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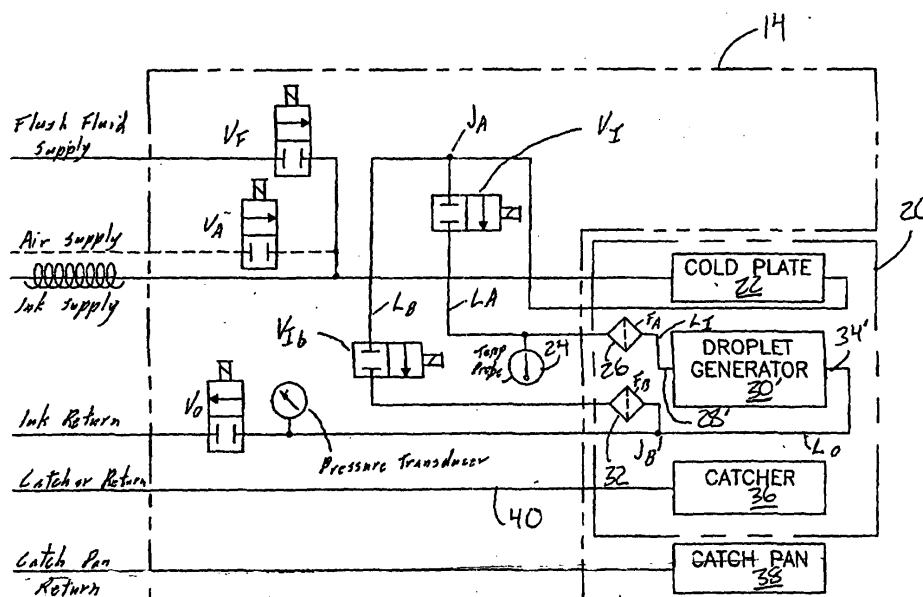
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• **Woolard, Daniel E.****Dayton Ohio 45419 (US)**(54) **A system and method for uniformly and equally supplying ink to both ends of a droplet generator**

(57) An ink jet printer has an associated droplet generator (30') with multiple fluid ports (28', 34') to the droplet generator. At least one of the multiple fluid ports (28') serves as a monodirectional inlet port through which fluid is supplied to the drop generator (30'), and at least

one of the multiple fluid ports (34') is bidirectional, serving as an outlet during startup and shutdown of the printhead (20) and serving as an additional ink inlet port during regular operation of the printhead (20), thereby reducing the inlet flow rates below the turbulence onset flow rate.

Fig. 3



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Description

[0001] The present invention relates to continuous ink jet printers and, more particularly, to a system and method for reducing turbulence in the fluid cavity of a drop generator.

Background Art

[0002] Ink jet printing systems are known in which a print head defines one or more rows of orifices which receive an electrically conductive recording fluid, such as for instance a water base ink, from a pressurized fluid supply manifold and eject the fluid in rows of parallel streams. Printers using such print heads accomplish graphic reproduction by selectively charging and deflecting the drops in each of the streams and depositing at least some of the drops on a print receiving medium, while others of the drops strike a drop catcher device.

[0003] Droplet generators are one of the major components in a continuous ink jet printhead. Droplet generators often use a nozzle plate attached to a resonant body to stimulate the jets. Several different methods are currently in practice to supply fluid to the nozzle plate. One known method includes fluid passages originating at the nodal line of the resonant body, with internal cavities leading to the nozzle plate. Another known method teaches that the fluid ingress can be achieved by feeding ink through a fluid port in the end wall of the droplet generator, where the fluid port is located down close to the nozzle plate face of the droplet generator. This eliminates the longer internal cavities required with a nodal line feed droplet generator. This latter method is referred to as a bottom front feed droplet generator. As a variation of that concept, it is known that fluid can be fed from the side, as opposed to the front.

