

[54] **NOZZLE STRUCTURE FOR JET PRINTERS**

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[51] Int. Cl. B05b 3/14

[58] Field of Search 239/102; 346/75, 140

[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|-----------|---------|------------------|-----------|
| 3,334,350 | 8/1967 | Adams..... | 346/75 |
| 3,214,101 | 10/1965 | Perron..... | 239/102 |
| 3,281,859 | 10/1966 | Stone..... | 239/102 X |
| 3,400,892 | 9/1968 | Ensminger..... | 239/102 |
| 3,155,141 | 11/1964 | Doyle et al..... | 239/102 X |
| 3,281,860 | 10/1966 | Adams et al..... | 239/102 X |

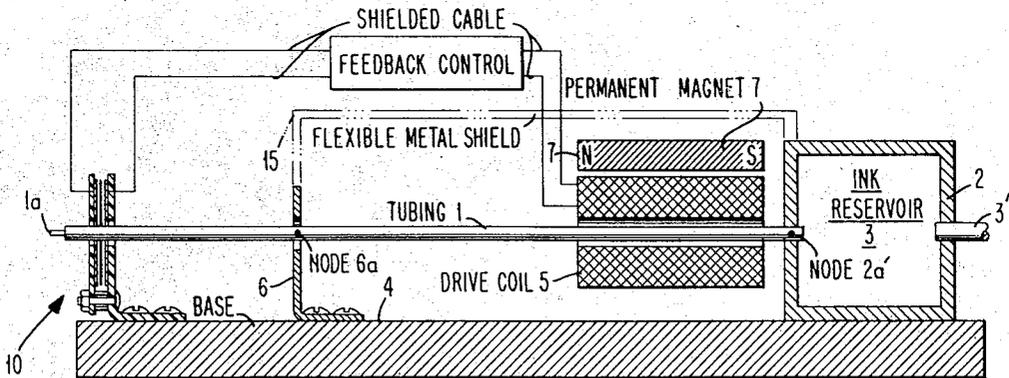
| | | | |
|-----------|--------|---------------|------------|
| 3,512,172 | 5/1970 | Colecchi..... | 346/140 X |
| 3,361,352 | 1/1968 | Harris..... | 239/102 X |
| 2,550,771 | 5/1951 | Camp..... | 239/102 UX |

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[57] **ABSTRACT**

An ink jet nozzle structure comprising a thin tube, connected to a pressurized ink reservoir, is encircled by an A. C. driven coil which induces longitudinal reciprocating motion to cause formation of ink droplets. A permanent magnet is in the proximity of the drive coil provides a biasing action. The tube length is chosen so as to permit it to vibrate resonantly at the frequency of the induced longitudinal reciprocating motion. Resonant vibration permits the tube to be supported at two points along its length greatly increasing its mechanical stability. An air damper located near the tip of the nozzle broadens the resonant response and provides differential signals proportional to the longitudinal movement of the tube to maintain movements at a fixed or preset level.

