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(71) Applicant : **SCITEX DIGITAL PRINTING, Inc.**
3100 Research Boulevard
Dayton, Ohio 45420-4099 (US)

(72) Inventor : **Loyd, John C.**
7955 Brainard Woods Drive, Centerville
Ohio 45458 (US)
Inventor : **Ralston, James C.**
10097 Simms Station Road
Spring Valley, Ohio 45370 (US)

(74) Representative : **Hillier, Peter et al**
Reginald W. Barker & Co., 13, Charterhouse
Square
London, EC1M 6BA (GB)

(54) **Ink replenishment system for a continuous ink jet printer.**

(57) A continuous ink jet printer employing conductive ink and having a main ink supply (14), a supplemental ink supply (30), and a replenishment carrier fluid supply includes an ink replenishment system that replenishes ink or carrier fluid based on the resistivity of ink in the main ink supply (14).

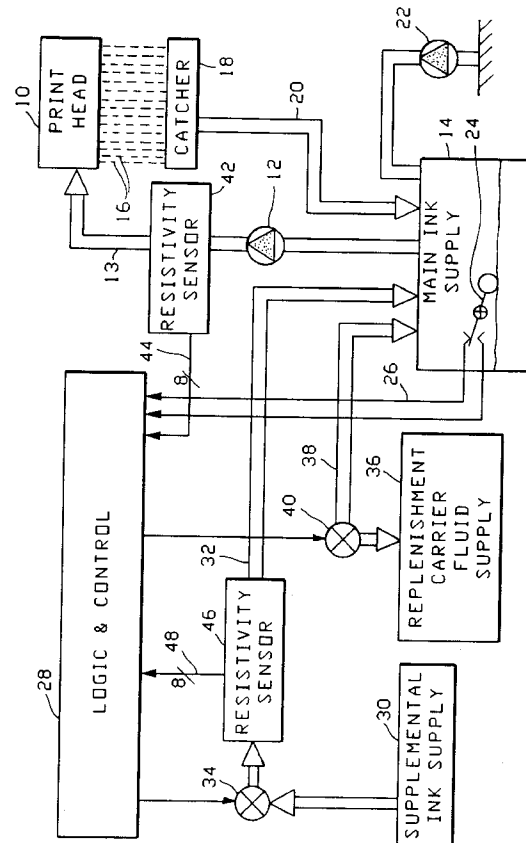


FIG. 1

Field of the Invention

The present invention relates to apparatus and methods for replenishing ink in a continuous ink jet printer.

5 Background of the Invention

In a continuous ink jet printing system, conductive ink which includes a carrier fluid such as water or an organic solvent and a colorant, such as a dye or pigment is continuously recirculated through the system to a print head. The print head generates a plurality of ink drops which are selectively charged and deflected such that some of the drops fall on a print receiving medium and some of the drops are caught and recirculated. Due to evaporation of the carrier fluid during such recirculation, the colorant concentration in the recirculating ink may increase. It is desirable for proper operation of the ink jet printing system to maintain the colorant concentration in the ink to a desired predetermined range. When printing rates are high, there is very little evaporation of carrier fluid from the ink and the ink concentration can be maintained simply by adding ink from a supplemental ink supply. Alternatively, when the printing rates are low or when the printer is in an idle state with all of the ink recirculating, the evaporation rate of carrier fluid is high. In this case, it is necessary to add carrier fluid without colorant from a replenishment carrier fluid supply to maintain the colorant concentration level within the desired predetermined range for proper operation of the ink jet printing system.

Prior art ink replenishment systems have employed ink viscosity measurement or ink optical density measurement to determine the amount of replenishment carrier fluid to add to the ink to maintain the desired concentration of colorant. These methods require the use of complex and expensive hardware, and are difficult to calibrate, for example, when the color or chemical make-up of the ink used in the system is changed, manual recalibration of the system is required. The light source and detector in the optical density measurement technique need to be recalibrated and/or changed. Furthermore, the cells through which the ink flows in the optical density measurement apparatus are quite thin and distortion of the geometry of the cells due to pressure changes in the ink can effect the accuracy of the measurement.

