United States Patent [19]

Ascoli

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[45] **May 22, 1973**

[54] **SUPPLY DEVICE FOR AN OUTLET NOZZLE IN AN INK JET WRITING METHOD**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **317/3**
[51] **Int. Cl.** **G01d 15/18**
[58] **Field of Search** 317/3

[56] **References Cited**

UNITED STATES PATENTS

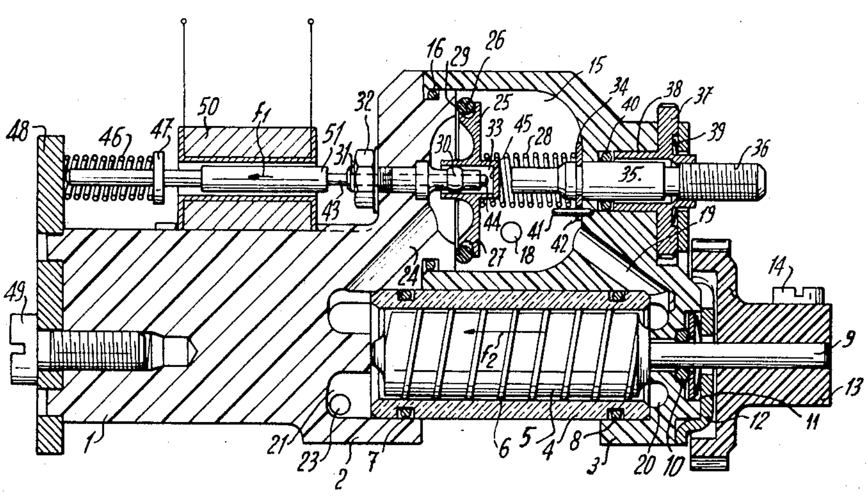
3,458,760 7/1969 Ascoli 317/3
3,458,762 7/1969 Ascoli 317/3

Primary Examiner—L. T. Hix
Attorney—Emory L. Groff and Emory L. Groff, Jr.

[57] **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.

9 Claims, 8 Drawing Figures



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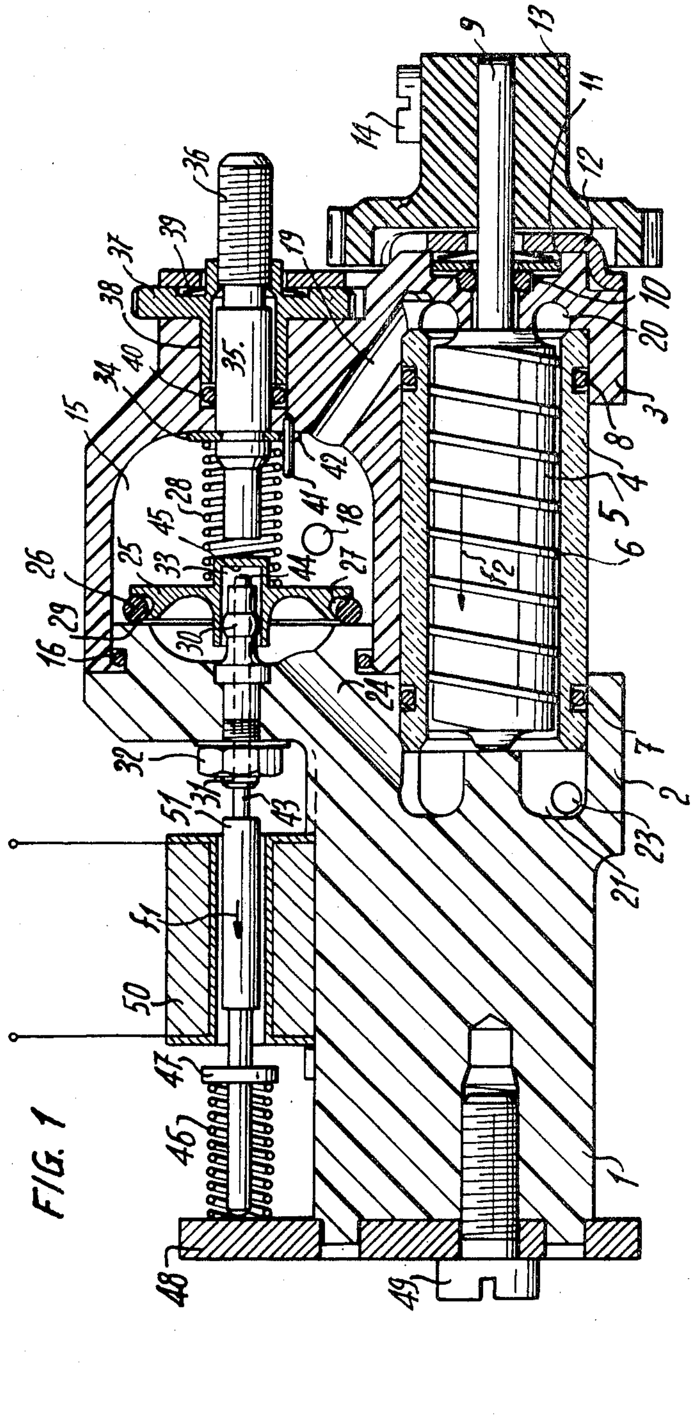