[0004] The standard operation of ink jet printers, well known in the art, has relied on ink being supplied into one end of the droplet generator, such as is disclosed in U. S. Patent No. 4,999,647 and also in commonly assigned, co-pending U.S. patent application Serial No. 09/211,059. The outlet port is used to provide an ink return path when ink is cross-flowed through the droplet generator during printer startup to remove internal particles and re-dissolve ink residue from the prior printer shutdown. This "single feed" configuration has been satisfactory for products with up to 2700 orifices and droplet generation rates of 110,000 kHz/jet, and many such printers can be operated without projecting the fluid flow into the turbulent regime.

[0005] Suppression of turbulence in drop generators has become an issue as the printhead gets longer or the drop formation rate increases. At some point, the high flow rate of ink into the drop generator results in turbulence in the fluid cavity of the droplet generator. Such turbulence in the fluid cavity of the drop generator can affect the directionality and speed of the ink drops formed by the drop generator. As an example, a current

two-drop per pixel printer at 300 dpi (requires 2 drops per 300 dpi pixel for full coverage of the pixel) requires an ink flow-rate of 750 mL/min when operated at an ink temperature of 43°C. This ink flows through a fluid cavity bore having a diameter of 0.170 inches in the droplet generator without the onset of turbulence. Turbulent flow begins to occur for this particular droplet generator configuration as the flow-rate approaches 800 mL/min. Variations in part fabrication such as tube bonding uniformity or the trench machining are known to lower this onset of turbulent flow. To fulfill the requirement for generating droplets at a frequency of 165,000 drops per second for a single drop per pixel printer at 300 dpi, the ink flow-rate required is over 1300 mL/min. Attempting to supply this ink flow to the droplet generator with a single feed line of the same bore diameter results in significant disturbance of the drop formation resulting from the turbulent fluid flow on the inlet flow end. As a result, the print quality and the operating latitude of the printhead can be adversely affected. It is therefore desirable to operate the printheads without turbulence present in the fluid cavity.

[0006] Increasing the thru-bore diameter lowers the inlet the inlet fluid velocity for the same flow rate, effectively raising the threshold flow rate for turbulence. However, this is not an acceptable option due to problems associated with lowered frequency of operation and decreased jet break-off length uniformity. One possible means to suppress turbulence in a printhead is disclosed in U.S. Patent No. 4,638,327. The drop generator in the '327 patent is divided into an upper and lower section by a means of a turbulence damping multilayer screen structure. Such a structure can work acceptably in a bolt together drop generator, such as are shown and described in that patent. However, such bolt together designs are useful only for low resolution drop generators having low drop formation frequencies. High resolution, high drop formation rate drop generators tend to require a monolithic design that does not facilitate the inclusion of such turbulence damping means.

[0007] It would be desirable, therefore, to be able to operate high frequency, long array drop generators which are not subject to the problem of turbulence in the fluid cavity.

Summary of the Invention

[0008] This need is met by the system and method according to the present invention, wherein ink is uniformly and equally supplied to both ends of a droplet generator, suppressing turbulence in high frequency, long array drop generators.

[0009] In accordance with one aspect of the present invention, an ink jet printer has an associated droplet generator with multiple fluid ports to the droplet generator. At least one of the multiple fluid ports serves as a mono-directional inlet port through which fluid is supplied to the drop generator, and at least one of the mul-

multiple fluid ports is bi-directional, serving as an outlet during startup and shutdown of the printhead and serving as an additional ink inlet port during regular operation of the printhead, thereby reducing the inlet flow rates below the turbulence onset flow rate.

[0010] Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

Brief Description of the Drawings

[0011]

Fig. 1 is a prior art view of a fluid schematic for a typical ink jet printer;

Fig. 2 is a closeup of the printhead docking station of the fluid schematic of Fig. 1, illustrating the single feed ink supply to the droplet generator; and

Fig. 3 is a closeup of the printhead docking station, modified in accordance with the present invention to illustrate the system and method suppressing turbulence in the printhead.

Detailed Description of the Preferred Embodiments

[0012] The present invention provides a system and method for suppressing turbulence in the fluid cavity of a high frequency, long array drop generator. The system and method for suppressing turbulence provides for uniformly and equally supplying ink to both the inlet and outlet ports of the droplet generator.

