

[54] **LATERAL OSCILLATION TO FORM INK DROPLETS**

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

[56] **References Cited**

UNITED STATES PATENTS

3,579,245	5/1971	Berry	346/75 X
3,596,275	7/1971	Sweet	346/75 X
3,060,429	10/1962	Winston	346/1
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FOREIGN PATENTS OR APPLICATIONS

1,123,587	8/1968	Great Britain	346/75
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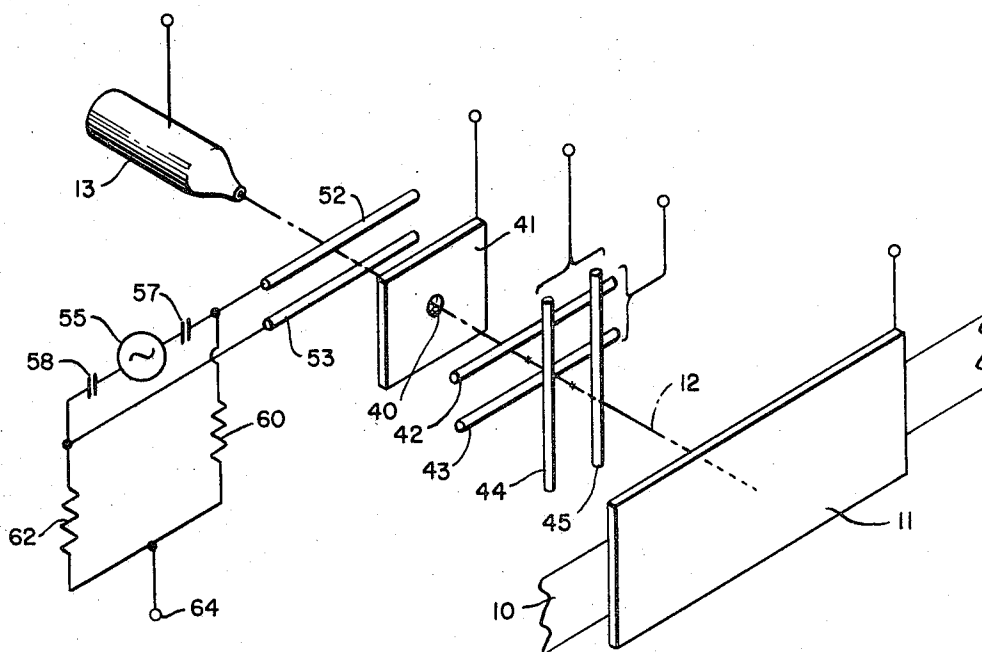
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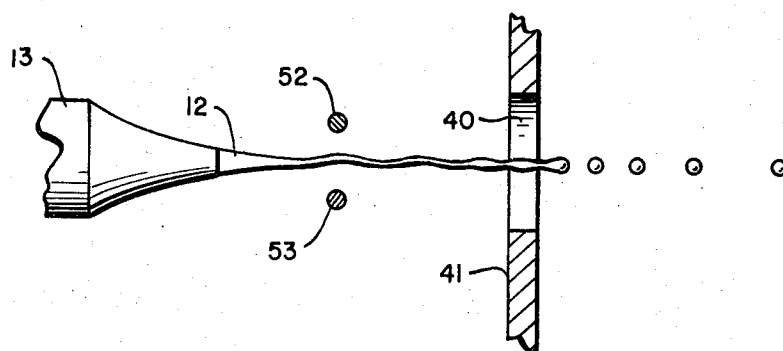
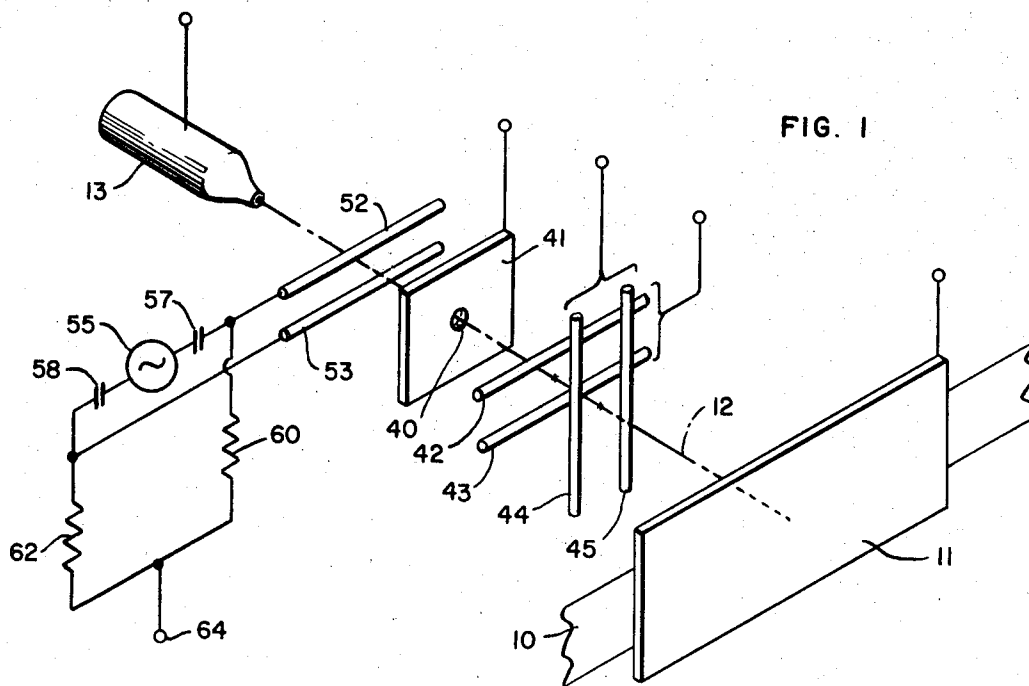
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[57] **ABSTRACT**

