United States Patent

Taylor

[15] **3,655,530**

[45] **Apr. 11, 1972**

[54] **FABRICATION OF ORIFICES**

[72] Inventor: **Richard P. Taylor,** Chillicothe, Ohio

[73] Assignee: **The Mead Corporation,** Dayton, Ohio

[22] Filed: **June 15, 1970**

[21] Appl. No.: **46,395**

[52] U.S. Cl. **204/26,** 204/15, 204/229, 204/275, 346/75, 346/1

[51] Int. Cl. **C23b 5/56,** C23b 5/48, B01k 3/00

[58] Field of Search 204/15, 16, 229, 26, 273, 275; 346/75, 1

[56] **References Cited**

UNITED STATES PATENTS

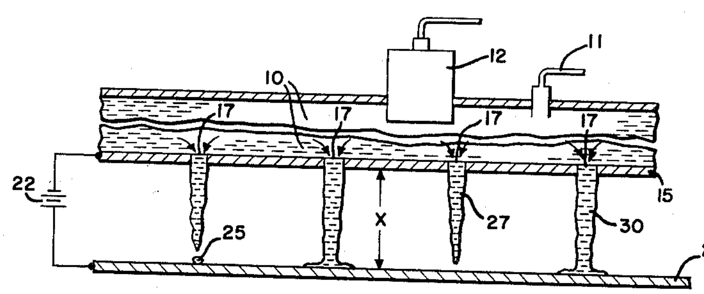
1,416,929	5/1922	Bailey	204/16
3,409,524	11/1968	Olson	204/143
3,480,530	11/1969	Voorhies	204/229

Primary Examiner—John H. Mack
Assistant Examiner—T. Tufariello
Attorney—Marechal, Biebel, French & Bugg

[57] **ABSTRACT**

A method and apparatus for fabricating an aperture of predetermined cross-sectional area in an orifice plate for use in a non-contact printer, includes the steps of fabricating in the orifice plate an aperture of cross-sectional area no less than the predetermined cross-sectional area, flowing an electrolytic deposition solution under pressure through the aperture, applying a constant frequency stimulating disturbance to the stream of electrolytic deposition solution emerging from the aperture, placing an electrically conductive surface in the path of the stream and at a distance from the orifice plate equal to the unbroken filament length of said stream through an aperture of the predetermined cross-sectional area, causing the deposition solution to deposit on the walls of the aperture by connecting the orifice plate and the electrically conductive surface to opposite sides of a source of electric potential whereby the unbroken filament comprises part of the closed electro-deposition circuit, and continuing to supply the electrolytic deposition solution to the aperture until the aperture attains the predetermined cross-sectional area thereby producing filament breakup ahead of the electrically conductive surface and automatically opening the electro-deposition circuit.

