(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 067 948**
B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **14.08.85**

(51) Int. Cl.^{4}: **B 41 J 3/04**

(21) Application number: **82103883.3**

(22) Date of filing: **05.05.82**

(54) Method and apparatus for producing liquid drops on demand.

(30) Priority: **18.06.81 US 274989**

(43) Date of publication of application:
29.12.82 Bulletin 82/52

(45) Publication of the grant of the patent:
14.08.85 Bulletin 85/33

(84) Designated Contracting States:
DE FR GB IT

(56) References cited:
GB-A-2 033 305
US-A-3 683 212
US-A-3 921 916
US-A-4 209 794

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Description

This invention relates to methods and apparatus for generating liquid drops on demand under control of a suitable electrical signal.

Ink jet printing has been known in the prior art, including systems which use a pressure generated continuous stream of ink, which is broken into individual drops by a continuously energized transducer. The individual drops are selectively charged and deflected either to the print medium for printing or to a sump where the drops are collected and recirculated. Examples of these pressurized systems include US—A—3,596,275 to Sweet, and 3,373,437 to Sweet et al. There have also been known in the prior art ink jet printing systems in which a transducer is used to generate ink drops on demand. One example of such a system is commonly assigned US—A—3,787,884 to Demer. In this system, the ink is supplied to a cavity by gravity flow and a transducer mounted in the back of the cavity produces motion when energized by an appropriate voltage pulse, which results in the generation of an ink drop so that only those ink drops required for printing are generated. A different embodiment of a drop-on-demand printing system in which the transducer is radially arranged is shown in US—A—3,683,212 to Zoltan.

The prior art drop-on-demand printing systems have been limited by low drop production rates, low resolution, and low efficiency. Typical prior art drop-on-demand printing systems have utilized a constant cross-section nozzle and ink having a viscosity during operation lower than 10 centipoise. Attempts to increase the drop production rates, and thus to increase the print resolution, have led to stream instability.

It is an object of the invention to overcome this problem and to provide a method of generating liquid drops on demand and apparatus for carrying out that method, which is capable of operating at increased speeds compatible with high resolution printing.

Briefly the invention provides a drop-on-demand ink jet printing method and apparatus comprising a print head having a fluid chamber supplied with a suitable high viscosity marking fluid. An orifice comprising a strongly converging nozzle is in fluid communication with the fluid chamber, and an electromechanical transducer is mounted in mechanical communication with the fluid chamber. The transducer is selectively energized with a series of signals so that one drop of the marking fluid is ejected from the orifice for each of the signals having at least a predetermined amplitude.

More precisely, the invention provides a method of producing single liquid drops of demand, comprising ejecting the volume of liquid required to form a single drop from a tapering nozzle passage as and when a drop is demanded, said method being characterised in that the liquid used has a viscosity in the range of 15 to 100 centipoise and in that the nozzle passage tapers towards the exit orifice of the nozzle and has an included or apex angle of between 60 and 80 degrees.

The invention includes apparatus for carrying out the foregoing method, said apparatus comprising a print head having an ink chamber to which ink is supplied and from which ink exits through a nozzle passage under the control of an electromechanical transducer mounted in mechanical communication with the ink chamber, said transducer being operative on appropriate energisation to cause a single drop to be ejected from the nozzle and said nozzle passage converging towards the exit orifice of the nozzle, said apparatus being characterised in that the nozzle passage has an included or apex angle of between 60 and 80 degrees whereby single drops of liquid having a viscosity in the range 15 to 100 centipoise can be formed.

The invention will now be further described with reference to the accompanying drawings, in which:—

Figure 1 is a schematic view showing a converging nozzle;

Figure 2 is a drop-on-demand ink jet printer embodying a converging nozzle;

Figure 3 is a section view taken along line 3—3 of Figure 2 of the drop-on-demand ink jet print head.

Figure 4 is a view, partially in section, of an alternate embodiment of a drop-on-demand ink jet print head;

Figure 5 is a right side view of an array of drop-on-demand ink jet print heads;

Figure 6 is a section view taken along lines 6—6 in Figure 5.