An electrostatic, ink-jet printing apparatus wherein electrostatically charged ink is extracted from a nozzle in an axial direction by an electrostatic potential existing between the nozzle and a valving electrode. The droplets of ink are then deflected in orthogonal, lateral directions by two pairs of deflection electrodes in order to trace an indicium on the record medium. An additional pair of deflection electrodes is placed in the region upstream of the point in which droplet formation takes place. A sinusoidal voltage is applied between these additional deflecting electrodes, shaking the stream of ink in a lateral direction in order to facilitate droplet formation and promote uniform droplet size and spacing.

1 Claim, 2 Drawing Figures





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LATERAL OSCILLATION TO FORM INK DROPLETS

FIELD OF THE INVENTION

This invention relates to printing apparatus and more particularly to ink-jet printing apparatus in which the ink is guided electrostatically onto a record medium, wherein varying forces are applied to the ink in order to facilitate droplet formation.

BACKGROUND OF THE INVENTION

U.S. Pat. No. 3,060,429 granted to C. R. Winston on Oct. 23, 1962, shows an electrostatic printer in which a stream of ink is extracted from a nozzle by the electrostatic potential existing between the nozzle and a valving electrode. Two orthogonal pairs of deflection electrodes are placed downstream of the valving electrode and voltage differences applied between the electrodes of each pair deflect the stream of ink in the vertical and horizontal directions, causing the stream of ink to trace an indicium on a record medium. In order to facilitate formation of droplets of uniform size and spacing, apparatus has been disclosed in U.S. Pat. No. 3,500,436 granted to Robert W. Nordin on Mar. 10, 1970, to vibrate the nozzle of an electrostatic printing apparatus. A commonly assigned copending application Ser. No. 688,947 filed on Dec. 7, 1967, by James M. Berry discloses applying an alternating electrostatic field between the nozzle and the valving electrode, thereby superimposing an alternating potential upon the constant DC potential that extracts the ink from the nozzle. It has been observed that shaking the nozzle of an ink-jet printer is not optimally effective due to the cushioning effect of that portion of the ink jet that extends immediately in front of the nozzle. For similar reasons it has been found not to be optimally effective to apply alternating axial potentials between the valving electrode and the nozzle.

It is an object of the present invention more effectively to cause the stream of an ink-jet printer to break into droplets of uniform size and spacing.

SUMMARY OF THE INVENTION

In accordance with the present invention, a stream of electrostatically charged liquid ink is formed substantially along an axis and is shaken in a direction perpendicular to the axis to facilitate the breakup of the stream into droplets of uniform size and spacing. In a preferred embodiment of the invention the stream is extracted from a nozzle in an electrostatic field existing between the nozzle and a valving electrode or grid placed some distance in front of the nozzle. The ink flows through an aperture in the valving electrode and proceeds to pass between two pairs of deflection electrodes which cause the ink to be deflected in orthogonal directions in order to trace an indicium on a record medium. The improvement comprises placing an additional pair of deflection electrodes in the region upstream of the point at which droplet formation takes place and applying a varying potential between the two additional deflection electrodes, thereby shaking the stream of ink droplets in a direction substantially perpendicular to the axis of the stream of ink in order to set up (bulges) in the stream of ink to facilitate the development of equally sized droplets with approximately equal spacing between them.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be more completely understood from the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 is a schematic diagram of an ink-jet printer having an additional set of deflection electrodes placed upstream of the point at which droplet formation takes place; and

FIG. 2 is an enlarged view of the nozzle and ink stream in the system shown in FIG. 1.

DETAILED DESCRIPTION

Referring now to the accompanying drawing and more particularly to FIG. 1, a record medium 10 such as paper, is placed in front of a conductive platen 11 as shown in the above-mentioned Winston patent. A stream 12 of ink is electrostatically drawn from a nozzle 13 and is accelerated through an aperture 40 in a valving electrode 41 that is maintained at a high voltage with respect to the nozzle 13. After passing through the aperture 40, the ink stream 12 proceeds between a pair of vertical deflection electrodes 42 and 43 and then through a pair of horizontal deflection electrodes 44 and 45. U.S. Pat. No. 3,432,844 granted to Charles R. Winston on Mar. 11, 1969, discloses a logic system for applying deflection voltages to the deflection electrodes 42, 43, 44, and 45 in order to cause the stream 12 of ink to trace indicia on the surface of the record medium 10.