3 Claims, 5 Drawing Figures



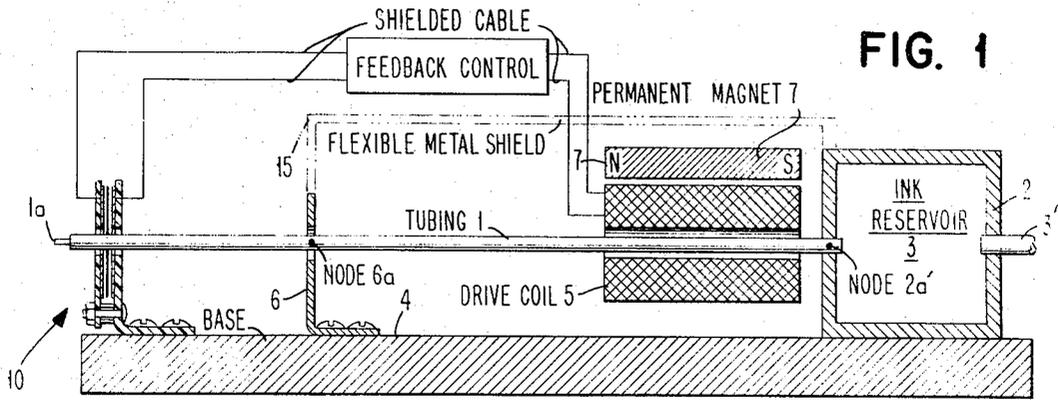


FIG. 1

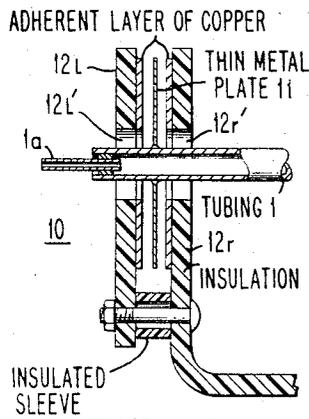


FIG. 2

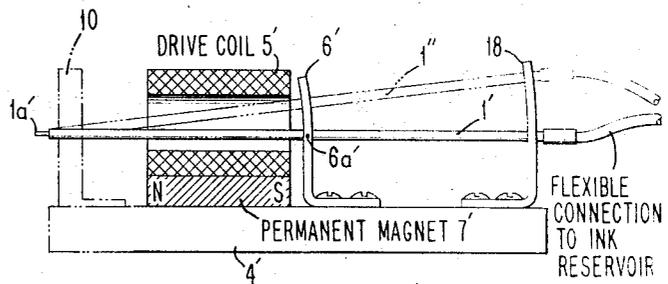


FIG. 3

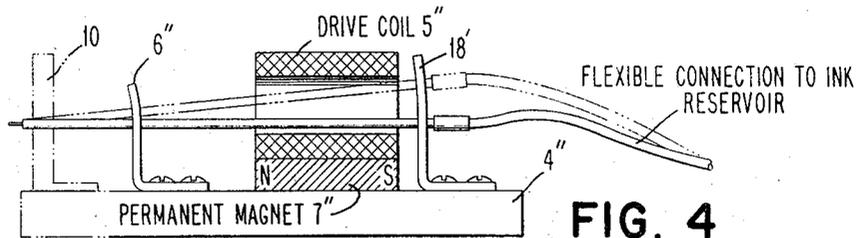


FIG. 4

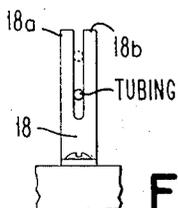


FIG. 5

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NOZZLE STRUCTURE FOR JET PRINTERS

BACKGROUND OF THE INVENTION

The formation of uniform ink droplets and the charging of each individual droplet with a precise charge has not been too successful by prior art ink jet printers. Non-uniform or "satellite" droplet formation has been a continuing problem due to the presence of non-sinusoidal vibration in the jet nozzle. The prior art fails to provide any satisfactory means for operating closely spaced groups of ink jets where precise positioning of individual jets is required. Although specific nozzle designs have been produced with a modest degree of success, they have been held to limited speeds of operation beyond which reliability suffers and print quality deteriorates.

OBJECTS

The principal object of the invention is to overcome the cited disadvantages in prior art jet printers by providing an improved jet printer nozzle structure which is highly reliable, faster in operation and more accurate in printing quality than the prior art ink jet printers.

Another object is to provide a novel arrangement for the nozzle utilizing dimensional relationships that provide a resonant mode of operation to eliminate the formation of satellite drops in the jet stream.

A more detailed object is to improve the stability and performance of the nozzle structure by substantially eliminating the "dead" area of response before tube movement can occur.

Yet another detailed object is to provide a nozzle structure which can be positioned with ease.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of an ink jet nozzle structure and vibrating means therefor.

FIG. 2 is a detail of the electromechanical damper means for broadening frequency response and generating differential signals.

FIG. 3 is a cross-sectional view of a nozzle structure adapted for relatively low frequency operations.

FIG. 4 is a cross-sectional view of a nozzle structure adapted for relatively high frequency operations.