Referring to Figure 2, the printer apparatus comprises a print head 10 to which is supplied high viscosity liquid ink from ink supply means 12. The viscosity requirement is a function of nozzle size and maximum drop-on-demand drop production rate. The viscosity for inks for high resolution printing extends up to 100 centipoise, and the viscosity can be substantially higher for applications in which lower resolution is suitable. Control means 14 provides the voltage control pulses to selectively energize print head 10 to produce one ink drop for each voltage pulse supplied to print head 10. Print head 10 comprises head body 20 having a chamber or cavity 22 formed therein. Cavity 22 is maintained filled with ink through supply line 24 from ink supply means 12. Ink from supply means 12 is not pressurized so the ink in cavity 22 is maintained at or near atmospheric pressure under static conditions. An exit from cavity 22 is provided by nozzle portion 26 which is designed so that the ink does not flow out of nozzle portion 26 under static conditions. An intermediate ink reservoir 28 is formed in head body 20 and is separated from cavity 22 by internal wall portion 30. The top of cavity 22, as shown in Figure 2, is closed by a suitable transducer means which is fixed to the head body. Internal wall portion 30 is designed so that a narrow passageway 32 is provided for the transfer of liquid ink from intermediate ink reservoir 28 to ink cavity 22. The transducer means comprises a membrane member 34 which is fastened to an electromechanical transducer 36. Transducer 36 displaces radially when energized with a suitable voltage pulse and bends membrane 34 inwardly (as shown dotted in Figure 3), and produces a pressure wave in cavity 22 so that liquid ink is expelled out through nozzle portion 26 to form a single drop. Control means 14 provides the voltage control pulses to selectively energize transducer 36 to produce one ink drop for each voltage pulse applied to transducer 36.

The nozzle portion 26 of the drop-on-demand ink jet printing apparatus comprises a converging nozzle. As shown in Figure 1, the nozzle has an entrance dimension d_1, which is larger than the exit dimension d_2. The nozzle shown in the drawing has a substantially linear taper in the dimension of the nozzle along its physical length l however, other tapers such as a horn configuration would also be suitable. The flow through the nozzle is in the direction from the larger opening to the smaller opening, as shown by the arrow.

From a fluid mechanics viewpoint, the effective viscous length l_{d_2} of a converging nozzle can be calculated as

$$l_{d_2}=1/3[(d_2/d_1)^3-1]d_2l/(d_2-d_1)$$

where d_1, d_2 are the dimensions at the entrance and exit of the converging section, respectively, and l is the physical length of the nozzle (see Figure 1). Thus, it can be seen that the converging nozzle is physically "long" but hydraulically "short". Since the converging nozzles are "short", the converging nozzles do not provide reliable drop-on-demand operation when using prior art ink formulations having moderate viscosities up to about 16 centipoise due to drop formation instability. However, it was found that highly reliable drop-on-demand operation can be produced with converging nozzles when using marking fluids having a substantially higher viscosity than typical prior art systems. Although the prior art systems using constant cross-section nozzles would not even work in the drop-on-demand mode when utilizing marking fluids of the substantially higher viscosity (up to 100 centipoise for high resolution printing, for example), the combination of the converging nozzle and the high viscosity marking fluids produced not only higher reliable drop-on-demand operation, but also much higher drop-on-demand drop production rates than those obtainable by prior art drop-on-demand ink jet printers.

The operation was superior in other ways as well. For example, air ingestion into the nozzle is completely inhibited and the stream stability is improved so that a stream of drops of equal size and spacing can be produced. The stream directionality is improved, and the jet velocity is easily increased which is essential for high speed printing. The nozzle can be operated at any frequency in the frequency spectrum up to 120 kHz without jet failure, and the nozzle can be operated up to 80 kHz drop-on-demand drop production rate in high resolution printing operation.

The converging nozzle can be produced by any suitable technique. The preferred technique for producing a converging nozzle is by anisotropically etching the nozzle in a silicon substrate. This technique will be described with reference to the embodiment of the drop-on-demand print head shown in Figure 4. The print head comprises cylindrical transducer member 60 closed at one end by a nozzle plate 62, having formed therein nozzle portion 64. The other end of the transducer is fixed to body member 66. When transducer 60 is actuated by a suitable voltage drive pulse, i.e. with a drive pulse having an amplitude greater than a predetermined threshold, transducer 60 is deflected to the position shown dotted in Figure 4 to cause a single drop of ink 78 to be expelled out through nozzle portion 64. Energisation of the transducer with a drive pulse of less than the predetermined threshold amplitude does not cause a drop to be ejected so drops can be selected by varying the amplitude of a continuous drive signal.

