SUPPLY DEVICE FOR AN OUTLET NOZZLE IN AN INK JET WRITING METHOD

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ABSTRACT
A convex ink meniscus is obtained at the outlet of the nozzle by hydrostatic pressure created by a pump situated between the ink reservoir and the nozzle. The ink jet is obtained by an electric field. The pump is of the continuous type, means being provided to reduce the operational pressure at the level of the nozzle from the value necessary to create a convex meniscus to a value for which the ink remains substantially contained inside the nozzle. A control device acts on these means to render them inoperative and ensures the re-establishment of the meniscus-forming pressure at the beginning of each period of writing. The pump may have a member having a surface of revolution in which a spiral passage is hollowed, a second member with a second surface of revolution is applied against the first and movable by electromagnetic means.
SUPPLY DEVICE FOR AN OUTLET NOZZLE IN AN INK JET WRITING METHOD

The invention relates to a device for supplying ink to an outlet nozzle in a method of writing by ink jet, in which method the pressure of the ink in the nozzle is stabilized around a value ensuring the formation of a convex meniscus at the outlet of the nozzle, a flow in the form of a jet of ink of very small cross-section only being produced when this meniscus is subjected to the action of an electrical field of a certain value.

Such a method has already been described, for example, in U.S. Pat. No. 3,458,760 and No. 3,458,762. Similarly, a device for supplying ink to an outlet nozzle has been described in U.S. Pat. No. 3,296,624. In this writing method, the best results are obtained when the pressure of the ink in the nozzle is kept very close to the pressure which would cause commencement of flow without the presence of the electrical field. Under these conditions, it will be understood that the system is very sensitive to any jolting, shaking, or untimely pressure variation, all elements capable of causing a flow of ink in the absence of an electrical field. Such flows are the cause of soiling the end of the nozzle as well as the electrodes, which soiling is capable of comprising the perfect centering of the ink jet emission, as well as the accuracy of its deflection by the control electrodes.

The U.S. Pat. No. 3,296,624 proposed a solution to this problem by inserting between the ink reservoir and the outlet nozzle an electrically controlled pump enabling the very rapid establishment of the operational pressure, from a distinctly lower pressure, under the action of an electrical control synchronized with the establishment of the ink jet extraction electrical field.

However, the electromagnetic pumps described in the abovementioned patent have a discontinuous cycle of operations. After a certain number of characters have been written, a rest time is necessary to ensure the return of the piston into its initial position. In applications where a large number of lines must be written without interruption, a pump with continuous operation would consequently be very desirable. This type of pump has generally the disadvantage of relatively slow establishment of the operational pressure on starting. This relative slowness involves a corresponding delay between the moment when the pump is engaged, at which moment the contact triggering the writing operation is itself actuated, and the moment when the writing can actually begin, operational pressure being reached.

It is an object of the present invention to provide a device for supplying with ink, from a reservoir, an outlet nozzle in a method of writing by ink jet in which a convex meniscus of ink is obtained at the outlet of a nozzle by hydrostatic pressure created by a pump situated between the reservoir and the outlet nozzle, the ink jet being obtained by an electrical field, characterized in that the pump is a continuously operating type, means being provided to reduce the operational pressure at the level of the nozzle from the value necessary for creating a convex meniscus to a value for which the ink remains substantially contained inside the nozzle, a control device acting on these means to render them inoperative and to ensure the re-establishment of the pressure of formation of the meniscus at the beginning of each period of writing.

The accompanying drawing shows, diagrammatically and by way of example, two embodiments of an ink supply device according to the invention, purely by way of illustrative but non-limiting example.

FIG. 1 is a vertical sectional view of one embodiment of an ink supply device according to the invention.

FIG. 2 is a view in longitudinal section of a writing head incorporating an outlet nozzle, with a diagrammatic representation of the electrical control circuit of the device.

FIGS. 3a, 3b and 3c show on a very large scale, the end of an outlet nozzle in three different states.

FIG. 4 is a vertical section of a pump in a variation of the foregoing embodiment.

FIG. 5 is a plane view of the active surface of the rotor of the pump of FIG. 4.

FIG. 6 is also a plane view of the other surface of the rotor of the embodiment shown in FIG. 4.

With reference to FIG. 1, the pump 1 shown is a viscosity pump of the Archimedes screw type. It comprises essentially two flanges 2 and 3 supporting a glass tube 4 inside of which rotates a rotor 5 with an Archimedes screw 6. Rubber rings 7 and 8 ensure sealing between the tube 4 and the flanges 2 and 3. The rotor 5 is extended towards the right by a spindle 9 which passes through the flange 3 by means of a sealing joint 10 held in a housing 11 of the flange by a thrust plate 12. The rotor 5 is driven by a motor, not shown, through a pinion 13 fixed on the spindle 9 by a screw 14.

