

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
5 April 2001 (05.04.2001)

PCT

(10) International Publication Number
WO 01/23186 A1

(51) International Patent Classification⁷: **B41J 2/175**

Kum Ming, Nigel; 4308 West Point Loma Boulevard,
Apartment J, San Diego, CA 92107 (US).

(21) International Application Number: PCT/US00/26973

(22) International Filing Date:

29 September 2000 (29.09.2000)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

60/156,733 30 September 1999 (30.09.1999) US
09/672,358 28 September 2000 (28.09.2000) US

(71) Applicant: **KIMBERLY-CLARK WORLDWIDE, INC.** [US/US]; 401 N. Lake Street, Neenah, WI 54956 (US).

(74) Agents: **FLACK, Steven, D.** et al.; Kimberly-Clark Worldwide, Inc., 401 N. Lake Street, Neenah, WI 54956 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

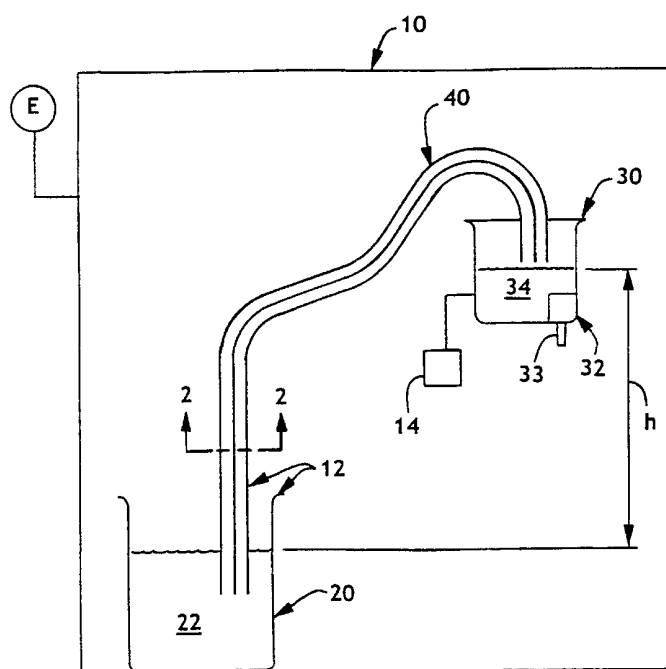
(72) Inventors: **JANSSEN, Robert, Allen**; 2845 Abbottswell Drive, Alpharetta, GA 30022 (US). **HAASE, Lori, Lyn**; 9965 Barston Court, Alpharetta, GA 30022 (US). **WOO,**

Published:

— With international search report.

[Continued on next page]

(54) Title: **PRINthead INK DELIVERY APPARATUS AND METHOD TO INCREASE THE INK DELIVERY PRESSURE ON A PRINthead UTILIZING SAID APPARATUS**



(57) Abstract: A printhead ink delivery system for use in ink jet printers is provided which includes an ink reservoir (20), a printhead (30) and a fluid conduit (40) in fluid connection with the ink reservoir (20), with the fluid conduit including at least two lumens. The fluid conduit desirably includes between two and ten lumens and is constructed of a hydrophilic polymer.



WO 01/23186 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

PRINthead INK DELIVERY APPARATUS AND METHOD TO INCREASE THE INK DELIVERY PRESSURE ON A PRINthead UTILIZING SAID APPARATUS

FIELD OF THE INVENTION

5

The present invention is generally directed to a printhead ink delivery apparatus and a method for increasing the delivery pressure to a printhead utilizing said apparatus. More particularly, the present invention relates to an apparatus and method for increasing the delivery pressure on an ink jet printhead as well as a method for prolonging the use
10 life of a filter in a printhead.

BACKGROUND OF THE INVENTION

Ink jet pens/printers are well known in the art. Ink jet printers typically include an ink
15 delivery apparatus which delivers ink from an ink reservoir to a printhead (or printhead cartridge). The printhead is most often a drop-on-demand cartridge and as such, relies on either of two technologies to eject an ink droplet from a printer nozzle/orifice onto a substrate. These printheads can be classified into either "thermal bubble" type printheads or "piezoelectric" type printheads. Such printheads require a certain level of pressure
20 head to maintain pressure on the nozzles in order to force ink through the printhead onto a substrate.

Thermal bubble type printheads typically include a thin film resistor that is heated to cause a sudden vaporization of a small portion of the ink. The rapid expansion of the ink vapor into a bubble forces a small amount of ink through the printhead orifice or nozzle.
25 This thermal bubble is replaced by ink drawn from a primary ink reservoir.

Piezoelectric type printheads use a piezoelectric element that is responsive to a control signal for abruptly compressing a volume of ink in the printhead, to thereby produce a pressure wave that forces the ink drops through a printhead nozzle/orifice. As ink is forced from the piezoelectric printhead, it is replaced with ink from a primary ink
30 reservoir.