Nozzle plate 62 comprises a silicon substrate formed of single crystal material oriented with the (100) planes parallel to the front surface. The front surface 68 and the rear surface 70 of the nozzle plate are coated with etchant masking material. An aperture is made in the masking material on the rear surface of the nozzle plate. The nozzle plate is then subjected to a suitable anisotropic etching solution such as a water, amine, pyrocatechol etchant, for example. It has been known for some time that the (111) plane is a slow etch plane in single crystal silicon. The nozzle is etched in the form of a truncated pyramid type opening with a square entrance aperture, tapered sides, and a smaller square exit aperture. The tapered sides form an angle α of 54.7° to the front surface since the etching is along the crystal planes of the silicon substrate. The etching is continued until an exit aperture of the desired size is formed.

In a particular embodiment, the silicon nozzle plate was about 1.27×10^{-2} cms, i.e. five mils thick and the nozzle plate was etched to produce about a 26×10^{-6} sq.cm. i.e. a two mil square, exit aperture. In an embodiment similar to that shown in Figure 4, the print head, including the above-described nozzle plate, produced reliable drop-on-demand operation up to a drop production rate of 60 kHz at a resolution of about 95 pels/cm i.e. 240 pels/inch. This resolution is considered high resolution printing since it produces print resolution approaching that of engraved type. However, the print quality began to decline at drop production rates over 40 kHz. In this apparatus, inks having a viscosity with a range from about 15 centipoise up to 100 centipoise worked to produce ink drops in a drop-on-demand mode, and the preferred range of viscosity was from 20 to 40 centipoise.

In a second embodiment similar to that shown in Figure 4, about a 9.3×10^{-6} sq.cm. i.e. a 1.2 mil square nozzle was used and this apparatus produced printing at a drop-on-demand production rate of 80 kHz at a resolution of about 177 pels/cm i.e. 450 pels/inch. This apparatus worked to produce ink drops in the drop-on-demand mode with inks having a viscosity from about 10 centipoise up to about 70 centipoise. The preferred range of viscosity was from about 20 to 40 centipoise.

Figures 5 and 6 show a print head array 40 comprising forty print heads 42 arranged in four rows 44 with corresponding orifices 46 offset so that a line of printing can be produced at a resolution approaching engraved type as the print head moves across a print sheet. Each of the print heads 42 comprises a hollow cylindrical piezoelectric transducer 48 which forms an ink chamber 50 to which ink is supplied from common reservoir 52. A housing 54 is provided which includes a tapered channel 56 for each print head which transmits ink from ink chamber 50 to the corresponding orifice 46 in nozzle plate 58. The orifices are strongly convergent nozzles, as indicated in Figure 6. In the preferred embodiment nozzle plate 58 comprises a single crystal silicon substrate and orifices are formed by anisotropic etching as described above to form square orifices in nozzle plate 58, as shown in Figure 5.

In a particular embodiment, a forty nozzle array similar to that shown in Figures 5 and 6 was constructed with about a 26×10^{-6} sq.cm. i.e. a 2 mil square nozzles. This array can be operated to produce printing at a resolution of about 95 pels/cm i.e. 240 pels/inch at a drop-on-demand drop production rate of up to 40 kHz. The array operated successfully with ink having a viscosity down to 15 centipoise and up to 100 centipoise. However, the optimum range for the viscosity was 20 to 40 centipoise.

Claims

1. A method of producing single liquid drops of demand, comprising ejecting the volume of liquid required to form a single drop from a tapering nozzle passage as and when a drop is demanded, said method being characterised in that the liquid used has a viscosity in the range of 15 to 100 centipoise and in that the nozzle passage tapers towards the exit orifice of the nozzle and has an included or apex angle of between 60 and 80 degrees.

2. A method as claimed in Claim 1, further characterised in that the liquid has a viscosity in the range of 20 to 60 centipoise.

3. A method as claimed in Claim 1, further characterised in that the liquid has a viscosity in the range of 20 to 40 centipoise.

4. A method as claimed in Claim 3, further characterised in that the apex angle is substantially 70 degrees.

5. A method as claimed in any one of Claims 1 to 4, further characterised in that the drops can be ejected selectively using a drive signal at a base frequency of up to 120 kHz, a drop being ejected only when the amplitude of the drive signal exceeds a predetermined threshold amplitude.

6. A method as claimed in Claim 5, further characterised in that the drops can be ejected selectively at a base frequency of up to 80 kHz, a drop being ejected only when the amplitude of the drive signal exceeds a predetermined threshold amplitude.