[0013] Referring now to the drawings, Fig. 1 illustrates a fluid schematic 10 of an existing single-feed ink supply to a droplet generator for a typical, single printhead, ink jet printer. Ink is supplied from a fluid system 12 to a printhead docking station 14, via the heated umbilical 16. The single feed ink supply is along ink path 18.

[0014] Continuing with Fig. 1, and referring also to Fig. 2, ink is supplied via ink path 18 to the printhead 20, reaching the cold plate 22. The cold plate uses the ink supplied to the printhead to cool the high voltage charge plate driver electronics, as is described and claimed in commonly assigned, co-pending U.S. patent application Serial No. 09/211,251. Ink continues along ink path 18 through the cold plate and printhead frame, re-entering the printhead docking station 14. Ink then passes by an ink temperature sensor, such as thermistor 24, before re-entering the printhead to be filtered, for example through a 1.2 micron Pall filter element 26, before being introduced to the inlet end 28 of the droplet generator 30.

[0015] The second filter 32 in the printhead filters air used during the shutdown sequence of the printhead and is usually identical to the ink filter element 26. In normal operation, valves V_F , V_I , and V_A are all closed. During startup, the V_O valve is open allowing ink to flow through the droplet generator 30 and out the exit port 34 of the droplet generator. The ink then passes by pressure transducer 35, through the cross-flush solenoid

valve V_O , and is returned to the fluid system 12. This flushes air, dried ink and other debris from the droplet generator. The V_O valve can then be closed, pressurizing the droplet generator so that ink jets are formed at each of the orifices in the orifice plate (not shown) which is bonded to the droplet generator. This ink may be returned to the fluid system by means of the catcher 36 and catch pan 38. The ink jets can then be selectively charged and deflected. Some drops are selected to be print drops and some are deflected into the catcher 36 from which they can be returned via the fluid line 40 to the ink tank 42, shown in Fig. 1.

[0016] At shutdown, the ink pump is turned off and valves V_F and V_I are opened according to a prescribed sequence to allow flush fluid to rinse ink from the droplet generator 30 and final filter 26. The shutdown sequence then involves closing V_F and opening V_A , with the air pump 44, located in the print station, turned on to blow the flush fluid out of the droplet generator 30. Startup and shutdown sequences are well known and used in prior art systems.

[0017] When the drop generator 30 is a high frequency, long array drop generator, turbulence in the fluid cavity of the drop generator must be addressed and alleviated. The present invention proposes dividing and supplying ink flow to both the inlet port 28 and the outlet port 34 of droplet generator 30, to eliminate turbulent fluid flow caused as ink flow rates and drop generator array lengths increase.

[0018] Fig. 3 shows a fluid system in accordance with the present invention, wherein a system and method are provided for uniformly and equally supplying ink to both the inlet and outlet ports of the droplet generator. Ink passes through the printhead 20 frame and cold plate 22 prior to splitting the ink flow. Compared with the prior art fluid system, all the changes are located in the printhead docking station 14 and the printhead 20. In normal operation, valves V_F and V_A are closed. Ink supplied to the printhead docking station passes through the cold plate 22 to cool printhead electronics. The supplied ink then encounters valves V_I and V_{IB} . During startup, valve V_{IB} is closed and valves V_I and V_O are open, allowing ink to flow across a thermistor for temperature measurement, through the droplet generator 30', and out the exit port 34' of the droplet generator. After an appropriate amount of flushing, valve V_{IB} is also opened. This flushes air and debris out the fluid line LB from JA to JB, which path includes the valve V_{IB} and final filter 32. Since the outlet valve V_O is open, the ink flushing out this fluid line bypasses the drop generator 30' and is returned to the ink tank 42, shown in Fig. 1. The V_O valve can then be closed, pressurizing the droplet generator 30' so that ink jets are formed at each of the orifices in the orifice plate, not shown. As both the V_I and V_{IB} valves are open, ink is supplied to the droplet generator 30' through both the LI and LO fluid lines. By using the same style valves and filters in both the LA and LB fluid lines, the fluid flow rates to the droplet generator 30' through the two ports 28'

and 34' will be approximately matched. Similarly, as the valves and filters in both the LA and LB fluid lines are matched and there are no heater sources associated with either fluid line, ink supplied through line LA has approximately the same temperature as ink supplied through line LB. Temperature differences could result in differences in stimulation, drop deflection, and ink-paper interaction across the width of the droplet generator. In this way, the fluid velocity into the droplet generator 30' is approximately $\frac{1}{2}$ that encountered with the prior art, lowering the Reynolds number for the fluid flow, and eliminating the turbulence problem while in the printing mode of operation.