Printheads often include a secondary ink reservoir within their structure (as opposed to the primary ink reservoir of the ink delivery apparatus) which receives the ink from the primary ink reservoir through a fluid conduit. This secondary reservoir may also include a filter for filtering ink before it is ejected from the printhead through the
35 printhead nozzles/orifices. Often, the types of filters and nozzles capable of being used in

a printhead are limited by the pressure requirements of the printhead for forcing ink through the unit. For instance, filters which separate very small particulates from the ink require greater pressure for their successful continuous operation. The pressure effectively drops in the printhead as the ink passes across the filter and passes through the nozzles. Furthermore, as all filters clog somewhat (from built up particulates within the printhead) during repeated printing operations, the pressure required to effectively force the same volume of ink (and maintain a constant flow) across their surfaces and out the nozzles increases over time. As a result, when filters in printhead cartridges start to become clogged, they will normally need to be discarded, because the ink flow rate will be reduced to the point that it will starve the printhead nozzles. Despite the need for greater pressure, currently available ink delivery apparatus are limited in the level of pressure (pressure head) which they can deliver without causing leakage of ink from the printhead nozzles. That is, the design of conventional print heads limit the ability to exploit techniques or phenomena, such as for example capillarity, that may be used to enhance pressure.

The ink delivery apparatus used with these printheads typically includes a primary ink reservoir and a fluid conduit or feeder tube, for delivering the ink from the primary ink reservoir to the secondary ink reservoir of the printhead. The primary ink reservoir may be either a rigid structure or a flexible collapsible structure, as is described in U.S. Utility Application Serial Number 09/493,368 filed January 28, 2000 assigned to the present Assignee. In this fashion, the printhead is provided with a constant replenishable ink supply for printing. The feeder tubes which have been used for delivering the ink from the primary ink reservoir to the printhead are typically single channels or single lumen tubes. Printers utilizing these tubes rely to a limited extent on capillary action to draw fluid through the ink delivery apparatus, and are therefore limited by the structure of the feeder tubes. These tubes effectively restrict the vertical positioning of the printhead within an ink jet printer with respect to the primary ink reservoir.

The widths of ink jet printers are typically between 24 and 36 inches. Additionally, wide-format printers will print on media up to 72 inches (180 cm) in width. Thus, the feeder tubing needed to connect the printhead cartridges to the primary ink reservoirs of these printers should ideally be able to extend between 2 and 6 feet, depending on the printer type. Tubing of these lengths provides the most flexibility in the placement of the printheads. Such lengths allow the connection of the reservoir and printhead at maximum separation when the ink reservoirs are positioned at one end of the printer and the printheads are at the other. With the currently available ink delivery apparatus, such

tubing is usually oriented in a horizontal configuration between the primary ink reservoir and the printhead, since the delivery pressure (or pressure head) provided by capillary action is limited by the feeder tube construction.

5 Currently available feeder tubes therefore have lengths up to 180 cm (in order to accommodate wide format printers). Since it is desirable to position a printhead near eye level so as to observe the firing of the printhead nozzles (that is ejection of the ink) during the printing process, the ink reservoir and fluid conduit have therefore also been positioned at or near eye level. At times, locating the ink reservoir at or near eye level has posed a convenience issue, interfering with the observation of and the ability to easily
10 work with the printhead, especially while refilling the ink reservoir.

 Currently available feeder tubes are made of polypropylene or polyvinyl chloride (PVC) having an inside diameter typically in the range of 3 to 5mm, limiting the extent that capillary action helps draw the ink to the printhead cartridges. This restriction also limits the flexibility in vertical positioning the printhead cartridge relative to the ink reservoir
15 within the inkjet printer.

 Various approaches have been utilized to insure that substantially constant back pressure is provided to the printhead in order to regulate the size and quantity of the ink droplets, as the ink is depleted during the ink jet printing operations. This back pressure also prevents leakage of ink from the printhead nozzles when the printhead nozzle is not
20 firing. Such approaches are described in U.S. Patent Nos. 4,509,062 to Low et al., 4,771,295 to Baker, and 5,010,354 to Cowger et al. In particular, U.S. Patent 5,010,354 describes capillary tubes which are contained within a separate chamber of an inkjet printhead cartridge, as opposed to being connected between an ink reservoir and the cartridge. The purpose of the capillary tubes in this patent is described as providing a
25 slight negative pressure (less than ambient) to prevent ink from leaking out of the printhead during storage, and air from leaking in.

 Additionally, U.S. Patent 5,148,185 describes capillary action achieved by linking successively smaller reservoirs in series within an inkjet printhead cartridge. This type of arrangement poses a challenge in designing a printer utilizing this technology.

30 U.S. Patent 5,621,446 describes a combination of an ink sponge and small tubes which are used to provide capillary action within a printhead cartridge. The stated purpose of these materials is to prevent the introduction of air bubbles into the cartridge, which would then interfere with normal firing of the inkjet nozzles.

Finally, in U.S. Patent 5,821,965, a porous material is used to provide capillary action within the printhead cartridge itself to create a slight negative pressure within the cartridge so as to prevent ink from leaking out and air from leaking in.

Therefore it is seen that a need remains for an ink delivery apparatus for use in an ink jet printer which provides additional pressure to the printhead through the use of capillary action while the printer is in use, and still maintains less than ambient pressure when the printer nozzles are not firing.

A need also remains for a printhead positioned at or near eye level and having the flexibility of positioning the primary ink reservoir vertically removed from the printhead location. In this regard it would be desirable to have the primary ink reservoir situated at a location such as on the floor level or below eye level. It would also be desirable to have the flexibility of positioning the printhead at several locations with respect to the primary ink reservoir.