7. A method of operating a drop-on-demand ink jet printer comprising an ink jet print head having an ink cavity, an ink outlet therefrom provided as a nozzle passage having an entrance dimension and an exit dimension, characterised in that the ratio of said entrance dimension to said exit dimension being such that the passage has an included or apex angle of between 60 and 80 degrees thereby producing a nozzle passage which converges strongly toward the exit orifice of the nozzle passage and in which the effective viscous length of said nozzle passage is short with respect to the physical length of the nozzle passage, and an electromechanical transducer mounted in mechanical communication with said ink cavity;

said method comprising filling said ink cavity with a marking fluid having any selected viscosity in the range of 15 to 100 centipoises at the normal operating temperature; and

selectively energizing said electromechanical transducer with a series of signals comprising signals at a base frequency up to 120 kHz to eject one drop of said marking fluid from said opening only when the amplitude of the signal exceeds a predetermined threshold amplitude, whereby said drop-on-demand ink jet print head is capable of operating with a marking fluid at each one of said viscosities throughout the stated range at any given time and with signals at any frequency within the stated range at any given time to produce reliable drop-on-demand printing operation.

8. Drop-on-demand ink jet printing apparatus for carrying out the method claimed in any one of Claims 1 to 6, said apparatus comprising a print head (10) having an ink chamber (22) to which ink is supplied and from which ink exits through a nozzle passage (26) under the control of an electromechanical transducer (36) mounted in mechanical communication with the ink chamber, said transducer being operative on appropriate energisation to cause a single drop to be ejected from the nozzle and said nozzle passage converging towards the exit orifice of the nozzle, said apparatus being characterised in that the nozzle passage has an included or apex angle of between 60 and 80 degrees whereby single drops of liquid having a viscosity in the range 15 to 100 centipoise can be formed.

9. Apparatus as claimed in Claim 8, further characterised in that the nozzle passage has an included or apex angle of about 70 degrees.

10. Apparatus as claimed in Claim 8 or 9, further

characterised in that the nozzle passage is anisotropically etched in a silicon substrate formed from single crystal material oriented with the (100) plane parallel to the major substrate surfaces.

11. Drop-on-demand ink jet printing apparatus comprising a print head having fluid chamber supplied with a marking fluid, an orifice in fluid communication with the fluid chamber, an electromechanical transducer mounted in mechanical communication with the fluid chamber means for producing a series of signals to selectively energize the transducer to eject one drop of the marking fluid from the orifice only when the amplitude of the signal exceeds a predetermined threshold amplitude, and said orifice comprising a nozzle passage having an entrance dimension and an exit dimension, characterised in that the ratio of said entrance dimension to said exit dimension being such that the passage has an included or apex angle between 60 and 80 degrees thereby producing a nozzle passage which converges strongly toward the exit orifice of the nozzle and in which the effective viscous length of said nozzle passage is short with respect to the physical length of said nozzle passage;

said marking fluid has a viscosity in the range of 15 to 100 centipoises at the normal operating temperature of said print head; and

said series of signals for selectively energizing said electromechanical transducer comprises signals at a base frequency up to 120 kHz.

Patentansprüche

1. Verfahren zur Erzeugung einzelner Flüssigkeitstropfen auf Anforderung, mit Ausdrücken des für die Bildung eines einzelnen Tropfens benötigten Flüssigkeitsvolumens aus einem sich verjüngenden Düsendurchlauf bei und zur Zeit der Anforderung eines Tropfens, dadurch gekennzeichnet, dass die benutzte Flüssigkeit eine Viskosität im Bereich von 15 bis 100 cP besitzt, und dass sich der Düsendurchlauf zur Ausgangsmündung der Düse hin verjüngt und einen eingeschlossenen bzw. Spitzenwinkel von zwischen 60 und 80 Grad besitzt.

2. Verfahren nach Anspruch 1, weiterhin dadurch gekennzeichnet, dass die Flüssigkeit eine Viskosität im Bereich von 20 bis 60 cP besitzt.

3. Verfahren nach Anspruch 1, weiterhin dadurch gekennzeichnet, dass die Flüssigkeit eine Viskosität im Bereich von 20 bis 40 cP besitzt.

4. Verfahren nach Anspruch 3, weiterhin dadurch gekennzeichnet, dass der Spitzenwinkel im wesentlichen 70 Grad beträgt.

5. Verfahren nach einem der Ansprüche 1 bis 4, weiterhin dadurch gekennzeichnet, dass die Tropfen durch Anwendung eines Ansteuersignals mit einer Grundfrequenz von bis zu 120 kHz gezielt ausdrückbar sind, wobei ein Tropfen nur dann ausgedrückt wird, wenn die Grösse des Ansteuersignals eine vorbestimmte Schwellgrösse überschreitet.