FIG. 1

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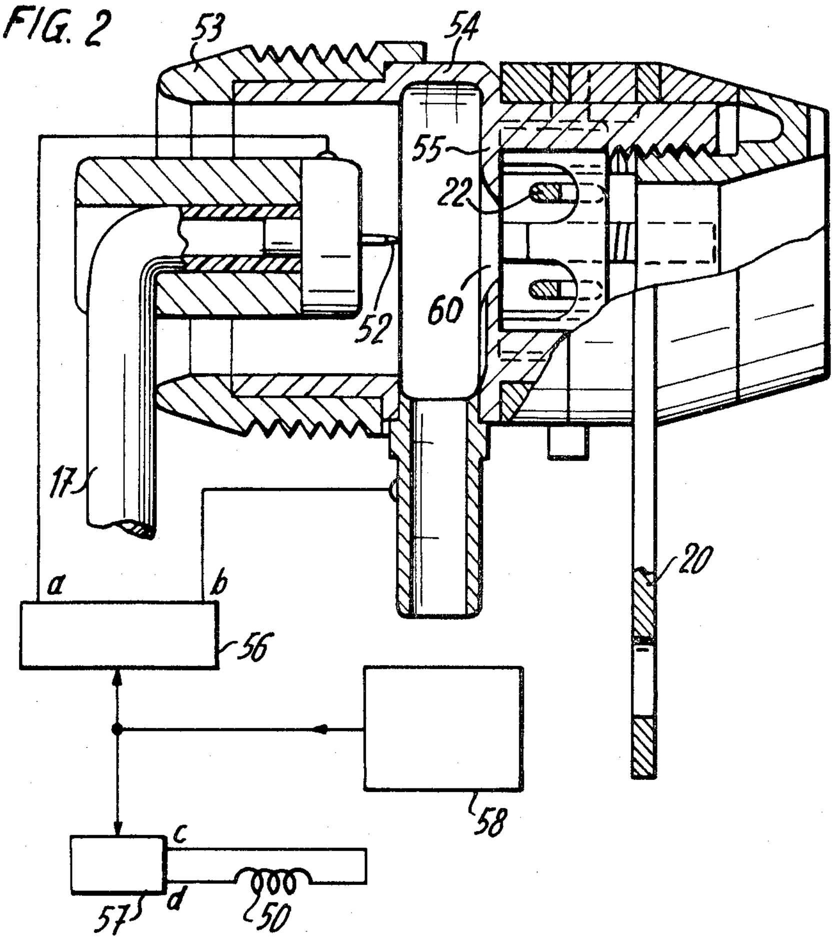
FIG. 2