It has been found that under the parameters disclosed in the above-mentioned Winston '429 patent, the ink stream extracted from the nozzle 13 breaks into droplets approximately half-way between the end of the nozzle 13 and the valving electrode 41. It is a basic principle of operation of the deflection electrodes 42-45 that each individual droplet of ink should contain substantially the same charge-to-mass ratio. Similarly the solid stream itself should contain the same charge-to-mass ratio as each individual droplet.

In order to facilitate the break-up of the stream of ink into individual droplets, two additional deflection electrodes 52 and 53 are placed across the stream of ink. These two parallel deflection electrodes are in a plane that is substantially perpendicular to the axis defined by the stream 12 of ink. The additional deflection electrodes 52 and 53 are placed upstream of the location at which droplet formation takes place.

As the jet of ink issues from the nozzle 13, it rapidly accelerates under the influence of the field between the nozzle 13 and the electrode 41. This causes the jet or stream to be reduced in diameter. When the diameter of the jet is small enough, the jet becomes unstable and begins to bulge and neck down (forming varicosities) at more or less irregular intervals, preparatory to breaking into droplets. The length of these intervals increases as the fluid continues to be accelerated. It is well known that the instability of a stream of jet of liquid is present whenever the circumference of the jet is less than or equal to the length of the interval between varicosities which tend to form. Therefore, the additional deflection electrodes 52 and 53 are preferably placed at the axial location on the accelerating stream where instability begins. In this way oscillations can be introduced into the jet at this point of the beginning of instability

for overriding the tendency to irregular droplet size and frequency of droplet formation in order to control the regularity of the size and intervals of the droplets subsequently formed.

In order to introduce these oscillations, an AC signal generator 55 is connected through two isolation capacitors 57 and 58 to the two auxiliary deflection electrodes 52 and 53. On each half-cycle of the AC potential, the stream is deflected toward one or the other of the auxiliary electrodes. Since the AC potential keeps reversing, the stream is effectively shaken up and down near the point where instability begins, the stream axis being alternated in whip-like fashion and thus determining the regularity and frequency of the droplets and their intervals.

The excursion of the stream 12 in a direction perpendicular to its axis of flow gradually changes to axial varicosities as shown in FIG. 2. This change from lateral to axial oscillation might not be unlike the phenomenon of a spring-mass system having two degrees or dimensions of freedom. Oscillations in one dimension gradually change to oscillations in the other dimension and back again. However, in the case of the fluid of FIG. 2, the jet breaks into droplets before the oscillations can change back again.

It will be evident that the average potential of the electrodes 52 and 53 should be maintained somewhere between the voltages of the nozzle 13 and the valving electrode 41. This can most easily be done by connecting two resistors 60 and 62 between the deflection electrodes 52 and 53 and a potential reference terminal 64. The terminal 64 is then maintained at a potential that is appropriate to the location of the auxiliary electrodes 52 and 53 within the electrostatic field between the nozzle 13 and the valving electrode 41.

As one specific example of the present invention, in an apparatus similar to that shown in FIG. 5 of the above-mentioned Winston patent '429, auxiliary electrodes comprising two conductive wires having diameters of 0.001-inch are mounted 0.008-inch apart spanning an aperture with a diameter of 0.125-inch

through a 0.010-inch-thick plastic board. The board is mounted 0.020-inch away from the nozzle with the wires on the side of the board nearest the nozzle. An average potential difference of 2,050 volts is maintained between the nozzle and the auxiliary electrodes with a peak-to-peak, 20 kilocycle AC potential of 530 volts applied between the auxiliary electrodes.

As another example, the wires can be maintained at an average potential of 2,150 volts with respect to the nozzle with a 20 kilocycle, peak-to-peak, AC potential of 1,200 volts applied between the auxiliary electrodes.

Although a particular embodiment of the invention is shown in the drawing and has been described in the foregoing specification, it is to be understood that other modifications of this invention, varied to fit particular operating conditions will be apparent to those skilled in the art; and the invention is not to be considered limited to the embodiment chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true scope of the invention.

What is claimed is:

1. In apparatus for forming a succession of electrically charged liquid ink droplets of substantially uniform size and spacing and including means for generating an electrostatic field for taperingly drawing a stream of ink in a continuous liquid phase from a nozzle substantially along the axis thereof, the improvement comprising:

a pair of electrodes, as shaking means, spaced from said nozzle and disposed in parallel about said stream along the stream taper whereat the circumference of the stream is no greater than the interval between varicosities that would develop in the stream in the absence of said shaking means for producing a periodically varying electrostatic potential field transverse to said stream and shifting the stream axis from the axis of the nozzle at a frequency corresponding to the frequency of droplet formation.

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