6. Verfahren nach Anspruch 5, weiterhin dadurch gekennzeichnet, dass die Tropfen mit einer Grundfrequenz von bis zu 80 kHz gezielt ausdrückbar sind, wobei ein Tropfen nur dann ausgedrückt wird, wenn die Grösse des Ansteuersignals eine vorbestimmte Schwellgrösse Überschreitet.

7. Verfahren zum Betreiben eines Tropfen auf Anforderung liefernden Tintenstrahldruckers mit einem Tintenstrahldruckkopf mit einem Tintenhohlraum, einem als Düsendurchlauf mit einer Eingangsabmessung und einer Ausgangsabmessung vorgesehenen Auslass für die Tinte aus diesem, dadurch gekennzeichnet, dass die besagte Eingangsabmessung zur besagten Ausgangsabmessung in einem solchen Verhältnis steht, dass der Durchlauf einen eingeschlossenen bzw. Spitzenwinkel von zwischen 60 und 80 Grad besitzt, womit ein Düsendurchlauf hergestellt wird, der stark zur Ausgangsmündung des Düsendurchlaufs hin zusammenläuft und in dem die effektive viskose Strömungslänge des besagten Düsendurchlaufs im Verhältnis zur physikalischen Länge des Düsendurchlaufs kurz ist, und ein in mechanischer Verbindung mit besagtem Tintenhohlraum montierter elektromechanischer Wandler vorgesehen ist, wobei das besagte Verfahren darin besteht, dass der besagte Tintenhohlraum mit einer Markierflüssigkeit angefüllt wird, die bei der normalen Betriebstemperatur eine beliebig ausgewählt Viskosität im Bereich von 15 bis 100 cP besitzt; und dass der besagte elektromechanische Wandler gezielt mit einer Reihe von Signalen erregt wird, die Signale mit einer Grundfrequenz von bis zu 120 kHz umfassen, um einen Tropfen der besagten Markierflüssigkeit nur dann aus der besagten Oeffnung auszudrücken, wenn die Signalgrösse eine vorbestimmte Schwellgrösse überschreitet, womit der besagte Tropfen auf Anforderungliefende Tintenstrahldruckkopf zum Betrieb mit einer Markierflüssigkeit mit jeder der besagten Viskositäten im gesamten angegebenen Bereich zu jeder gegebenen Zeit und mit Signalen beliebiger Frequenz innerhalb des angegebenen Bereichs zu jeder gegebenen Zeit befähigt wird, um sicheren Tropfen auf Anforderungliefernden Druckbetrieb zu liefern.

8. Tropfen auf Anforderunglieferndes Tintenstrahldruckgerät zum Ausführen des Verfahrens nach einem der Ansprüche 1 bis 6, wobei das besagte Gerät einen Druckkopf (10) mit einer Tintenkammer (22) umfasst, der Tinte zugeführt wird, und aus welcher Tinte unter Steuerung durch einen in mechanischer Verbindung mit der Tintenkammer monitierten elektromechanischen Wandler (36) durch einen Düsendurchlauf (26) austritt, wobei durch den besagten Wandler bei entsprechender Erregung das Ausdrücken eines einzelnen Tropfens aus der Düse bewirkt wird und der besagte Düsendurchlauf zur Ausgangsmundung der Düse hin zusammenläuft, dadurch gekennzeichnet, dass der Düsendurchlauf einen eingeschlossenen bzw. Spitzenwinkel von zwischen 60 und 80 Grad besitzt, womit einzelne

Flüssigkeitstropfen mit einer Viskosität im Bereich von 15 bis 100 cP gebildet werden können.

9. Gerät nach Anspruch 8, weiterhin dadurch gekennzeichnet, dass der Düsendurchlauf einen eingeschlossenen bzw. Spitzenwinkel von ca. 70 Grad besitzt.

10. Gerät nach Anspruch 8 oder 9, weiterhin dadurch gekennzeichnet, dass der Düsendurchlauf anisotrop in ein Siliciumsubstrat eingeätzt ist, das aus Einkristallmaterial gebildet ist, dessen (100)-Ebene parallel zu den Hauptsubstratflächen ausgerichtet ist.