Furthermore, it is seen that a need remains for a printhead ink delivery apparatus which provides flexibility in positioning a printhead and also provides increased delivery pressure to the printhead, allowing for the use of a variety of filters in a printhead cartridge, or prolonging the use of filters by increasing the delivery pressure to a printhead during use. It is to such that the present invention is directed.

SUMMARY OF THE INVENTION

The present invention meets the needs of the art by providing an ink delivery apparatus for use in ink jet printers. The ink delivery apparatus provides an ink reservoir and a fluid conduit in fluid connection with the ink reservoir and a printhead, with the fluid conduit including at least two lumens that are sized for maintaining pressure at the printhead. Desirably the fluid conduit includes between two and ten lumens and is constructed of a hydrophilic polymer. In particular, the fluid conduit can be constructed of at least one polyurethane.

In this fashion the ink delivery apparatus increases the delivery pressure to the inkjet nozzles by capillary action external to the printhead cartridge; the increase in delivery pressure helping to counteract pressure losses through a cartridge filter, as well as increasing the flexibility of locating the ink reservoir and printheads in a vertical orientation with respect to each other on an ink jet printer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a block diagram of an ink jet printhead and ink delivery apparatus within an ink jet printer, according to the present invention.

5

FIG. 1B is a block diagram of an alternate embodiment of an ink jet printhead and ink delivery apparatus within an ink jet printer, according to the present invention.

FIGS. 2A-2D are cross-sectional views of feeder tubes/fluid conduits for use with the ink delivery apparatus of FIG. 1 taken along lines 2---2.

10

FIG. 3 is a cross-sectional block diagram of feeder tubes from a trial example, having different inside diameters, and contained in a beaker of ink.

15 DETAILED DESCRIPTION

With reference to the drawings, in which like numerals refer to like parts, FIG. 1A illustrates a block diagram/schematic of an ink jet printer 10 with a printhead ink delivery apparatus 12 including a primary ink reservoir 20, a fluid conduit 40, and a printhead 30 according to the present invention. The ink jet printer is in electrical connection to a power source shown generally as E.

20

The ink delivery apparatus comprises a primary ink reservoir 20 for holding a requisite portion of ink 22. The primary ink reservoir 20 is typically a polymeric receptacle which may be open, closed and vented, or collapsible. Such reservoirs typically contain approximately 0.5 liters of ink jet ink. Such inks include without limitation thermal and piezo type ink jet inks. Such inks usually have surface tensions in the range of 30-60 dynes/cm although averaging around 40 dynes/cm. The viscosity of such inks normally ranges from about 1 to 7 centipoise (cP), with most inks averaging around 4-5 cP.

25

The primary ink reservoir is positioned to allow the proper delivery pressure to the printhead through the fluid conduit 40, and may be located up to 180 cm from the printhead in the horizontal direction, with some vertical separation of the two components. The amount of vertical separation will depend on the required pressure head on the printheads that are necessary to eject or fire ink. Desired pressures on printheads vary, but are typically between about 2 and 3 cm of liquid height.

30

A printhead 30 is shown in Fig. 1A as having a closed (sealed) secondary ink reservoir for holding ink 34. For the purposes of this application, the terms "sealed" and/or "closed" shall mean a system such as a reservoir or vessel that is constructed so that a change in internal volume will generate a corresponding change in internal
5 pressure. For example, as fluid is withdrawn/ejected from the printhead secondary reservoir, a negative pressure will result (or at least a pressure less than that in the primary ink reservoir, which is atmospheric). Also, for the purposes of this application, the term "pressure head" shall refer to the height level within the apparatus that fluid flows or travels by capillary action (capillary pressure), without being actively pumped. Finally, for
10 the purposes of this application the terms "capillary action", "capillary pressure", or "capillarity" shall mean the attraction between molecules, similar to surface tension, which results in the rise of a liquid in small tubes or fibers, or in the wetting of a solid by a liquid.

Additionally, the printhead includes a filter 32 and a printhead nozzle (orifice) 33 for ejecting ink from the printhead. The printhead includes a filter (such as a screen) to catch
15 particulates so as to avoid clogging individual nozzle channels in the printhead. Typical filters can filter out particulates greater than 10 microns in size. Alternatively, the secondary ink reservoir may be open as shown in Fig. 1B, provided that the fluid conduit/feeder tube is maintained submersed below the secondary ink reservoir ink level and the pressure head on the capillary is above the level of the ink in the secondary
20 reservoir. Desirably, for either embodiment, the fluid conduit should be maintained submersed below the ink level of the secondary ink reservoir so as to prevent introduction of air into the ink line, and to assure a continuous flow of ink.

The printhead 30 may be either a "thermal bubble" type printhead or a "piezoelectric" type printhead. As such, the printhead also includes the requisite
25 components of each type, known in the art and shown generally as 14. Examples of printheads to be used in accordance with the present invention include "thermal bubble" type printheads manufactured by Hewlett Packard of Palo-Alto, California, Cannon of Tokyo, Japan, Lexmark of Lexington, Kentucky, Xerox of Stamford, Connecticut, and Olivetti Corporation of Ivrea, Italy, as well as "Piezoelectric" type print heads manufactured
30 by Trident International of Brookfield, Connecticut, Spectra of Hanover, New Hampshire, Hitachi Koki Imaging Solutions of Simi Valley, California, Xaar of Cambridge, United Kingdom, Modular Ink Jet Technology of Stockholm, Sweden, On Target Technologies of Santa Clara, California, Brother of Nagoya, Japan, Scitex of Dayton, Ohio and Epson of Torrance, California.