6 Claims, 4 Drawing Figures



PATENTED APR 11 1972 3,655,530

FIG-1

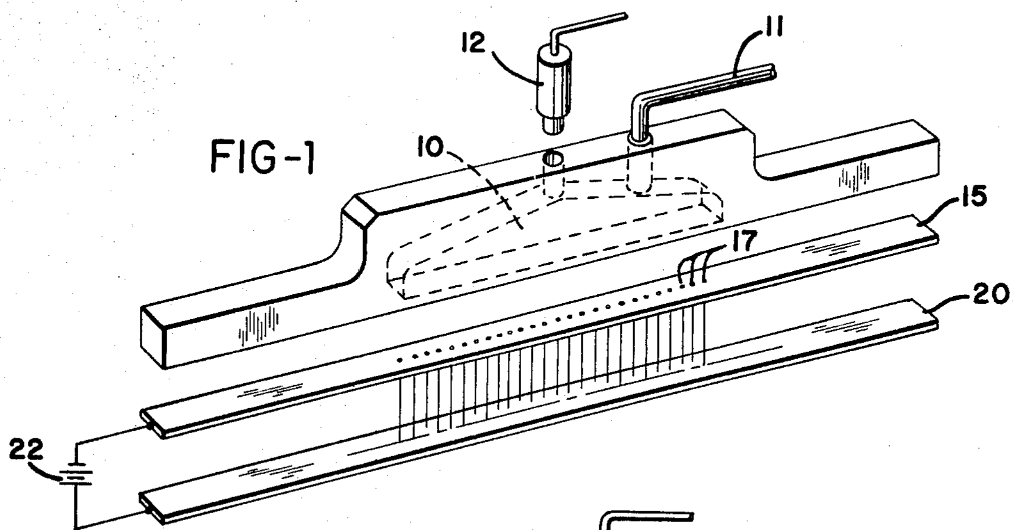


FIG-2

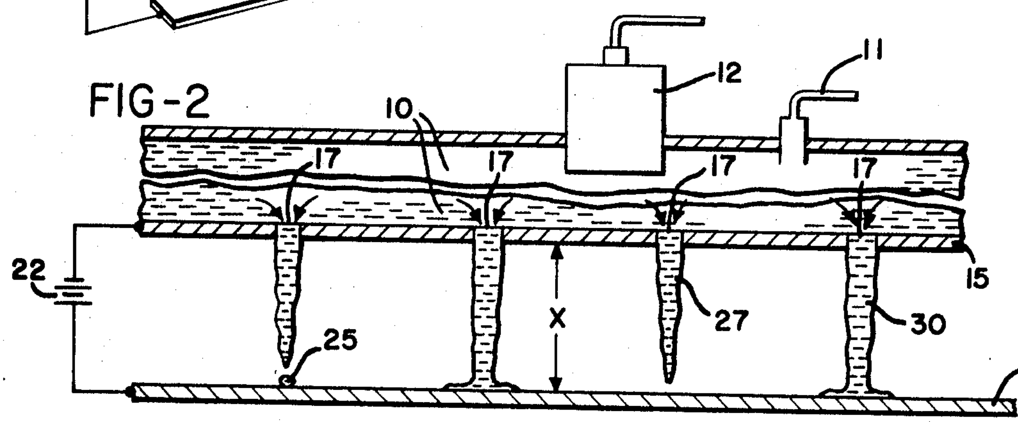


FIG-3

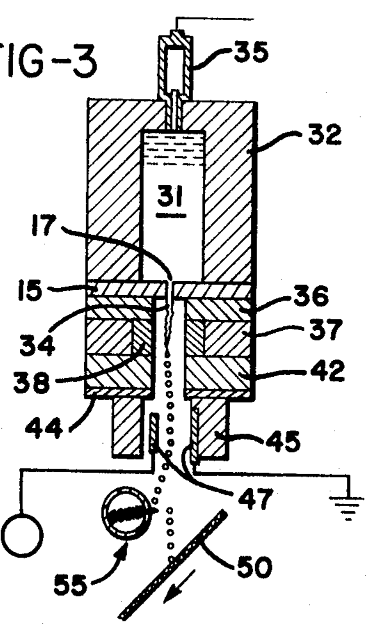
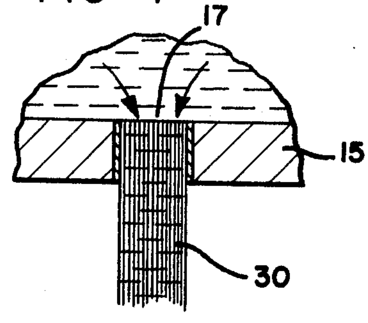


FIG-4



INVENTOR

RICHARD P. TAYLOR

BY

Marechal, Biebel, French & Bugg
ATTORNEYS

FABRICATION OF ORIFICES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to copending application IMAGE CONSTRUCTION SYSTEM USING MULTIPLE ARRAYS OF DROP GENERATORS, Ser. No. 768,790, filed Oct. 18, 1968 and now U.S. Pat. No. 3,560,641 and assigned to the assignee of the present invention.

BACKGROUND OF THE INVENTION

In making apertures in orifice plates for use in high speed non-contacting printers, as hereinafter described, it has been found that such apertures or holes must be uniform in size so that the filament length of the stream of liquid does not vary in length. Such variations in length of the filament gives rise to loss of resolution in printing.

As more fully described in said copending application Ser. No. 768,790, liquid under pressure is forced through apertures in an orifice plate. The drop generating system is stimulated at a selected frequency to induce formation of equally sized drops at the end of the liquid filaments issuing from the apertures. The drops are then selectively charged by charging rings, and pass through a deflection field, to be directed either into a catcher for removal from the system, or to deposit in predetermined locations on a moving web.

To facilitate high speed printing, an array of orifice plates is employed with a corresponding increase in the number of apertures. The presence of a great number of apertures requires that they be of sufficient uniformity in size to minimize loss in the resolution and clarity of the printed material.