11. Tropfen auf Anforderung lieferndes Tintenstrahldruckgerät mit einem Druckkopf mit einer Flüssigkeitskammer, der eine Markierflüssigkeit zugeführt wird, einer in Flüssigkeitsverbindung mit der Flüssigkeitskammer stehenden Mündung, einem in mechanischer Verbindung mit der Flüssigkeitskammer monitierten elektromechanischen Wandler, und Mitteln zum Erzeugen einer Reihe von Signalen für die gezielte Erregung des Wandlers, um einen Tropfen der Markierflüssigkeit nur dann aus der Mündung auszudrücken, wenn die Signalgrösse eine vorbestimmte Schwellgrösse überschreitet, und wobei die besagte Mündung einen Düsendurchlauf mit einer Eingangsabmessung und einer Ausgangsabmessung umfasst, dadurch gekennzeichnet, dass die besagte Eingangsabmessung zur besagten Ausgangsabmessung in einem solchen Verhältnis steht, dass der Durchlauf einen eingeschlossenen bzw. Spitzenwinkel von zwischen 60 und 80 Grad besitzt, woraus sich ein Düsendurchlauf ergibt, der stark zur Ausgangsmündung der Düse hin zusammenläuft, und in dem die effektive viskose Strömungslänge des besagten Düsendurchlaufs im Verhältnis zur physikalischen Länge des besagten Düsendurchlaufs kurz ist; wobei die besagte Markierflüssigkeit bei der normalen Betriebstemperatur des besagten Druckkopfs eine Viskosität im Bereich von 15 bis 100 cP besitzt; und die besagte Reihe von Signalen für die gezielte Erregung des besagten elektromechanischen Wandlers Signale mit einer Grundfrequenz von bis zu 120 kHz umfasst.

Revendications

1. Procédé de production à la demande de gouttes isolées de liquide, comportant l'expulsion du volume de liquide nécessaire pour former une goutte unique à la sortie d'un passage conique de buse chaque fois qu'une goutte est demandée, le procédé étant caractérisé en ce que le liquide utilisé a une viscosité de l'ordre de 15 à 100 centipoises et en ce que le passage de la buse se rétrécit vers l'orifice de sortie de la buse et possède un angle inclus ou angle au sommet de 60 à 80 degrés.

2. Procédé selon la revendication 1, caractérisé en outre en ce que le liquide a une viscosité de l'ordre de 20 à 60 centipoises.

3. Procédé selon la revendication 1, caractérisé en outre en ce que le liquide a une viscosité de l'ordre de 20 à 40 centipoises.

4. Procédé selon la revendication 3, caractérisé en outre en ce que l'angle au sommet est d'environ degrés.

5. Procédé selon l'une quelconque des revendications 1 à 4, caractérisé en outre en ce que les gouttes peuvent être expulsées sélectivement grâce à un signal de commande à une fréquence de base maximale de 120 kHz, une goutte n'étant expulsée que lorsque l'amplitude du signal de commande dépasse un seuil préétabli.

6. Procédé selon la revendication 5, caractérisé en outre en ce que les gouttes peuvent être éjectées sélectivement à une fréquence de base maximale de 80 kHz, une goutte n'étant expulsée que lorsque l'amplitude du signal de commande dépasse un seuil préétabli.

7. Procédé d'exploitation d'une imprimante à jet de gouttes d'encre à la demande, constitué d'une tête d'impression par jet d'encre possédant une cavité

à encre, une sortie d'encre hors de la cavité et un passage de buse ayant une dimension d'entrée et une dimension de sortie, caractérisé en ce que le rapport entre la dimension d'entrée et la dimension de sortie est tel que le passage possède un angle inclus ou angle au sommet de 60 à 80 degrés, réalisant ainsi un passage de buse qui converge fortement vers l'orifice de sortie du passage de buse et dans lequel la longueur visqueuse utile du passage de buse est courte comparée à la longueur physique du passage de buse et un transducteur électromécanique monté en communication mécanique avec la cavité à encre

le procédé comportant le remplissage de la cavité à encre par un liquide de marquage ayant une certaine viscosité de l'ordre de 15 à 100 centipoises à la température normale de fonctionnement; et

l'excitation sélective du transducteur électromécanique par une série de signaux comprenant des signaux à une fréquence de base maximale de 120 kHz pour expulser une seule goutte du liquide de marquage par l'ouverture uniquement lorsque l'amplitude du signal dépasse un seuil préétabli, grâce à quoi la tête d'impression par jet de gouttes d'encre à la demande peut fonctionner avec un liquide de marquage à chacune des viscosités de la gamme indiquée, à tout instant donné, et avec des signaux à toute fréquence de la gamme indiquée, à tout moment, pour effectuer une opération d'impression sûre par gouttes à la demande.