A feeder tube or fluid conduit 40 is in fluid communication between the primary ink reservoir 20 and the secondary ink reservoir of the printhead 30. The feeder tube is comprised of at least two lumens or bores that are defined by the walls of the feeder tube or fluid conduit, and which make up the interior passageways between the ends of the fluid conduit. The feeder tube has a total height "h" between the level of ink in the primary reservoir 20 and the level of ink in the secondary reservoir of the printhead 30. Each of the lumens in the feeder tube are sized to have an inside diameter "d", as can be seen more clearly in FIG. 2, which is generally uniform along the entire lumen length, from the primary ink reservoir 20 to the printhead 30. Depending on the number of lumens within tubes having a given outside diameter, the lumen inside diameters may vary. Generally, feeder tube outside diameters should be determined by the inner diameter of the lumens. It should be recognized that depending on the number of lumens or type of extrusion methods used to produce the feeder tubes, individual lumens within a feeder tube can have different inside diameters. For instance, FIGS. 2A-2D represent cross-sectional views of feeder tubes 40 for use with the ink delivery apparatus 12 of FIG. 1 taken along line 2---2. In particular, FIG. 2A illustrates a multi-lumen feeder tube having two lumens 44 of different cross-sectional shape. FIG. 2B illustrates a cross-section of a multi-lumen feeder tube with three lumens 46. FIG. 2C illustrates a cross-section of a multi-lumen feeder tube with four lumens 48. FIG. 2D illustrates a cross-section of a feeder tube with two lumens 54 and 56, in which one of the lumens has an inside diameter (and area) significantly smaller than the other.

It has been found that the smaller the inside diameter of the lumen, the more capillarity is experienced by the feeder tube, that is the higher "h" value the tube can have and the higher additional pressure the feeder tube can deliver to a printhead. However, lumens with smaller inside diameters sacrifice flow rate per lumen, which affects the rate at which the printhead can fire droplets of ink onto a substrate. Therefore, having a larger number of lumens in the same cross-sectional area compensates for the loss of flow through lumens of smaller inside diameter. The flow in all of the individual lumens would be summed to equal that of the flow of a single large inside diameter lumen.

It is desirable that a feeder tube be constructed having as many lumens of small inside diameter as possible.

The typical flow rate required for a printhead is between about 0.005 to 1.0 cc/sec. This would also be the preferred flow rate range at a vertical distance of 3-5 feet between the printhead and the primary ink reservoir. The number of lumens in a feeder tube should therefore at a minimum range between 2 and 10, depending on the type of printing

application desired. The inside diameter of each of the lumens is desirably between 0.01 and 3.0 mm. More desirably, the inside diameters of the lumens is between 0.10 and 1.0 mm. For a multilumen feeder tube having more than 6 lumens, an arrangement of the lumens can include a honeycomb. Such an arrangement would include 6 of the lumens
5 as the points of a hexagonal arrangement and one lumen in the middle of the hexagon.

The multilumen feeder tube with small inside diameters provides additional capillary effect to raise the height of the ink from the primary ink reservoir 20, thereby adding to the delivery pressure on the printhead cartridge. This increase in capillary effect/delivery pressure also allows for an increase in the vertical distance between the reservoir and the
10 printhead. Further, it allows for the use of finer filters in the printhead cartridge without sacrificing pressure in the printhead, as well as the prolonged use of filters after some filter clogging.

The feeder tubes (fluid conduits) 40 are desirably made by extrusion of a hydrophilic material such as polyurethane. In this fashion any capillary action in the feeder tube
15 lumens is enhanced. Such a material is available from BF Goodrich under the brand name Estane®. However, other feeder tube materials may be used. These include polyvinyl chloride, ester or ether based urethanes, or olefins, although olefins are not preferred since they have a tendency to kink and are often hydrophobic. The extruded feeder tubing is available from Duall Plastics Inc. of Athol, Massachusetts, FBK Medical
20 Device Technologies of Birmingham, Alabama, Precision Extrusion, Inc. of South Glenn Falls, New York, and Medefab (Medical Device Fabrication), a division of HMD, Inc. of Jaffrey, New Hampshire. The fluid conduit 40 can be used in an ink delivery apparatus in combination with methods for creating negative (less than ambient or back) pressure in a printhead, such as those heretofore described.

25 The multilumen fluid conduit 40 of the present inventive apparatus gives greater flexibility in vertical positioning the primary ink reservoir 20 with respect to the printhead 30. This flexibility is obtained by allowing for longer feeder tubes having multiple lumens of smaller inside diameters. These feeder tubes have a greater potential height "h" that the ink will travel, enabling the printer cartridge to be positioned a greater distance from
30 the primary ink reservoir without suffering from loss of pressure head. For instance, the printhead can be located at eye level and the reservoir can be positioned at or near floor level.

In order to demonstrate the increased capillary effect of feeder tubes with smaller inside diameter lumens the following trial examples were performed using feeder tubes
35 having various inside diameters. The feeder tubes used in the trial examples are meant

to be exemplary only, to aid in the understanding of the present invention. The invention is not meant to be limited thereto.