SUMMARY OF THE INVENTION

The present invention employs a method and apparatus to produce uniform apertures for use in a non-contact printing system. An orifice plate is provided with pre-formed apertures or holes, the diameter of the holes being at least the size of the predetermined diameter desired. Liquid is supplied to the orifice plate under pressure. The liquid supplied is an electrolytic solution containing, for example, nickel ions, and is flowed through each aperture or hole in the orifice plate. Suitable stimulation is provided at the orifice plate to cause uniform drop formation. After passing through the aperture, the liquid impinges on a contact bar. A potential difference is established between the bar and the orifice plate, with the the electrolytic liquid completing the circuit so long as the unbroken filament reaches the contact bar. As a result, metal from the electrolyte liquid is caused to deposit or plate on the wall of the apertures.

An unbroken filament of liquid issues from the apertures, but has the tendency of subsequently breaking into drops. The length of this filament is dependent primarily upon fluid pressure, fluid viscosity, stimulation frequency and the diameter or cross-section of the apertures. As the deposition builds up on the inside of the aperture and decreases the diameter of the aperture, the filament length will shorten, eventually not reaching and impinging on the contact bar. As a result, the electric circuit is opened, and deposition inside the apertures ceases. Therefore, by varying the distance of the contact bar from the orifice plate, the diameter of the apertures can be controlled.

The primary object of this invention is, therefore, to provide such a method of forming small apertures to predetermined size, and to provide apparatus for this method.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded view of the uniform aperture forming device;

FIG. 2 is a diagrammatic fragmentary view of the device;

FIG. 3 depicts an assembled drop generator unit; and

FIG. 4 is an enlarged view of a single aperture.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a fluid reservoir **10** has a fluid supply line **11** and a stimulator **12** attached thereto. The orifice plate **15** has apertures or holes **17** predrilled or otherwise formed to a diameter not less than the predetermined desired diameter. A contact bar **20** is positioned below orifice plate **15**. In order that the apertures **17** will attain uniform cross-sectional areas, bar **20** is positioned directly below orifice plate **15** and parallel therewith. Bar **20** and orifice plate **15** are each connected to opposite sides of a D.C. potential difference source **22**. In the usual case the ions in the electrolytic solution will carry a positive electrical charge, so potential source **22** will ordinarily be connected on the positive side to contact bar **20** and on the negative side to orifice plate **15**. This relation will cause the contact plate to act as the anode in the circuit.

To obtain apertures of uniform cross-sectional area, the plate **15** is fitted to the reservoir, and an electrolytic solution is caused to flow into reservoir **10** through fluid supply line **11**, as indicated in FIG. 2. Stimulator **12** induces drops **25** to form at the end of liquid filaments **30** at a frequency equal to the oscillation frequency of stimulator **12**. When a filament impinges on bar **20**, the electric circuit is complete, and metal from the electrolytic solution is caused to deposit or plate on the inside walls of apertures **17**, as seen in FIG. 4. As the cross-sectional area of each aperture **17** decreases in size, the length of the corresponding filament **30** decreases until the point of drop formation is above the bar **20**. Since only drops are now reaching bar **20**, the circuit is broken as to the corresponding filament, and electrolytic deposition in the aperture ceases. Thus, by controlling the stimulation frequency and the distance X between orifice plate **15** and bar **20**, uniformly sized apertures **17** may be obtained. Each one is controlled in size independently of the others.

In contrast to usual electroplating procedures the coating ions of this invention are supplied from a continually flowing fluid rather than from the anode of electrodeposition circuit. This means that the anode may be any conductive material such as graphite. However, the contact plate should not be made of a material which will be coated by the ions from the fluid since deposition of the ions on the contact plate will decrease the anode-orifice distance. Even the plating liquid itself may serve as an anode if it is pooled below the orifice plate and held at a constant level. Conversely it is desirable that the anode not function as a donor of coating material because the accompanying etching of the anode surface would increase the anode-orifice distance.

FIG. 3 depicts a drop generator employing an aperture **17** fabricated by the above method and apparatus. Liquid, such as ink, is pumped into chamber **31** in a top bar **32** and passes to the aperture **17** formed in orifice plate **15**, now fastened beneath this chamber. The resulting liquid filaments **34** break into drops, and a stimulating means in the form of vibrator **35** causes the drops to form at a frequency which is common to all filaments, resulting in drops of essentially equal size and spacing.

Beneath the orifice plate is gasket **36**, and a charging assembly in the form of plate **37** having openings in which charging electrode rings **38** are carried. Suitable electrical insulation (not shown) is provided between rings **38**, such as by an insulating coating on plate **37**.