[0019] In accordance with the present invention, the droplet generator 30' has multiple fluid ports, including at least the mono-directional inlet port 28' through which fluid is supplied to the drop generator, and the bi-directional fluid port 34', which serves as an outlet during startup and shutdown of the printhead and as an additional ink inlet port during regular operation of the printhead. This arrangement reduces the inlet flow rates below the turbulence onset flow rate for drop generator 30'.

[0020] At shutdown, the valves V_I and V_{IB} can be sequenced in cooperation with the valves V_O , V_F , and V_A to flush out and dry the droplet generator and the fluid lines to the printhead. Typically, the shutdown sequence would include states where one of the two valves V_I and V_{IB} will be closed, while the other is open, to facilitate the high flow rates through the fluid lines, filters and droplet generator required to effectively flush and dry the various components.

[0021] The dual feed technique described herein provides a system and method for supplying ink to a droplet generator with flow balanced to within 3% of an equal 50% division at the inlet and outlet ports of the droplet generator, of the flow. The arrangement according to the present invention also provides a mechanism for independent control of the two feed lines due to the solenoid valves in the supply lines. This allows for each filter to be evacuated separately, resulting in improved capability in completely removing all residual ink from the filters. The present invention, therefore, has the advantage of allowing flow to be directed through a single port to the droplet generator during startup and shutdown to more effectively flush the droplet generator and other components.

[0022] Having described the invention in detail and by reference to the preferred embodiment thereof, it will be apparent that other modifications and variations are possible without departing from the scope of the invention defined in the appended claims.

Claims

1. In an ink jet printing system having a printhead with an associated drop generator, the drop generator comprising:

a mono-directional inlet port through which fluids can be supplied to the drop generator; and a bi-directional fluid port associated with the drop generator, operating as an outlet port during startup and shutdown of the printhead and operating as a fluid inlet port during print operation of the printhead to reduce the inlet flow rates below the turbulence onset flow rate.

2. An ink jet printing system as claimed in claim 1 wherein during print operation of the printhead, fluid flow to the drop generator through the bi-directional fluid port is approximately equal to fluid flow to the drop generator through the mono-directional inlet port.

3. An ink jet printing system as claimed in claim 1 wherein during print operation of the printhead, temperature of fluid flow to the drop generator through the bi-directional fluid port is approximately equal to temperature of fluid flow to the drop generator through the mono-directional inlet port.

4. A method for supplying ink flow to a droplet generator associated with a printhead of an ink jet printer, comprising the steps of:

introducing ink to the printhead along an ink flow path; and
splitting the ink flow path into an inlet port flow path and an outlet port flow path, whereby ink enters the droplet generator at both ends of the droplet generator, in approximately equal flow amounts.

5. A method as claimed in claim 4 wherein clean air is supplied to the drop generator through the inlet port flow path to remove liquid from the drop generator.

6. A method as claimed in claim 4 wherein air and contaminants can be flushed from the outlet port flow path while said outlet port flow path is operating as an outlet port for the drop generator.

7. In an ink jet printing system having a printhead with an associated drop generator with first and second fluid ports and a fluid system for supplying fluid to the drop generator, the fluid system comprising:

means to supply fluid to a first fluid port of the drop generator; and
means to control fluid flow at a second fluid port of the drop generator such that the second fluid port operates as a bi-directional port serving as an outlet port during startup and shutdown of the printhead and operating as a fluid inlet port during print operation of the printhead to reduce inlet flow rates below a turbulence onset flow

rate.