8. Appareil d'impression par jet de gouttes d'encre à la demande selon l'une quelconque des revendications 1 à 6, l'appareil étant constitué l'une tête d'impression (10) possédant une chambre à encre (22) dans laquelle est envoyée de l'encre et d'où l'encre sort par un passage de buse (26) sous l'action d'un transducteur électromécanique (36) monté en communication mécanique avec la chambre à encre, le transducteur opérant au moment d'une excitation appropriée pour commander l'expulsion d'une

goutte unique de la buse, et le passage de buse convergeant vers l'orifice de sortie de la buse, l'appareil étant caractérisé en ce que le passage de buse comporte un angle inclus ou au sommet de 60 à 80 degrés, grâce à quoi des gouttes isolées de liquide à viscosité de l'ordre de 15 à 100 centipoises peuvent être formées.

9. Appareil selon la revendication 8, caractérisé en outre en ce que le passage de buse comporte un angle inclus ou angle au sommet d'environ 70 degrés.

10. Appareil selon la revendication 8 ou 9, caractérisé en outre en ce que le passage de buse est ménagé par attaque chimique anisotrope dans un substrat de silicium réalisé à partir d'une matière monocristalline orientée avec le plan (100) parallèle aux surfaces principales du substrat.

11. Appareil d'impression par jet de gouttes d'encre à la demande, comprenant une tête d'impression possédant une chambre à liquide alimentée en liquide de marquage, un orifice permettant le passage du liquide de la chambre à liquide, un transducteur électromécanique en communication mécanique avec la chambre à liquide, et un moyen de production d'une série de signaux pour exciter sélectivement le transducteur afin d'expulser une goutte unique de liquide de marquage par l'orifice uniquement lorsque l'amplitude du signal dépasse un seuil préétabli, et l'orifice comprenant un passage de buse ayant une dimension d'entrée et une dimension de sortie, caractérisé en ce que le rapport entre la dimension d'entrée et la dimension de sortie et tel que le passage possède un angle inclus ou angle au sommet de 60 à 80 degrés, produisant ainsi un passage de buse qui converge fortement vers l'orifice de sortie de la buse et dans lequel la longueur visqueuse utilise du passage de buse est courte comparée à la longueur physique du passage de buse

le liquide de marquage a une viscosité de l'ordre de 15 à 100 centipoises à la température normale de fonctionnement de la tête d'impression; et

la série de signaux pour exciter sélectivement le transducteur électromécanique est constituée de signaux à une fréquence de base maximale de 120 kHz.