Example 1 Conditions

5

Two polyolefin single lumen feeder tubes 50 and 52 (as shown in FIG. 3) having inside diameters of 2.7 mm and 1.0 mm respectively, were obtained from HMD, Inc. of Jaffrey New Hampshire. As can be seen in FIG. 3, the tubes were placed in a 250 ml glass beaker 49, partially filled with black ink. The tubes were held at the same level
10 below the surface and the fluid in the tubes immediately rose to a height from capillary action.

Example 1 Test Results

The distance that the ink was raised by capillary action in the feeder tube with a lumen of smaller inside diameter was measured and compared with the measured
15 distance that the same ink was raised in the tube having a lumen of larger inside diameter. The tube with the larger inside diameter exhibited a rise of ink significantly less than that of with the smaller inside diameter, demonstrating that the tube with the smaller inside diameter will provide added pressure to a printhead cartridge. In particular, after placement in the ink bath, the feeder tube having the larger inside diameter 50
20 demonstrated less capillary effect h_3 than the feeder tube 52 having the smaller inside diameter lumen, which demonstrated a capillary effect h_2 .

Results from Example 1 are reflected in the following Table 1.

Table 1

Approximate Internal Diameter of Feeder Tubes	Approximate Height Above Fluid Surface	Feeder Tube Figure No.
2.7 mm	2.0 mm	50
1.0 mm	6.0 mm	52

Example 2 Conditions

- 5 A single two lumen feeder tube having two lumens with a cross sectional area represented by FIG. 2D was obtained from Precision Extrusion, Inc. of South Glenn Falls, New York. The larger of the two lumens had an approximate inside diameter of 2.3 mm and the smaller of the two lumens had an approximate inside diameter of 0.7 mm
- 10 (available as Product number 20357, 0.105 Dual Lumen). The feeder tube was manufactured by extrusion of a thermoplastic polyurethane blend. As in example 1, the tube was placed in a 250 ml glass beaker. However, in this example the beaker was partially filled with Encad Magenta Novajet GO ink, available from Encad, Inc. of San Diego, California.

Example 2 Test Results

The distances that the ink was raised by capillary action in each of the lumens were measured and are expressed in Table 2 shown below, demonstrating a larger rise in the lumen of smaller inside diameter.

Table 2

Approximate Internal Diameter of Lumen	Approximate Height Above Fluid Surface
2.3 mm	5.0 mm
0.7 mm	20.0 mm

Equation 1 shown below may be used to calculate the approximate increase in pressure head that a feeder tube of a given diameter will provide due to capillary action.

EQUATION 1

5

$$h = \frac{2 \gamma \cos \theta}{g r \rho}$$

where h represents pressure head measured in centimeters of fluid, the symbol
 10 gamma (γ) in the numerator represents the surface tension of the liquid in
 dynes/centimeter, and the angle θ representing the angle that the liquid makes when in
 contact with the surface of the feeder tube. In perfect wetting, the angle would be 0° and
 in perfect dewetting the angle would be 180° . An angle of 0° would be ideal as it would
 give a maximum of wetting in a hydrophilic tube, that would be a maximum of pulling force
 15 to a given height. In the denominator the density of the fluid is represented by the symbol
 rho (ρ) in g/cm^3 , g represents the gravitational constant of 980 cm/sec^2 , and r represents
 the inside radius of the lumen in cm.

This can be illustrated by the following example:

If $g = 980 \text{ cm/sec}^2$, ρ is equal to 1 g/cm^3 , γ is equal to 40 dynes/cm , r is equal to 0.05 cm
 20 and θ is equal to 0° the following height may be calculated.

$$h = \frac{2 \gamma \cos \theta}{g r \rho}$$

25
$$h = \frac{2 (40 \text{ dynes/cm})(\cos 0^\circ)}{(1 \text{ g/cm}^3) (980 \text{ cm/sec}^2) (0.05 \text{ cm})}$$

$$h = \frac{2 (40 \text{ dynes/cm})(1)}{(1 \text{ g/cm}^3) (980 \text{ cm/sec}^2) (0.05 \text{ cm})}$$

$$h = 1.6 \text{ cm}$$

In this fashion the pressure heads provided by the following feeder tubes (with respective
5 inside diameter) can be calculated:

Table 3

Tube (Inside Diameter) in mm)	Pressure Head (h) in cm
2.0 mm	0.8 cm
1.0 mm	1.6 cm
0.1 mm	16 cm

The additional pressure head provided by the feeder tubes can be utilized in different ways. For example, using multiple 0.1 mm lumens would provide an additional pressure
10 head of 16 cm due to capillary action. This 16 cm of pressure head could be used to offset any back pressure created by clogging of the filter in the print head cartridge. The 16 cm of pressure head could alternatively be used to reduce the length of tubing used to connect the secondary ink reservoir with the ink cartridge. The additional pressure head provided by capillary action is especially dramatic in office and desktop printers, which
15 typically have feeder tube lengths on the order of 30 cm.