8. A fluid system as claimed in claim 7 wherein during print operation of the printhead, fluid flow to the drop generator through the second fluid port is approximately equal to fluid flow to the drop generator through the first fluid port. 5
9. A fluid system as claimed in claim 7 wherein the second fluid port can have air and contaminants flushed from the second fluid port while the second fluid port is operating as an outlet port for the drop generator. 10
10. A fluid system as claimed in claim 7 wherein the fluid lines that supply ink to the second fluid port can be flushed free of air and contaminants when said second fluid port is operating as an outlet port for the drop generator. 15

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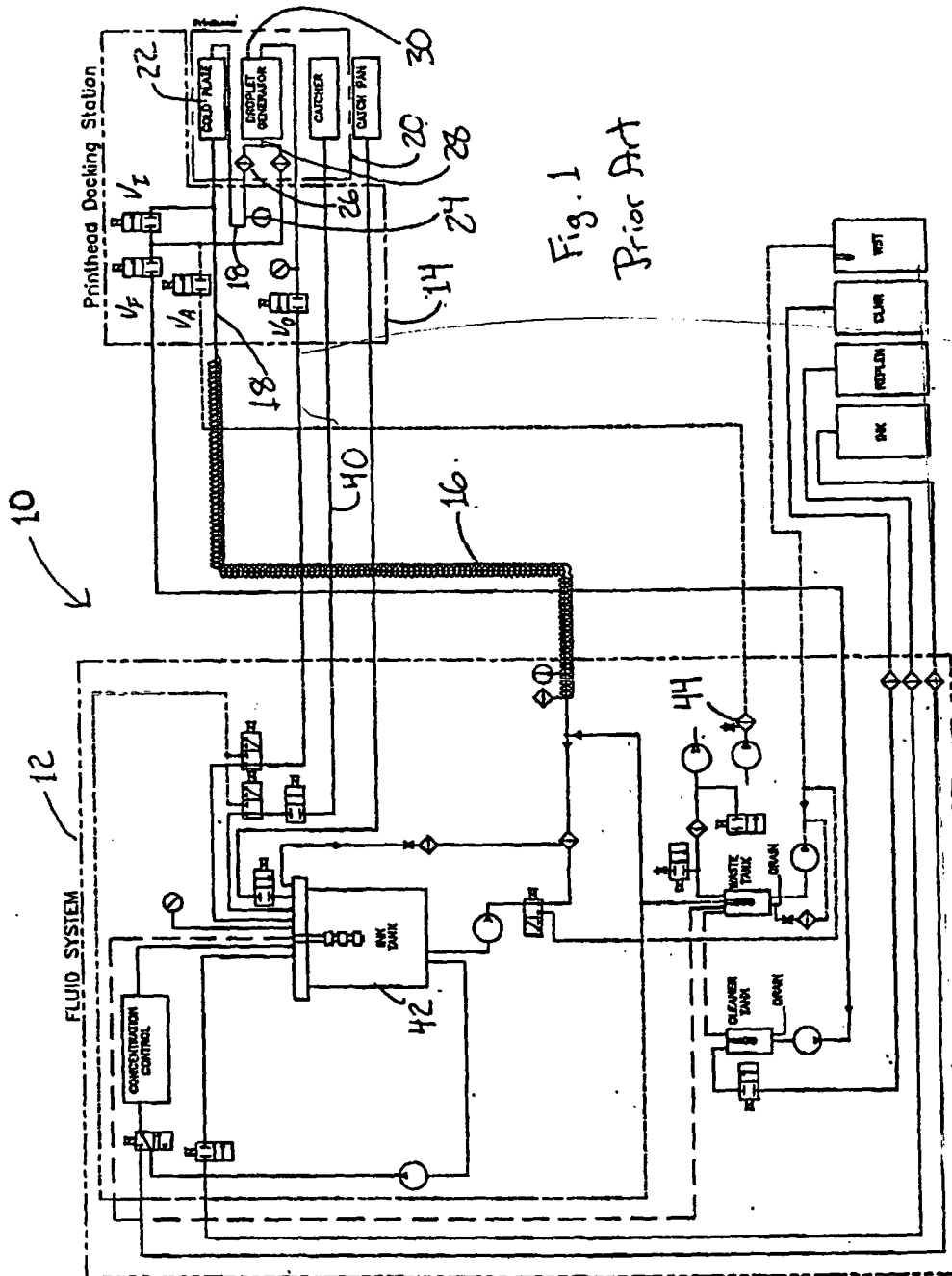