Above the tube 4, a cylindrical chamber 15 is arranged between the two flanges 2 and 3, a rubber seal 16 ensuring the fluid tightness thereof.

A port 18 opens into the chamber 15 and brings the ink from a reservoir, not shown. A duct 19 connects the chamber 15 to an input chamber 20 of the pump. At the other end of the rotor 5 of the latter occurs an output chamber 21 connected by an output duct 23 to the nozzle 52 by a pipe 17 (FIG. 2).

A duct 24 connects the output chamber 21 of the pump to the chamber 15. The ducts 19 and 24 hence establish, through the chamber 15, direct communication between the input chamber 20 and the output chamber 21 of the pump and consequently form a bypass.

This communication through the chamber 15 can be interrupted by valve means comprising a circular valve 25 bearing at its periphery a sealing ring 26, of rubber, engaged in a groove 27. The valve 25 is subject to the action of a spring 28 which tends to apply it against a seat 29.

The valve 25 is guided by a ball joint 30 which forms part of a rod 31 fixed by a nut 32 to the flange 2. This ball joint penetrates into a cylindrical housing 33 of the valve.

Through its end opposite the valve 25, the spring 28 is supported on a collar 34 of a sliding rod 35 of which the threaded free end 36 cooperates with a milled adjusting nut 37. This nut is itself pivoted in a cylindrical housing 38 of the flange 3. It is held axially by means of the thrust plate 12 through a spring washer 39. A rubber ring 40 ensures fluid tightness between the sliding rod 35 and flange 3. On the other hand, a pin 41 engaged in a slot 42 of the collar 34 prevents the latter from turning.

It will be seen that by making the nut 37 rotate, the rod 35 slides in the flange 3 and the force exerted by the spring 28 on the valve 25 can thus be adjusted to the desired value.
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The guide rod 31 of the valve 25 is pierced throughout its length. It is traversed by a coaxial control rod 43 of which the end 44 can become supported against the bottom 45 of the housing 33 of the valve under the effect of a spring 46 which is supported, on one hand, against a collar 47 of the rod 43 and, on the other hand, against a step 48 fixed by a flange 2. The force of the spring 46 is distinctly greater than that of the spring 28, so that the control rod 43 normally lifts the valve 25 from its seat 29, establishing the free passage of ink through the by-pass 24, 15, 19.

On the other hand, the control rod 43 passes through an energizing coil 50 of an electromagnet of which one soft iron bush 51, fixed coaxially on the rod 43, constitutes the plunger core. When the electromagnet is not energized, in the rest position of the control rod 43, this core 51 is situated partly outside the winding. As soon as the winding 50 is traversed by a current of sufficient intensity, the core 51 is attracted towards the inside of the winding 50, in the direction of the arrow F1. The end 44 of the rod 31 hence ceases to contact the valve 25 and the latter is applied against its seat 29 by the spring 28, causing the closing of the by-pass 24, 15, 19, as shown in FIG. 1.

FIG. 2 shows a writing head such as described in U.S. Pat. No. 3,458,760 and of which only the elements necessary for the understanding of the operation of the device will be mentioned. A nozzle 52 for emitting a jet of ink is supported by an insulating element in the form of a bell 53 which is fixed to a metallic central body 54 of cylindrical general shape. A grid 55, pierced by a circular hole 56 centered on the nozzle 52, constitutes one of the generating electrodes of the electrical extraction field for the ink jet, the other being constituted by the nozzle 52 itself. The grid 55 and the nozzle 52 are connected to the two poles a and b of a supply unit 56 intended to provide the extraction potential for the jet. A second supply unit 57 is intended to provide the current necessary for the operation of the electromagnet 50, 51 between the terminals c and d. The two supply units 56 and 57 can be simultaneously triggered by known means from an actuating pulse provided by logical circuits 58 associated with those controlling the application of voltages to deflection electrodes 22 of the writing head.

The operation of the device is as follows:

When printing plant using the method of ink jet writing is subjected to a voltage, the actuating motor of the pump is started rotating the rotor 5. The whole of the circuit having been initially filled with ink, the Archimedean screw drives this fluid by viscosity in the direction of the arrow F2. However, as long as an actuating pulse has not been provided by logical circuits 58 to supply units 56 and 57, the electromagnet 50, 51 is not energized and the control rod 43, under the effect of its spring 46, holds the valve 25 open. Under these conditions, all the ink transported by the rotor 5 circulates in a closed circuit through the by-pass 24, 15, 19. Only the losses by frictions of the fluid in the circuit establish a very slight excess pressure at the level of the nozzle 52 with regard to the pressure in the ink tank, the surface 59 of the ink at the end of the nozzle 52 passes from the position illustrated in FIG. 3a to that illustrated in FIG. 3b.

