collectively represented by **18**, and the envelope further includes deflection plates **19** of conventional design. A power supply **20** with positive and negative voltages at its terminals is connected to a voltage dividing network consisting of resistors **22**, the guide roll **2**, the metal strip **11**, and the control electrode **17**.

In operation, the ink reservoir provides ink under sufficient hydrostatic pressure to protrude, but not flow from the capillaries. An electron beam **23**, turned on or off by modulator **21**, is selectively directed to one of the actuation electrodes **4** by deflection plates **19**. Current flows from the actuation electrode **4** through a resistor **6** and into metal film **7**. The voltage drop across the resistor causes a potential difference between the upper part of the electrode and the metal guide roll **2**, and this potential difference causes an electric charge to flow through the electrically resistive ink and to accumulate on its protruding surface. The electric charge develops a force in the potential gradient causing ink to be withdrawn from the capillary and form charged droplets **23** which travel across a gap to the paper sheet. The metal sheet **11** provides a current path for the resistive ink to prevent leakage current to neighboring electrodes. It should be understood that additional rolls of capillaries and alternate electron beam forming methods, such as memory or charactron tubes, may be used within the teachings of the invention.

What is claimed is:

1. A method for graphically depositing ink droplets from a plurality of capillary tubes in a capillary assembly onto an adjoining printing surface, including the steps of

positioning a common body of ink adjacent to each tube in the assembly,

impressing a hydrostatic pressure on said common body of ink so that the ink loads said tubes and the ink projects from the opening of the tubes,

operating a vacuum tube in accordance with transmitted electric signals to modulate an electron beam,

selectively directing said electron beam to energize an actuation electrode present in each of said capillary tubes, and

impressing a potential from a voltage source in association with said printing surface which is higher than the induced potential in the selected capillary tubes, to thereby create an electrostatic force to induce transfer of the ink from the selectively actuated capillary tubes across a gap to the printing surface.

2. An apparatus for producing rapid droplet illustrations on a printing surface, including

a capillary assembly, said assembly having a plurality of aligned capillary tubes communicating with the surface of the assembly at one end and adjoining a common body of ink at the opposite end,

means to transmit an electric signal in accordance with information desired to be graphically illustrated on the printing surface,

reservoir means to impress a hydrostatic pressure on said common body of ink to load said capillary tubes,

a vaccum tube operated by a voltage source to modulate an electron beam,

an actuating electrode in each capillary tube for selective energization by said electron beam, and

means for impressing a potential from a voltage source on said surface which is higher than the induced potential of the ink in said selected capillary tubes to thereby create an electrostatic force as an external force means to induce transfer of the ink from the selected capillary tubes across a gap onto said printing surface.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,693,179 Dated September 19, 1972

Inventor(s) Stephen F. Skala

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

IN THE DRAWING

The dots of the capital letter "E" should be viewed as being separated at substantially greater distances to correspond generally with the capillary wells.

IN THE SPECIFICATION

Column 2, line 49, the correct spelling is --described--.

Column 3, line 10-13 delete "the step of accelerating movement of the capillary assembly in a direction away from the proximate printing surface or by"; delete "or both"; after "force" change the comma (,) to a period (.).

Column 4, line 9 change "rolls" to --rows--.

IN THE CLAIMS

Claim 1, line 21, change "projects" to --protrudes--.

Claim 2, line 47, the correct spelling is --vacuum--.

IN THE FIGURES

Column 3, line 40 change "61" to --16--.

ON THE TITLE PAGE

Column 2, change "Goudla" to --Godula--.

Signed and sealed this 1st day of May 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334

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