Fig. 1
Prior Art

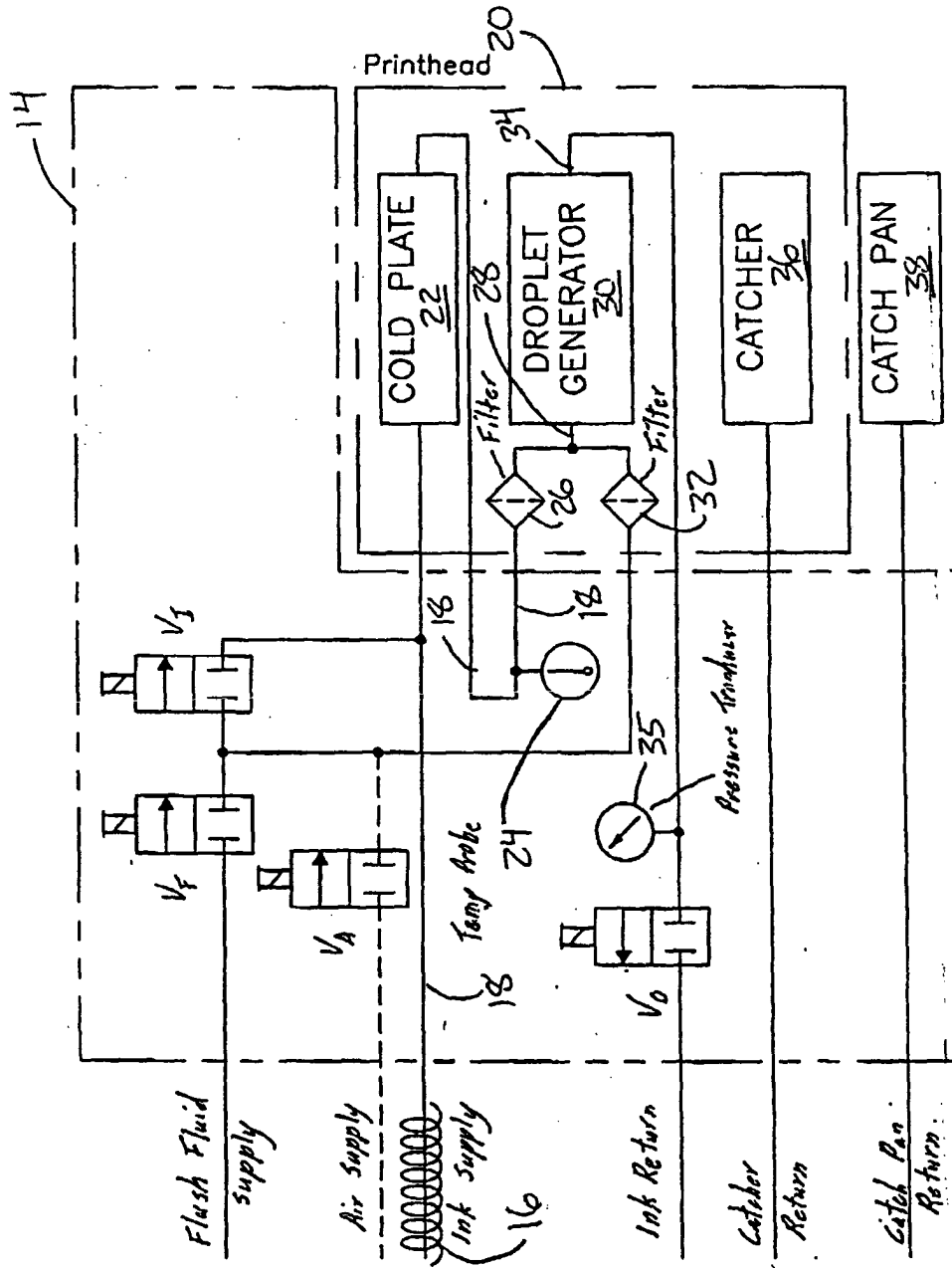
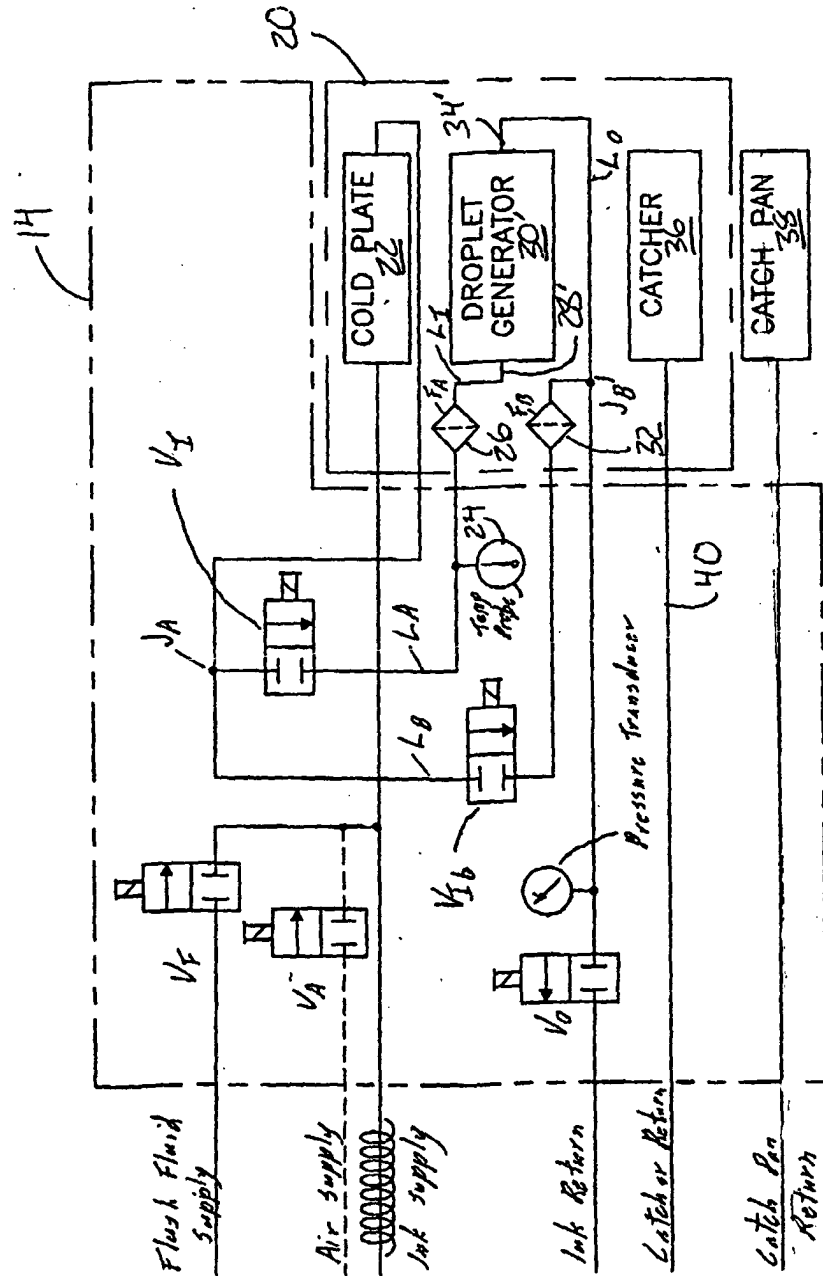


Fig. 2 Prior Art

Fig. 3





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EUROPEAN SEARCH REPORT

Application Number
EP 03 25 5928

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	EP 0 714 779 A (CANON KK) 5 June 1996 (1996-06-05) * column 11, line 49 - column 12, line 7 * * column 13, line 10 - line 29 * * figures 5-8 *	1-10	B41J2/17
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 20 November 2003	Examiner Bridge, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 03 25 5928

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