Another prior art system for replenishing ink in an ink jet printer is described in U.S. Patent 4,121,222 filed October 17, 1978 in the name of Diebold, et al. This system uses a printed drop count to determine how much replacement ink should be added and employs a balance scale to determine how much replenishment carrier fluid is needed. This system suffers from the problem that the hardware is complex and expensive. It is difficult to recalibrate when different batches of ink having slightly different concentrations of colorant and carrier fluid are used in the ink jet printer. It further suffers from the drawback that the measurement of ink by counting drops is an indirect measurement of ink volume and not as accurate as directly measuring a physical property of the ink.

There is a need therefore for an improved system for replenishing ink in an ink jet printer of the type having a main ink supply, a supplemental ink supply and a replenishment carrier fluid supply that is easily calibrated, inexpensive and capable of maintaining the ink concentration in the ink jet printer during both high and low printing rates.

40 Summary of the Invention

This need is met by the system and method of the present invention wherein the resistivity of the ink in the main ink supply is measured and the ink and/or replenishment carrier fluid are added to the main ink supply to maintain a desired resistivity. Ink used in continuous ink jet printers must be conductive so that the drops can be controlled by electrostatic deflection. As the ink evaporates, the salts which cause the ink to be conductive are left behind, causing the ink to be more conductive (i.e. lower resistivity). Thus, ink concentration is directly related to ink resistivity. The replenishment carrier fluid used in such printers does not contain the salts that make the ink conductive. Therefore, when carrier fluid is added to the ink, the conductivity of the ink is lowered (resistivity raised).

In one embodiment of the invention, the volume of the ink in the main ink supply is monitored, and when a predetermined volume has been depleted, the predetermined volume is replaced by either ink from the supplemental ink supply or replenishment carrier fluid from the replenishment carrier fluid supply based on the measured resistivity of the ink in the main ink supply. According to a further aspect of the present invention, the resistivity of the ink in the supplemental ink supply is also measured and when the resistivity of a new batch of ink differs from that of a previously measured batch, the desired resistivity values for the ink in the main ink supply is adjusted accordingly.

The ink replenishment system and method of the present invention is simpler and less expensive than the

prior art optical density, viscosity and drop counting measurement systems and according to a further feature of the invention is capable of automatically calibrating when the ink is changed. The system is advantageous over the drop counting method in that any slight error in the calculated volume of each drop does not affect the ink concentration.

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Brief Description of the Drawings

Fig. 1 is a schematic diagram of an ink replenishment system according to the present invention;

Fig. 2 is a schematic diagram illustrating the ink resistivity sensor shown in Fig. 1;

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Fig. 3 is a perspective view of the ink resistivity cell employed in the ink resistivity sensor shown in Fig. 2; and

Fig. 4 is a flow diagram illustrating the control logic employed in the logic and control unit in the replenishment system shown in Fig. 1.

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Detailed Description of the Invention

Referring to the drawings, Fig. 1 shows an ink replenishment system for use in a continuous ink jet printer according to the present invention. The ink jet printer includes a printhead 10 to which conductive ink is supplied under pressure by an ink pump 12 through fluid line 13 which draws ink from a main ink supply 14. The printhead 10 includes a plurality of orifices (not shown) that produce a plurality of ink jets 16 which break up into uniform streams of ink drops. Ink drops selected for printing are given an electrostatic charge different from non print drops. Ink drops which are not used for printing are directed into a catcher 18 and recirculated into the main ink supply 14 by fluid line 20. The main ink supply 14 is maintained at negative atmospheric pressure by a vacuum pump 22. Any suitable means can be employed to create the vacuum such as an aspirator or mechanical vacuum pump. The vacuum created by the vacuum pump 22 is effective in drawing the unprinted ink from the catcher 18 to the main ink supply 14. It will be clear to one skilled in the art that filters, flow restrictors and other components can be used in the ink jet printing system of the present invention without departing from the spirit or scope of the invention.

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A float switch 24 located in the main ink supply 14 senses when the level of ink in the main ink supply 14 is high and when the level drops to a predetermined low level. The float switch sends a high or low signal on line 25 or 26, respectively, to a logic and control unit 28.