As soon as the writing order has been given to the printing plant, the logical circuits 58 emit a control pulse which is transmitted to the two supply units 56 and 57, either simultaneously, or with a predetermined delay as regards the supply unit 57. The electrical field is established between electrodes 52 and 55 on one hand, the electromagnet 50, 51 is energized on the other hand. The control rod 43 is actuated in the direction of the arrow F2 against the action of the spring 46 enabling the valve 25 to be applied very rapidly against its seat 29 under the effect of the spring 28, closing the by-pass 24, 15, 19.

All the pressure of the pump is then transmitted to the ink which occurs in the nozzle 52 and which is immediately extracted, in the form of a jet of very small cross-section, by the electrical field. It will be noted that the slight "water hammer" caused by the very rapid closing of the valve 25 facilitates the start of the formation of the jet. By suitable choice of the force of the spring 28 acting on the valve 25, there is simultaneously effected a very accurate adjustment of the pressure at the level of the nozzle. In fact, as soon as the fluid pressure exceeds a detention pressure corresponding to the force of the spring 28, the valve 25 again opens and enables the by-pass to exert a regulating effect. This detention pressure can be adjusted with accuracy by rotation of the milled nut 37 until there are obtained, in the absence of electrical field, the conditions illustrated in FIG. 3c which correspond to the optimum operation of the writing head.

It is thus seen that the by-pass 24, 15, 19 plays the role of means enabling the operational pressure at the level of the nozzle 52 to be reduced from the value necessary for the formation of the convex ink meniscus 59 of FIG. 3e to a lower value for which the ink remains contained inside the nozzle 52, as illustrated in FIG. 3b. These means are rendered inoperative by the control device constituted by the logical circuits 58, the unit 57 and the electromagnet 50, 51, to re-establish the necessary pressure for obtaining the meniscus 59 of FIG. 3c.

Under certain conditions of use of the invention, it may be preferable to keep the electrical field permanently between the nozzle 52 and the gauze 55 from the moment when the printing plant is placed under voltage. The supply unit 56 is not then controlled by the logical circuits 58.

The variation shown in FIGS. 4 to 6 illustrates a solution according to which the establishment, and elimination respectively, of the ink pressure can be obtained without recourse to a separate by-pass of the pump. In this case, as shown in FIG. 4, the pump comprises a first flange 61 which has a cylindrical housing 62 with axis x-x'. This cylindrical housing is limited by a second flange 63, circular, made of non-magnetic material, which becomes screwed at 64 on the flange 61. A seal 65 ensures fluid-tightness between the two parts. A shaft 66 passes through the base 67 of the flange 61 along the axis x-x'. At its outer end, it bears a pinion 68 fixed by a pin 69. This pinion is rotated by a motor, not shown. The other end of the shaft 66 penetrates inside the housing 62 and terminates by a driving portion with three sides 110 bounded by a collar 111. A washer 112 is supported on a seal 113 which ensures fluid-tightness between the flange 62 and the flange 61.

Inside the housing 62 centered on the axis x-x', and made at least in part of magnetic material, occurs the rotor 114 of the pump.

It is limited upwardly by a flat circular surface 115 in which a channel 116 in the form of a spiral is hollowed. As is seen more clearly in FIG. 5, this channel 116 com-
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The rotor 114 is rotated by the shaft by means of the following device, illustrated in FIG. 6: a three armed spring 118 is fixed by a central triangular hole 119 on the three-sided driving portion 110 of the shaft 66. Each of the arms of this spring 118 has, near its end, a slot 120 which becomes hooked on as many beaks 121 fast to the lower surface of the rotor. The spring 118 is formed so that it tends to apply the rotor 114 against the collar 111 of the shaft. In this position, the flat circular surface 115 of the rotor occurs slightly spaced from a washer 122 fixed on the lower surface of the flange 63 and centered on the axis x-x'. This washer can be preferably of glass, and its surface situated facing the surface 115 of the rotor, optically polished.

The flange 63 has an annular housing 123 in which a magnetic soft iron core 124 of U-shaped cross-section becomes housed, which core contains an energizing winding 125.

An inlet channel 126 for the fluid to be placed under pressure connects the housing 62 of the pump to an outer reservoir, not shown. On the other hand, an outlet channel 127 enables the fluid under pressure to pass through the flange 63 in the direction of the outlet nozzle of a writing device, not shown.