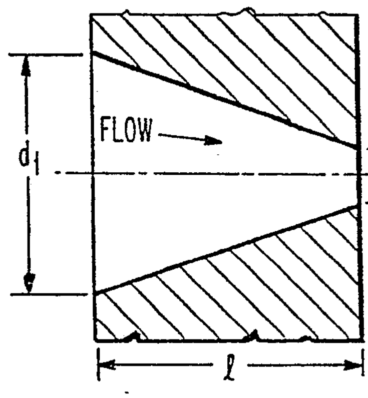

FIG.1

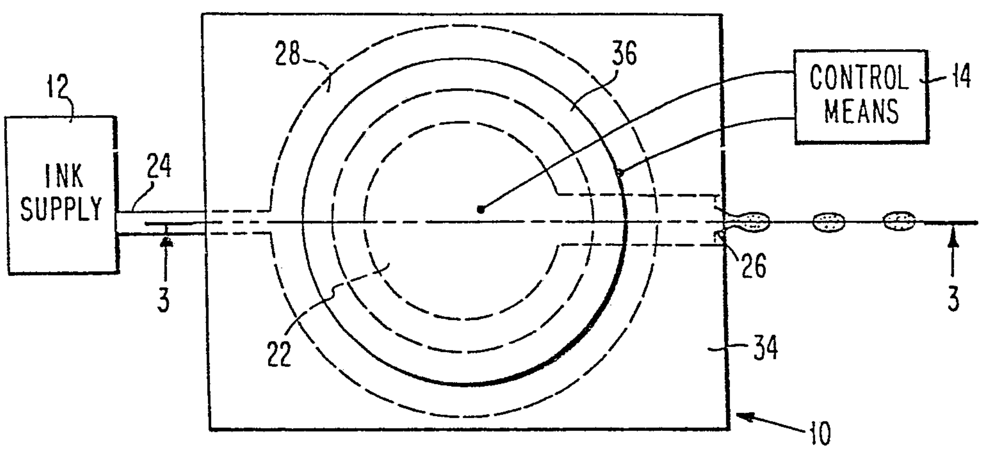

FIG.2

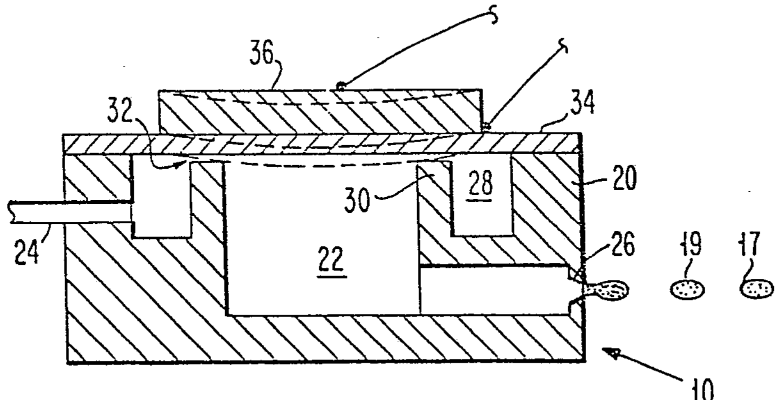

FIG.3

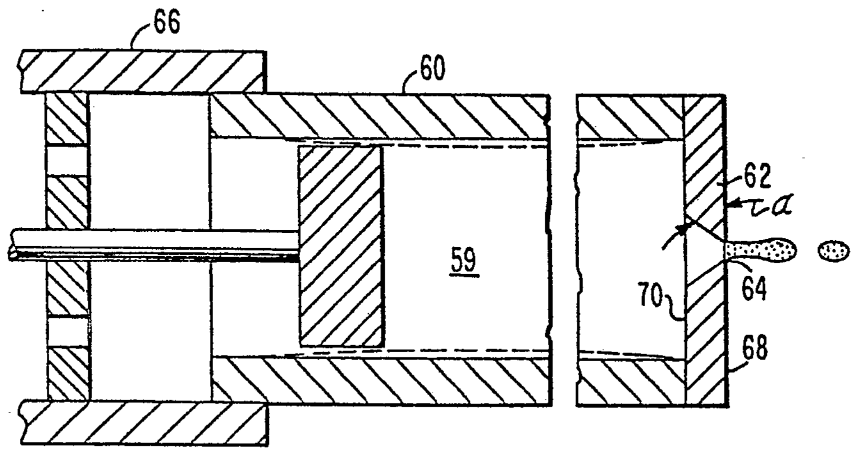

FIG.4

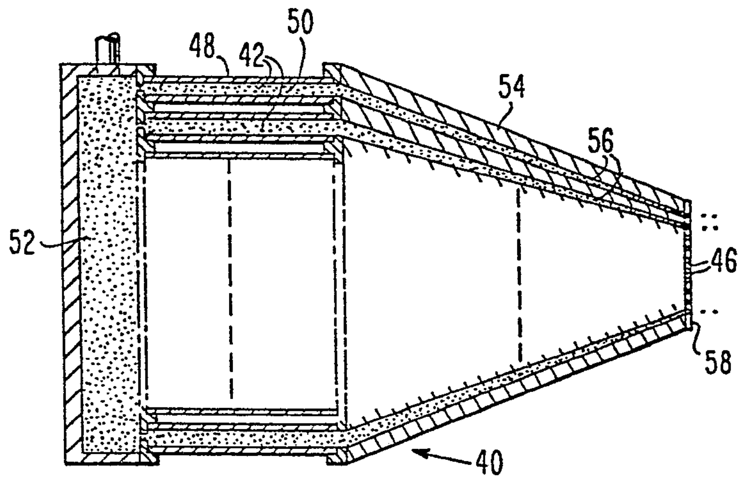

FIG.6

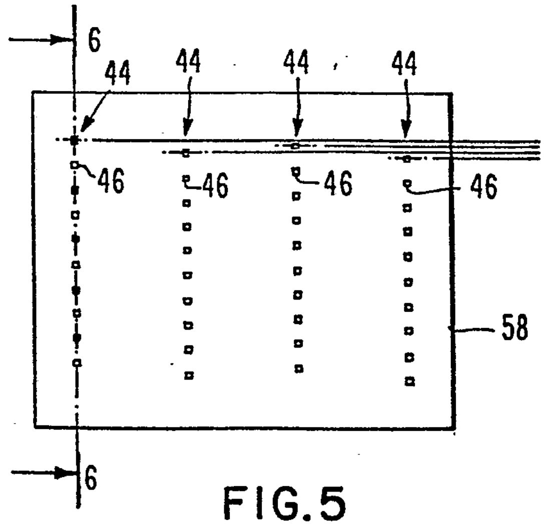

FIG.5