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A supplemental ink supply 30 is connected to main ink supply 14 by fluid line 32 through a normally closed valve 34. A replenishment carrier fluid supply 36 is connected to main ink supply 14 by fluid line 38 through a normally closed valve 40. Normally closed valves 34 and 40 are controlled by logic and control unit 28 to open and allow ink or replenishment carrier fluid to flow into ink supply 14 from supplemental ink supply 30 or replenishment carrier fluid supply 36 respectively. A resistivity sensor 42 located in fluid line 13 measures the resistivity of ink pumped from the main ink supply 14 to the printhead 10 and sends a signal representing the resistivity of the ink on line 44 to the logic and control unit 28. Similarly, a resistivity sensor 46 located in fluid line 32 measures the resistivity of the ink drawn from supplemental ink supply 30 and sends a signal representing the resistivity of the ink from the supplemental ink supply 30 to the logic and control unit on line 48.

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Turning now to Fig. 2, the resistivity sensor 42 (and similarly 46) is shown in more detail. The resistivity sensor 42 includes fixed resistors R1, R2 and R3 and a resistance cell 50 connected in a bridge configuration. A voltage source 52 is applied across the bridge and the values of the voltage at the nodes of the bridge are applied to a multiplexer 54 through buffer amplifiers 56, 58 and 60. Optionally, a thermistor 62 is provided on the resistance cell 50 to measure the temperature of the ink passing through the cell 50. The outputs of the thermistor 62 is also applied to the multiplexer 54 through a buffer amplifier 64. Multiplexer 54 sequentially supplies the voltage values at the nodes of the bridge and the thermistor output value to the input of an analog to digital converter 66, which in turn digitizes the voltage values and supplies them sequentially to the logic and control unit 28 where the resistivity of the ink in resistance cell 50 is calculated from the known resistance R1, R2 and R3. Optionally, the temperature of the ink can also be used to adjust the resistivity value calculated to normalize the resistivity value to a standard temperature.

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Fig. 3 is a perspective view of the resistance cell 50, which includes a hollow body 68 of insulating material. A first conductive metal fitting 70 is attached to one side of the hollow body 68 through which ink can enter the hollow body. A second similar conductive metal fitting is supplied on the opposite side of the hollow body 68. Conductive lugs 72 and 74 are in electrical contact with the conductive metal fittings and provide the connections to the bridge circuit shown in Fig. 2. In operation, fluid line 13 is connected to the conductive fitting 70 and its opposite counterpart. Likewise, for conductivity sensor 46, fluid line 32 is connected to the conductive fittings.

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from said replenishment carrier fluid supply to said main ink supply when the resistivity of ink in said main ink supply is below said predetermined value.

3. The ink replenishment system claimed in Claim 2, further comprising:
 - a. supplemental sensing means for measuring the resistivity of ink in said supplemental ink supply; and
 - b. means responsive to said supplemental sensing means for adjusting said predetermined resistivity value.
4. The ink replenishment system claimed in Claim 3, wherein said adjusting means adjusts said predetermined resistivity value according to the following rule:

$$\rho_{\text{new}} = f \rho_{\text{fresh}} + (1 - f) \rho_{\text{old}},$$
 where:

ρ_{new} is the updated desired resistivity value, ρ_{fresh} is the measured resistivity value of the ink in the supplemental ink supply, ρ_{old} is the previously calculated desired resistivity value, and f is a constant representing a volume fraction of liquid added to the main ink supply.
5. The ink replenishment system claimed in Claims 2 or 3, wherein said volume sensing means comprises a float switch located in said main ink supply.
6. The ink replenishment system claimed in Claim 2 or 3, wherein said resistivity sensing means comprises:
 - a hollow insulating body, a pair of conductive metal fittings for introducing ink into and out of the body, and a pair of electrical connections to said metal fittings.
7. A method of replenishing the ink in an ink jet printer of the type having a main ink supply, a supplemental ink supply and a replenishment carrier fluid supply, comprising the steps of:
 - a. sensing the resistivity of ink in the main ink supply; and
 - b. replenishing the ink in the main ink supply with ink from the supplemental ink supply and carrier fluid from the replenishment carrier fluid supply as a function of the resistivity of the ink in the main ink supply.
8. The method claimed in Claim 7, wherein said replenishing step comprises the steps of:
 - a. sensing when a predetermined volume of ink is depleted from the main ink supply; and
 - b. replacing the predetermined volume of ink in the main ink supply with ink from the supplemental ink supply if the resistivity of the ink in the main ink supply is higher than a predetermined value and replacing the predetermined volume of ink in the main ink supply with carrier fluid from the replenishment carrier fluid supply if the resistivity of ink in the main ink supply is below a predetermined value.
9. The method claimed in Claim 7 or 8 further comprising the steps of:
 - a. sensing the resistivity of ink in the supplemental ink supply; and
 - b. updating said predetermined value as a function of the resistivity of ink in the supplemental ink supply.