The operation of this pump is as follows:
The pump having been previously primed, the housing 62, as well as the inlet 126 and outlet 127 channels are filled with the writing fluid.

The rotor 114 is rotated permanently in the direction of the arrow P. Outside periods of writing, the energizing winding 125 is not under voltage and the rotor is held in the position illustrated in FIG. 4, applied by the spring 118 against the collar 111 of the shaft 66. The slight space between the surface 115 of the rotor 114 and the glass washer 122 constitutes a by-pass between the central cavity 117 and the housing 62 through which the fluid which could be driven by the spiral 116 towards the center can regain the housing 62. The pressure of the fluid at the outlet is equal to the pressure at the input of the pump.

At the beginning of a period of writing, the energizing winding 125 is placed under voltage.

The magnetic field which is established in the magnetic circuit 124 attracts the rotor 114 so as to apply its flat circular surface 115 against the polished surface of the washer 122. From this moment, the operational pressure is established at the output of the pump, the fluid being driven by viscosity in the spiral channel 116.

The piston effect caused by the rapid attraction of the rotor on re-establishment of the current contributes to the rapidity of establishment of the operational pressure.

This operational pressure can be adjusted in very accurate manner by controlling the intensity of the current in the energizing winding 125. In fact, as soon as the pressure of the fluid balances the attractive force of the magnetic circuit (taking into account the return force of the spring 118), the rotor tends to be separated from the surface of the washer 122, and the fluid can escape from the spiral channel 116. It is seen that a simple potentiometer in the energizing circuit suffices to effect this adjustment. A very flexible programme of adjustment of the pressure can also be effected by controlling the energizing current by electronic means.

The structure described lends itself very particularly to the production of the two flanges, and even of the rotor, of molded plastic material. As regards the latter, it would suffice to apply to its lower surface, a washer of magnetic material serving as a movable core for the magnetic circuit.

The magnetic circuit formed by the core 124 and the rotor 114 has a rather large air gap to avoid variations in the axial position of the rotor 114 in active position from modifying appreciably the reluctance of said circuit.

As a variation, it is clear that the axial displacement of the rotor 114 in the direction of the washer 122 could be actuated mechanically, for example by moving axially the shaft 66 on which the rotor could be directly fixed. The spiral-shaped channel could also be provided on a fixed part of the pump, the rotor being then able to be smooth or also provided with a spiral channel.

1 claim:
1. Device for supplying ink from a reservoir to an outlet nozzle for an ink jet writing method in which a convex ink meniscus is formed at the outlet of a nozzle by hydrostatic pressure generated by a pump situated between the reservoir and the outlet nozzle, the ink jet being formed by an electric field, said device comprising: a pump of continuous type; pressure-reducing means to reduce the operational pressure at the level of the nozzle from the value necessary to create a convex meniscus to a value for which the ink remains substantially contained within the nozzle; and a control device arranged to act on said pressure-reducing means to render them ineffective and to ensure the re-establishment of the meniscus-forming pressure at the beginning of each period of writing.
2. Device according to claim 1, wherein the pressure-reducing means comprise a by-pass connecting the pump outlet to the pump input, and a valve, governed by electrical circuits controlling the writing, arranged to close or open respectively said by-pass.
3. Device according to claim 2, including a spring to urge said valve into closed position against the effect of the outlet pressure from the pump, to form a valve for adjusting said pressure.
4. Device according to claim 3, including a rod arranged to lift said valve from its seat, a second spring acting on said rod, and an electromagnet acting to urge said rod against the effect of the second spring to enable the closing of the valve.
5. Device according to claim 1, wherein the pump comprises: a first member bounded on one of its surfaces by a first surface revolution, said surface forming a passage having the general form of a spiral, at least approximately centered on the axis of this surface revolution, the passage being open over at least a portion of its length on this first surface; a second member bounded on one of its surfaces by a concentric second surface of revolution and of shape identical with the first surface, a chamber filled by fluid to be placed under pressure in which chamber, said two surfaces are situated, one of the two members being rotatable with respect to the second member around the common axis of the two surfaces of revolution; and displacement means enabling the axial movement of one said member with respect to the other so as to apply said two surfaces of revolution against one another against the effect of the fluid-pressure.
6. Device according to claim 5, wherein said displacement means are magnetic means.

7. Device according to claim 6, wherein the member driven in rotation is axially movable and formed at least in part of magnetic material, a fixed electromagnetic winding being provided to produce the axial movement of the rotatable member.

8. Device according to claim 7, wherein the winding is situated outside said chamber.

9. Device according to claim 5, wherein it is the rotatable member which has said spiral-form passage.

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