FIG. 5 is a detail of the tube support.

DESCRIPTION OF THE INVENTION

The nozzle structure shown in FIG. 1 comprises a nickel tubing 1 secured within a wall opening 2a forming part of an ink reservoir 3 containing pressurized ink admitted by way of an entry port 3', the reservoir 3 being secured by way of suitable means, not shown, to a metal base 4. In proximity to and encircling said tubing 1 is an A. C. drive coil 5 which when energized induces magnetostrictive action that causes vibrations along the longitudinal axis of the tubing. The tubing 1 is further supported by means of a bracket 6 by virtue of which and in conjunction with opening 2a in the wall 2 of the reservoir 3, node points 6a and 2a' are established in the tubing. At these node points 6a, 2a' substantially little or no vibrational effects are present, whereas midway between these two points and at the tube orifice 1a, maximum vibrational effects exist. By suitable supporting means, not shown, a permanent magnet 7 is disposed above the drive coil 5. The permanent magnet provides a static magnetic bias to the tubing resulting in a magnetostrictive bias of the tubing to eliminate a "dead" area of response by virtue of which the movement frequency of the tubing is stabilized relative to the drive frequency.

Although the invention may be designed to accommodate a variety of different resonant frequencies, the structure of FIG. 1 has been designed to function at a natural resonant frequency of 50 kHz. in the three-quarter wavelength mode by virtue

of the fact that the nickel tubing is supported at points of maximum force with minimum displacement and the nozzle is located at a point of minimum force with maximum displacement. This construction enhances the sinusoidal character of the vibrational movement and tends to suppress responses at other than the resonant frequency. Since the resonant frequency of the arrangement is a function of the dimensional relationship of the tubing length on either side of the node point 6a, the resonant frequency of 50 kHz. results by locating the bracket 6 in such a position as to bring the point 6a a distance of one unit of length to the right of the nozzle orifice 1a, and two units of length from the node point 2a', assuming an entire tubing length of three units of length. The one unit of length tubing section extending to the left of the node point 6a represents a quarter wavelength of the resonant frequency while the section between the node points 6a, 2a' represents a one-half wavelength of the resonant frequency. Alternatively, the tubing can be resonated in the five-quarter or seven-quarter wavelength mode or any higher odd multiple of quarter wavelengths by logical extension of this principle. Thus in the five-quarter mode, one unit of length tubing section extending to the left of the node point 6a again represents a quarter wavelength while four units of length between node points 6a and 2a represent one wavelength of the resonant frequency. The presence of liquid under pressure in the nickel tubing has a damping effect which broadens the resonant response.

To further broaden the useful movement amplitude to frequencies of about 5 kHz. above and below the resonant frequency of 50 kHz. and to further enable the resonant frequency to be accurately monitored, there is provided a non-resonant electromechanical damper 10 shown located at the left end of the tubing 1. The damper as best seen in detail in FIG. 2, comprises a rigid, flat, thin metal plate 11 secured, by suitable known techniques, to the outer periphery of the tubing, in the manner shown. Spaced on either side of said plate 11 and disposed in parallel relation thereto are insulating members 121 and 12r suitably secured, in the manner shown, to the base 4. Suitable openings 121' and 12r' are provided to allow freedom of movement of the tubing during resonant operations. On the inner face of each of the members 121 and 12r is an adherent thin layer of copper. By virtue of this arrangement, a differential capacitive mechanism is formed to yield differential signals proportional to the movement amplitude of the tubing. These signals are utilized to monitor the resonant frequency, and by means of the feedback control 14 connected by means of shielded cables, as shown, the drive coil 5 can be controlled to maintain the tubing movement amplitude at any desired level.

To prevent electrostatic and electromagnetic effects from interfering with the signals from the differential capacitive mechanism, a flexible metal shield 15, shown in dotted, is extended between the bracket 6 and the reservoir 2 to isolate the effects produced by the drive coil 5.

The nozzle structures shown in FIGS. 3 and 4 are designed to permit accommodation of a multiplicity of jets in close proximity where each jet may be positioned individually and all jets share a common drive coil.