In operation, the printhead of an ink jet printer utilizing the ink delivery apparatus is first activated by known means to eject ink drops from the ink jet orifices (nozzles) 33. A pulse is sent into the printhead 30. The pulse may be either a thermal pulse or a piezoelectric pulse. The pulse shock then forces ink from the printhead onto a substrate.
20 The printhead is constantly refilled with ink from the primary ink reservoir. Upon ejection of the ink from the printhead nozzles, the positive pressure head resulting from the surface tension and wetting angle of the ink on the feeder tube 40 will bring more ink into the cartridge by means of capillary action. When there is added back pressure resulting from filter plugging (in addition to the back pressure intentionally created by other capillary

methods such as have already been described), the pressure head resulting from the capillary action would normally be compromised, resulting in a decrease of ink flow to the print head nozzles and eventual ink starvation. However, this is compensated for in the present invention by augmenting the capillary effect caused by the fluid conduit or feeder

5 tube

The present invention therefore provides an ink jet ink delivery apparatus which allows for the flexible placement of printheads 30 with respect to primary ink reservoirs 20 within an ink jet printer. Furthermore, the ink delivery apparatus provides for an increased pressure head on a printhead which enables the flow of ink to travel greater distances and overcome pressure requirements from filters within the printhead cartridge.

10

This pressure increase allows the use time of the printhead to be prolonged.

While the invention has been described in detail with particular references to the preferred embodiments thereof, it should be understood that many modifications and additions may be made thereto in addition to those expressly recited, without departure from the spirit and scope of the invention as set forth in the following claims.

15

CLAIMS

What is claimed is:

1. An ink jet delivery apparatus comprising :
a printhead;
an ink reservoir for supplying ink to said printhead;
a fluid conduit in fluid communication between said printhead and said ink reservoir,
said fluid conduit including at least two lumens that are sized
for maintaining pressure at the printhead.
2. The ink jet delivery apparatus of claim 1 wherein said fluid conduit includes between
two and ten lumens.
3. The ink jet delivery apparatus of claim 1 wherein said fluid conduit is comprised of a
hydrophilic polymer.
4. The ink jet delivery apparatus of claim 3 wherein said fluid conduit is comprised of
polyurethane.
5. An ink jet delivery apparatus comprising :
a primary ink reservoir;
a printhead including a secondary ink reservoir;
a fluid conduit in fluid communication between said secondary ink reservoir and said
primary ink reservoir,
said fluid conduit comprising at least two lumens that are sized
for maintaining pressure at the printhead.
6. The ink jet delivery apparatus of claim 5 wherein said printhead further includes a
filter.

7. The ink jet delivery apparatus of claim 5 wherein said fluid conduit includes between two and ten lumens.
8. The ink jet delivery apparatus of claim 5 wherein said fluid conduit is comprised of a hydrophilic polymer.
9. The ink jet delivery apparatus of claim 8 wherein said fluid conduit is comprised of polyurethane.
10. A method to increase the ink delivery pressure on a printhead comprising:
the steps of ;
 - a) providing a primary ink reservoir at least partially filled with ink ;
 - b) providing a printhead containing a secondary ink reservoir at least partially filled with ink, and a means for ejecting ink ;
 - c) providing a fluid conduit including at least two lumens, between said primary ink reservoir and said secondary ink reservoir for drawing said ink from said primary ink reservoir to said secondary ink reservoir;
 - d) ejecting ink from said printhead.
11. An ink jet delivery apparatus, comprising :
a printhead;
an ink reservoir for supplying ink to said printhead, said ink reservoir positioned between three and five feet below said printhead; and
a fluid conduit in fluid communication between said printhead and said ink reservoir, said fluid conduit comprising at least two lumens that are sized for maintaining pressure at the printhead.