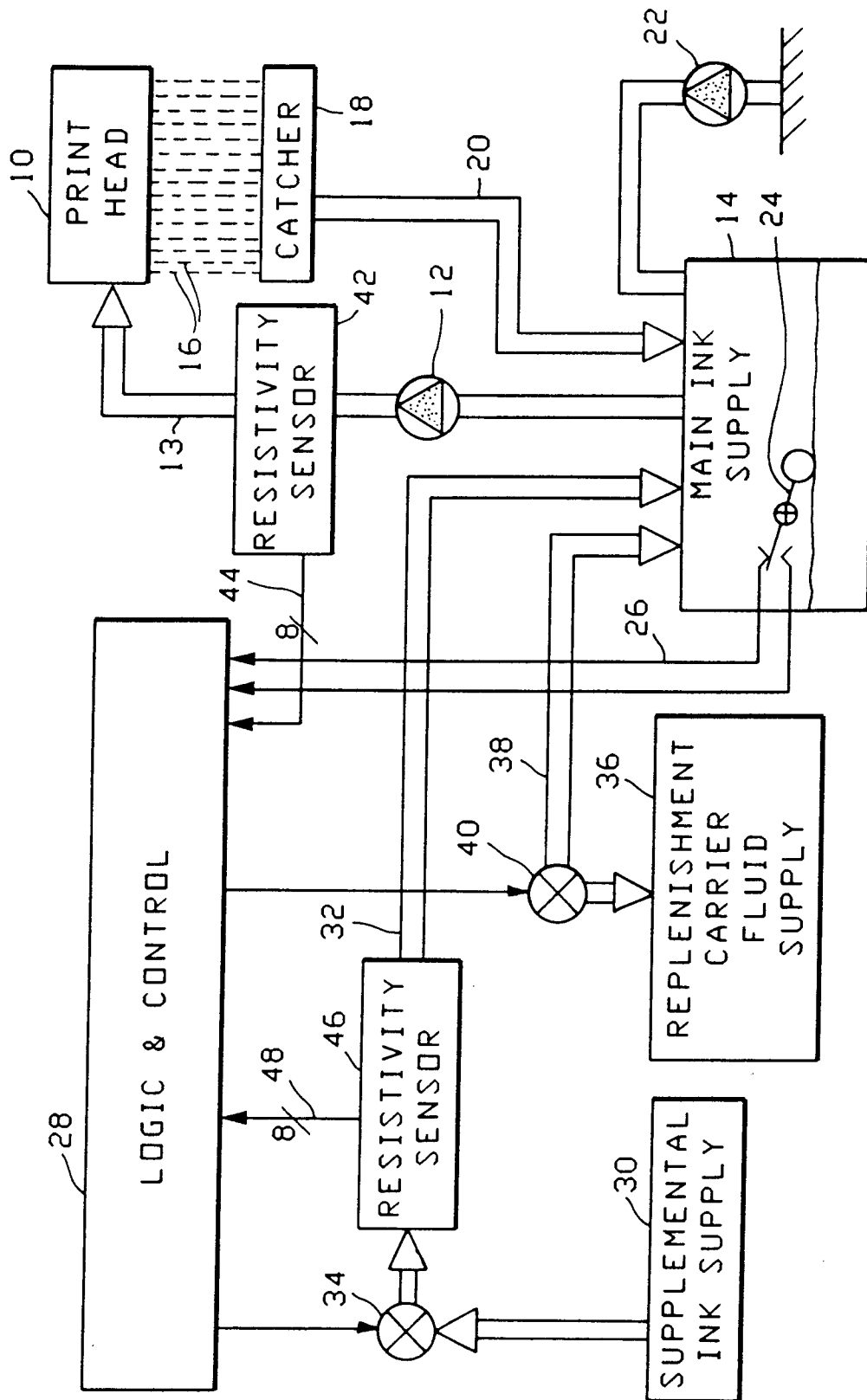


FIG. 1

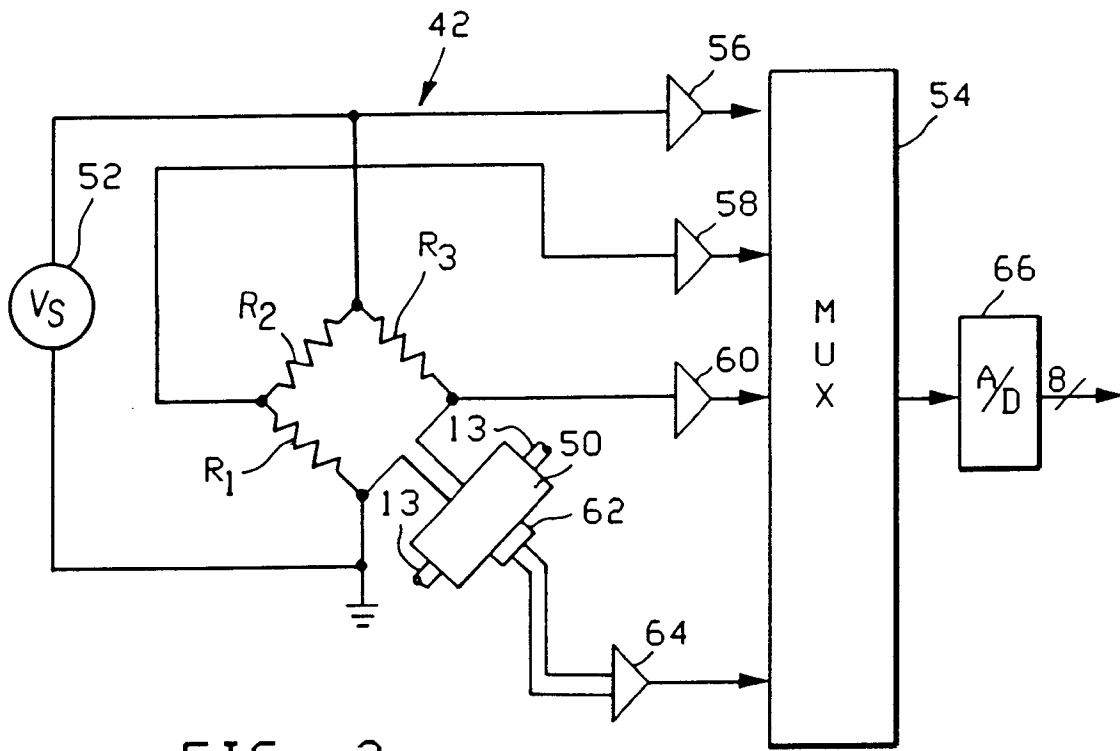


FIG. 2

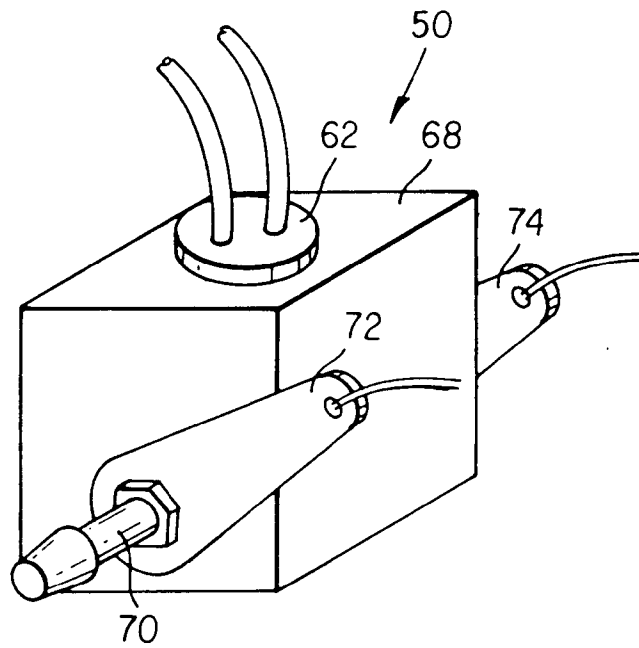


FIG. 3

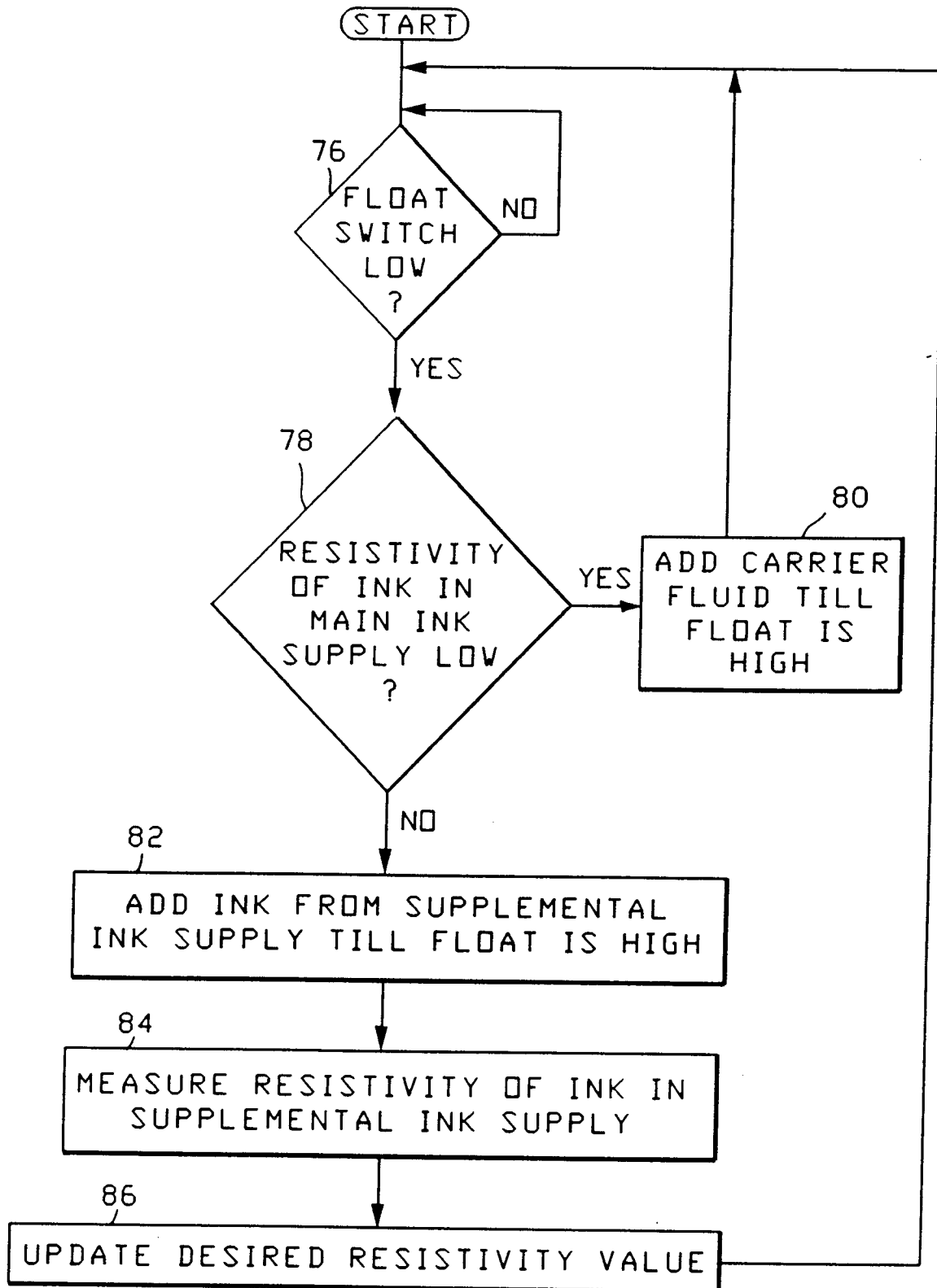


FIG. 4



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 8818

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
D,A	US-A-4 121 222 (DIEBOLD ET AL.) * abstract; figure * ---	1,7	B41J2/175 B41J2/195
A	US-A-3 715 219 (KURZ ET AL.) * abstract; figure 1 * ---	1,7	
A	DE-A-30 43 260 (RICOH CO.) * page 17, line 1 - page 21, line 1; figures 4,6 * ---	1,7	
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 87 (M-372) (1810) 17 April 1985 & JP-A-59 214 656 (SANYO DENKI K.K.) 4 December 1984 * abstract * -----	1,7	
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			B41J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 21 February 1994	Examiner De Groot, R
<p>CATEGORY OF CITED DOCUMENTS</p> <p>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</p> <p>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</p>			

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