The nozzle structure shown in FIG. 3 is designed for relatively low frequency operations. In this arrangement, drive coil 5' is located on base 4' with the biasing permanent magnet 7' located therebetween. The drive coil is located in such a manner as to induce magnetostrictive effects upon the portion of the tubing 1' located between the left end of the nozzle 1a' and the node point 6a', the latter being established by virtue of the position assumed by the bracket 6'. To aim the tubing 1' to any desirable direction, a second bracket 18 is provided and located on the base 4' in the manner shown. As seen from an end view in FIG. 5, each of the brackets is provided with an elongated slot, open at one end to receive the tubing. One dimension of adjustment is provided by moving the nickel tubing vertically between brackets 6' and 18'. A second dimension of adjustment is provided by rotating the nickel tubing in

the brackets in order to compensate for eccentricity. By virtue of this slot arrangement, each bracket is provided with tines 18a and 18b of sufficient spring tension to maintain the tubing at any desired position. To enable positioning of the tubing, a flexible connection is established to communicate with the ink reservoir.

Still referring to FIG. 3, the length of the nickel tubing between the jet nozzle end 1a and the nearest support, bracket 6', is adjusted to produce resonance in the quarter wavelength mode at the vibration frequency. The remaining portion of the tubing may be any length that can be conveniently accommodated by the second support 18. This configuration is suitable for all frequencies where the nickel tubing in the quarter wavelength mode is long enough to accommodate the drive coil.

The arrangement shown in FIG. 4 is designed for relatively high frequency operations. In this arrangement the drive magnet 5'' is conveniently located between brackets 18' and 6'' and corresponds to the position assumed by the drive coil 5 in the arrangement of FIG. 1. For biasing action permanent magnet 7'' is located between drive coil 5'' and the base 4''.

The entire length of the nickel tubing shown in FIG. 4 is selected so as to effect resonance in the three-quarter wavelength mode, the tubing support brackets 6'' and 18a being situated at points of minimum displacement. Maximum displacement thus occurs in the middle of the half wavelength section and at the nozzle end of the quarter wavelength section. This configuration is suitable for higher frequencies where the portion of the tubing in the quarter wavelength mode is too short to accommodate the drive coil.

Although nickel tubing has been specified in view of its desirable characteristics, the invention need not be limited to the use of nickel tubing since other metallic tubing having magnetostrictive properties may be utilized to carry out the desirable features of the invention.

Calculations involving operations at a resonant frequency of 90 kc. for the structure shown in FIG. 4 yield a wavelength of

2.20 inches for the three-quarter wave mode, an overall tubing length of 1.65 inches, with a 0.55 inch length for the tubing section between the nozzle 1a and the node 6a'.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein.

What is claimed is:

- 1. A nozzle vibrator providing a jet stream of individual ink droplets for an ink jet printer comprising:
 - a length of metal tubing having a nozzle at one end thereof;
 - a reservoir of pressurized ink connected to the opposite end of said tubing whereby the latter is supported for longitudinal vibration;
 - a stationary drive coil encircling said tubing for producing an alternating magnetic field and inducing magnetostrictive effects therein to cause longitudinal vibration in said tubing in response to the application of a driving frequency to said drive coil, the resonant frequency of said tubing being a function of the dimensional relationships of said tubing and of the driving frequency,
 - a support means for further supporting said tubing at a node point in the proximity of the nozzle end of said tubing,
 - non-resonant damping means interconnected to said tubing to broaden the resonant response thereof, and
 - means comprising a permanent magnet producing a fixed magnetic field to induce a constant magnetostrictive bias of said tubing.
- 2. A nozzle vibrator as in claim 1 in which said damping means is further modified by the provision of electrical means providing differential signals proportional to the movement amplitude of said tubing.
- 3. A nozzle vibrator as in claim 2 further including a feedback control means electrically interconnected to said drive coil and responsive to said differential signals to monitor and maintain control over the resonant frequency of said tubing.

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