1/4

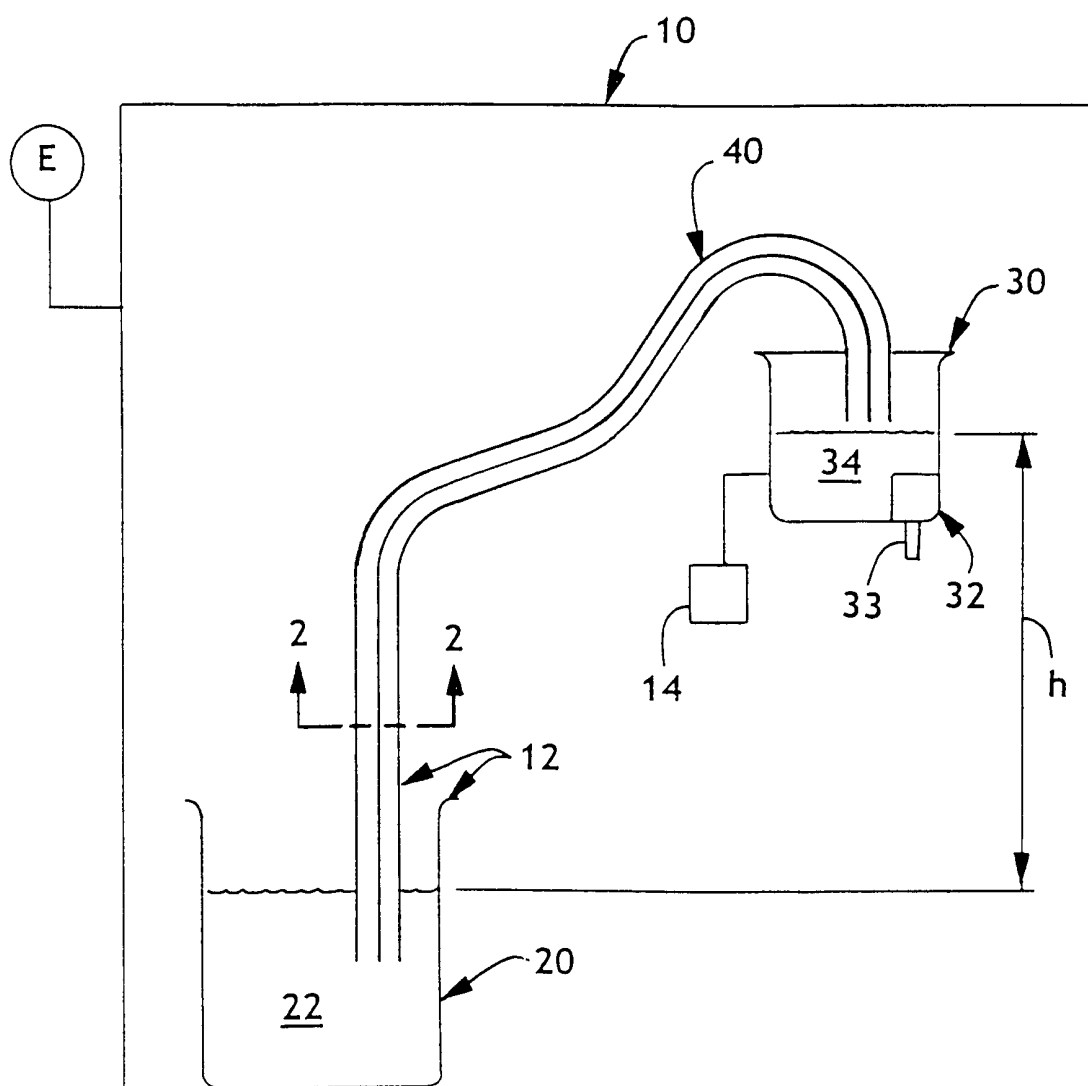


FIG. 1A

2/4

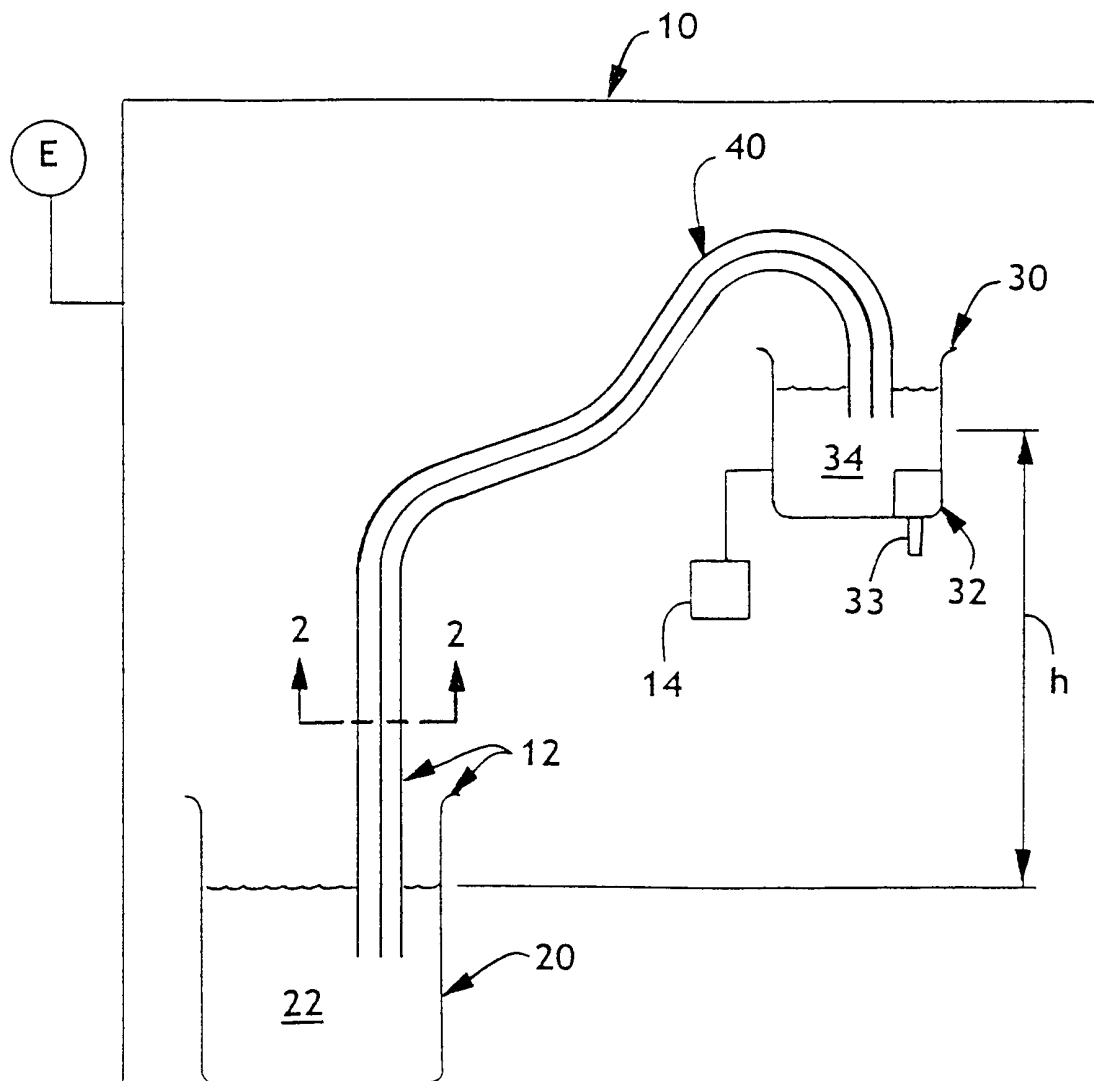


FIG. 1B

3/4

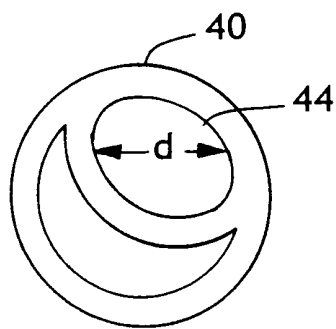


FIG. 2A

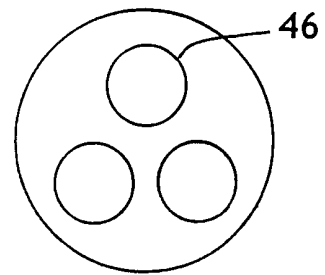


FIG. 2B

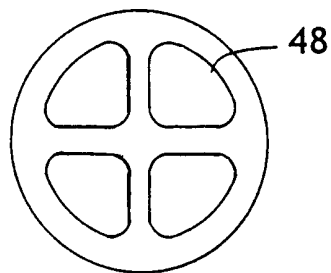


FIG. 2C

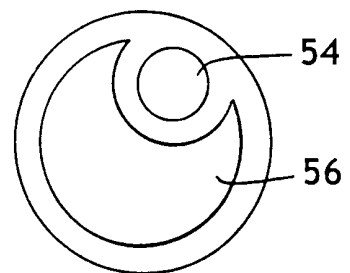


FIG. 2D

4/4

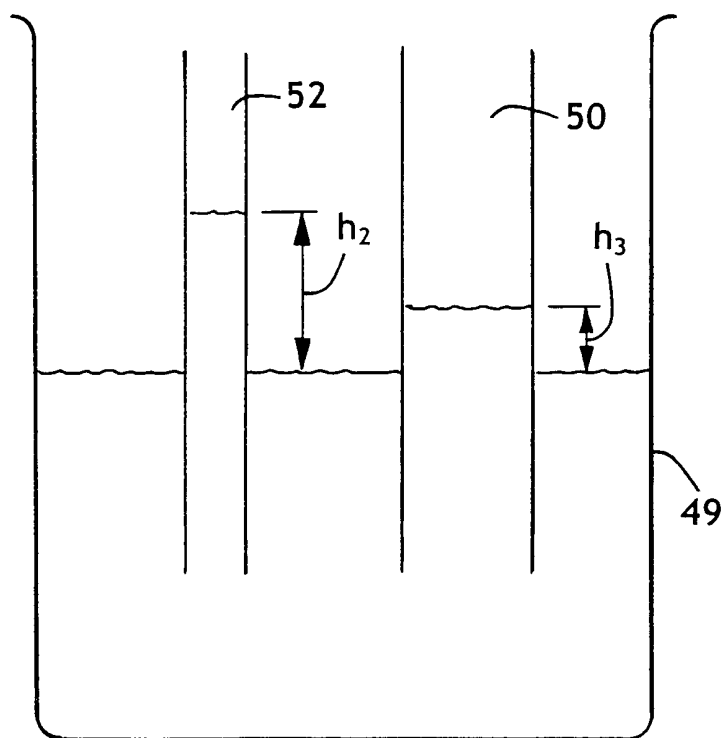


FIG. 3

INTERNATIONAL SEARCH REPORT

Internat' I Application No
PCT/US 00/26973

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B41J2/175

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 826 504 A (HEWLETT PACKARD CO) 4 March 1998 (1998-03-04) page 4, line 1 - line 45; figures 1,2,14-16	1,2,5-7, 10,11
A	page 4, line 46 - line 54 ---	3,8
P,A	US 6 007 190 A (FRIES WILLIAM M ET AL) 28 December 1999 (1999-12-28) column 5, line 40 - line 67; figure 11 column 10, line 43 - line 65; figure 9	1,2,5-7, 10,11
A	column 5, line 36 - line 39 ---	4,9
A	US 5 025 270 A (UMEZAWA KAZUHISA) 18 June 1991 (1991-06-18) the whole document --- -/--	1,2,5-7, 10,11

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

11 January 2001

Date of mailing of the international search report

19/01/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Adam, E

INTERNATIONAL SEARCH REPORT

Internat'l Application No

PCT/US 00/26973

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 043 746 A (ABE TSUTOMU) 27 August 1991 (1991-08-27) column 2, line 10 - line 41; figures 1,2 ---	1,2,5,7, 10,11
A	EP 0 904 940 A (BROTHER IND LTD) 31 March 1999 (1999-03-31) ---	
A	US 5 309 179 A (AGBEZUGE LAWRENCE K ET AL) 3 May 1994 (1994-05-03) -----	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/26973

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0826504 A	04-03-1998	US 6068370 A JP 10086403 A US 6003981 A	30-05-2000 07-04-1998 21-12-1999
US 6007190 A	28-12-1999	NONE	
US 5025270 A	18-06-1991	NONE	
US 5043746 A	27-08-1991	JP 60232964 A	19-11-1985
EP 0904940 A	31-03-1999	JP 11099655 A JP 11099665 A	13-04-1999 13-04-1999
US 5309179 A	03-05-1994	JP 6126979 A	10-05-1994