A spacer plate **42**, of electrically insulating material, is fastened below the charging assembly. Below the spacer plate is grounded guard electrode plate **44** on top of an electrostatic deflection assembly, comprising insulating support bars **45** mounting deflection electrodes **47** across which a substantial potential difference is applied. Uncharged drops follow a straight trajectory and deposit on moving web **50**, which preferably is moved at constant velocity correlated to the drop generating frequency so that a continuous line of drops will cause an essentially continuous mark or trace along the web. Charged drops will follow a curved trajectory due to the deflecting field, and these drops are removed from the system through a catcher assembly **55**.

Although the present invention has been described with reference to fabricating uniform apertures for use in a non-contacting printing system, it is to be understood that the present invention may be employed for any other purpose where apertures of uniform size are desired, e.g., in fabricating nozzles for a fuel injection apparatus.

While the method herein described, and the form of apparatus for carrying this method into effect, constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to this precise method and form of apparatus, and that changes may be made in either without departing from the scope of the invention.

What is claimed is:

1. The method of fabricating an aperture of predetermined cross-sectional area in an orifice plate comprising the steps of:

a. forming in the orifice plate an aperture of cross-sectional area greater than said predetermined cross-sectional area,
b. flowing an electrolytic deposition solution under pressure through the aperture,
c. applying a constant frequency stimulating disturbance to the stream of electrolytic deposition solution emerging from the aperture,
d. placing an electrically conductive surface in the path of said stream and at a distance from the orifice plate corresponding to the maximum unbroken filament length for an aperture having said predetermined cross-sectional area,
e. causing the deposition solution to deposit on the aperture by connecting the orifice plate and said electrically conductive surface to opposite sides of a source of D.C. electric potential whereby the unbroken filament comprises part of the electrodeposition circuit, and
f. continuing to supply electrolytic deposition solution through the aperture until the aperture attains said predetermined cross-sectional area and thereby causes filament breakup ahead of the electrically conductive surface and interrupts the electrodeposition circuit.

2. The method defined in claim **1** wherein said orifice plate contains a plurality of apertures and said conductive surface is equally spaced from said apertures.

3. Apparatus for fabrication of an aperture of predetermined cross-sectional area in an orifice plate comprising

a. an orifice plate having at least one aperture of cross-sectional area greater than said predetermined cross-sectional area,
b. means for flowing an electrolytic deposition solution under pressure through the aperture,
c. means producing stimulation of a predetermined constant frequency to the filament of deposition solution issuing from the aperture,
d. an electrically conductive surface mounted in spaced relation to said orifice plate such that said surface intercepts the path of said stream and at a distance from said orifice plate equal to the maximum unbroken filament length of said stream for an aperture having said predetermined cross-sectional area, and
e. means connecting said orifice plate and said electrically conductive surface to opposite sides of a source of D.C. electric potential whereby the unbroken filament comprises part of an electrodeposition circuit causing the deposition solution to deposit on the aperture walls until the aperture attains its predetermined cross-sectional area thereby producing filament breakup ahead of the electrically conductive surface and automatically opening the electrodeposition circuit.

4. The apparatus defined in claim **3** wherein the orifice plate contains a plurality of apertures and said conductive surface is mounted parallel to said orifice plate to insure opening of the electrodeposition circuits at the same time as filament length breakup and thereby to produce all of the apertures of the same size.

5. The apparatus defined in claim **3** wherein the source of D.C. electric potential is connected on its positive side to said electrically conductive surface and on its negative side to said orifice plate.

6. The method of producing a plurality of equal liquid filaments of the same size and forming equally sized drops from each filament, comprising the steps of:

a. forming in an orifice plate a plurality of apertures of cross-sectional area greater than said predetermined cross-sectional area,
b. flowing an electrolytic deposition solution under pressure through the apertures,
c. applying a constant frequency stimulating disturbance to all of the streams of electrolytic deposition solution emerging from the apertures,
d. placing an electrically conductive surface in the path of said solution streams and at a distance from the orifice plate corresponding to the maximum unbroken filament length for an aperture having said predetermined cross-sectional area,
e. causing the deposition solution to deposit in the apertures by connecting the orifice plate and said electrically conductive surface to opposite sides of a source of D.C. electric potential whereby the unbroken solution filaments comprise part of the electrodeposition circuit,
f. continuing to supply electrolytic deposition solution through the apertures until each aperture attains said predetermined cross-sectional area and thereby causes the associated solution filament to break up ahead of the electrically conductive surface and interrupt the electrodeposition circuit,
g. incorporating the orifice plate in a drop generator including a chamber for supply of liquid from a common source to all of the apertures,
h. supplying liquid under a predetermined constant pressure to the chamber to create a filament of liquid from each orifice, and
i. stimulating all of the liquid filaments at a common constant frequency to create equal drops off each filament.

* * * * *