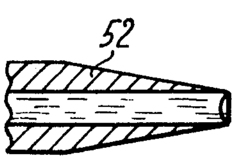


FIG. 3a

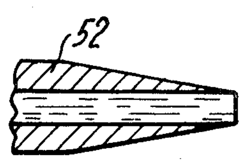


FIG. 3b

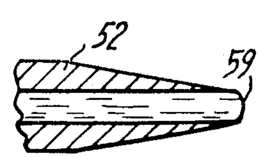


FIG. 3c

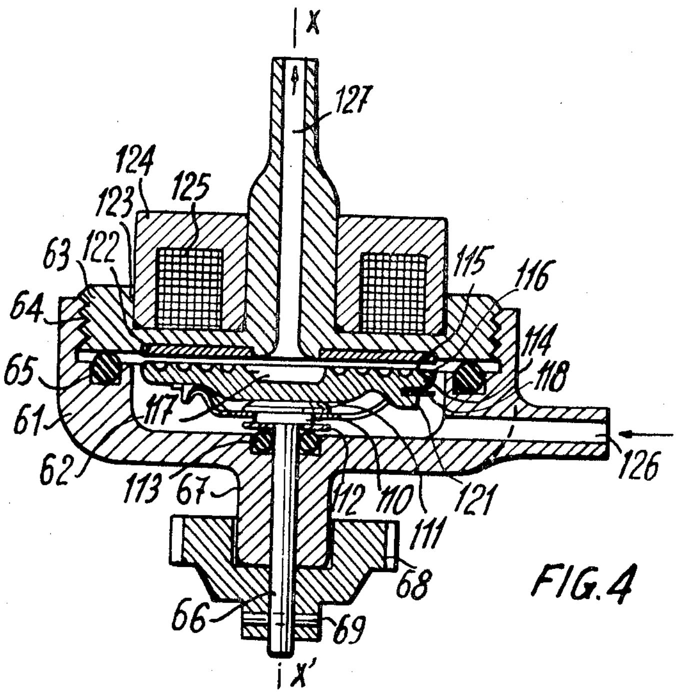


FIG. 4

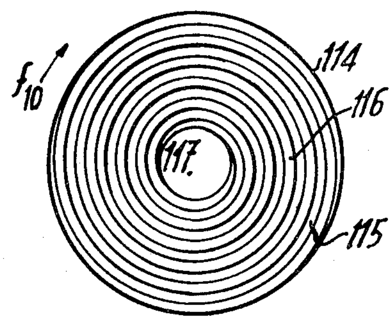


FIG. 5

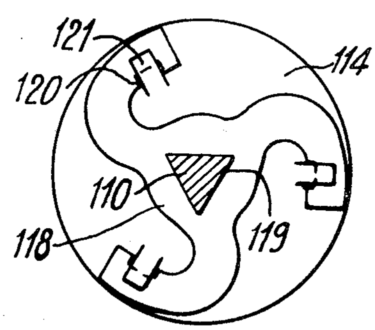


FIG. 6

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. **3***a*, **3***b* and **3***c* 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 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.

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 stop plate **48** fixed by a screw **49** to the 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 F^1. 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 **60** 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 Archimedes screw drives this fluid by viscosity in the direction of the arrow f^2. 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 friction of the fluid in the circuit establish a very slight excess pressure at the level of the nozzle **52** with respect to atmospheric pressure, so that the surface **59** of the ink at the end of the nozzle **52** passes from the position illustrated in FIG. **3***a* to that illustrated in FIG. **3***b*.

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 f^1 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. **3***c* 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. **3***c* to a lower value for which the ink remains contained inside the nozzle **52**, as illustrated in FIG. **3***b*. 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. **3***c*.

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 shaft **66** 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** commences in a central cavity 117 and ends, after several revolutions, at the periphery of the circular surface 115.

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 f^{10}. 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.

I 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 inoperative 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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