

Description

The present invention relates to ink jet printing systems, and more particularly to a method and apparatus for extending the environmental operating ranges of such systems.

Ink jet printers have become very popular due to their quiet and fast operation and their high print quality on plain paper. A variety of ink jet printing methods have been developed.

In one ink jet printing method, termed continuous jet printing, ink is delivered under pressure to nozzles in a print head to produce continuous jets of ink. Each jet is separated by vibration into a stream of droplets which are charged and electrostatically deflected, either to a printing medium or to a collection gutter for subsequent recirculation. U.S. Patent No. 3,596,275 is illustrative of this method.

In another ink jet printing method, termed electrostatic pull printing, the ink in the printing nozzles is under zero pressure or low positive pressure and is electrostatically pulled into a stream of droplets. The droplets fly between two pairs of deflecting electrodes that are arranged to control the droplets' direction of flight and their deposition in desired positions on the printing medium. U.S. Patent No. 3,060,429 is illustrative of this method.

A third class of methods, more popular than the foregoing, is known as drop-on-demand printing. In this technique, ink is held in the pen at below atmospheric pressure and is ejected by a drop generator, one drop at a time, on demand. Two principal ejection mechanisms are used: thermal bubble and piezoelectric pressure wave. In the thermal bubble systems, a thin film resistor in the drop generator is heated and causes sudden vaporization of a small portion of the ink. The rapidly expanding ink vapor displaces ink from the nozzle causing drop ejection. U.S. Patent 4,490,728 is exemplary of such thermal bubble drop-on-demand systems.

In the piezoelectric pressure wave systems, a piezoelectric element is used to abruptly compress a volume of ink in the drop generator, thereby producing a pressure wave which causes ejection of a drop at the nozzle. U.S. Patent 3,832,579 is exemplary of such piezoelectric pressure wave drop-on-demand systems.

The drop-on-demand techniques require that under quiescent conditions the pressure in the ink reservoir be below ambient so that ink is retained in the pen until it is to be ejected. The amount of this "underpressure" (or "partial vacuum") is critical. If the underpressure is too small, or if the reservoir pressure is positive, ink tends to escape through the drop generators. If the underpressure is too large, air may be sucked in through the drop

generators under quiescent conditions. (Air is not normally sucked in through the drop generators because the drop generators comprise capillary tubes which are able to draw ink against the partial vacuum of the reservoir.)

The underpressure required in drop-on-demand systems can be obtained in a variety of ways. In one system, the underpressure is obtained gravitationally by lowering the ink reservoir so that the surface of the ink is slightly below the level of the nozzles. However, such positioning of the ink reservoir is not always easily achieved and places severe constraints on print head design. Exemplary of this gravitational underpressure technique is U.S. Patent 3,452,361.

Alternative techniques for achieving the required underpressure are shown in U.S. Patent 4,509,062 and in copending application Serial No. K 975 07/115,013 filed October 28, 1987, both assigned to the present assignee. In the former patent, the underpressure is achieved by using a bladder type ink reservoir which progressively collapses as ink is drawn therefrom. The restorative force of the flexible bladder keeps the pressure of the ink in the reservoir slightly below ambient. In the system disclosed in the latter patent application, the underpressure is achieved by using a capillary reservoir vent tube that is immersed in ink in the ink reservoir at one end and coupled to an overflow catchbasin open to atmospheric pressure at the other. The capillary attraction of ink away from the reservoir induces a slightly negative pressure in the reservoir. This underpressure increases as ink is ejected from the reservoir. When the underpressure reaches a threshold value, it draws a small volume of air in through the capillary tube and into the reservoir, thereby preventing the underpressure from exceeding the threshold value.

While the foregoing two techniques for maintaining the ink pressure below ambient have proven highly satisfactory and unique in many respects, they nevertheless have certain drawbacks. The bladder system, for example, is not as volumetrically efficient as might be desired. To minimize the variability of underpressure as a function of reservoir volume, the bladder is desirably of rounded shape. Best volumetric efficiency is obtained, however, if the bladder has a rectangular shape. (Even with a rounded shape, the underpressure is still a function of the bladder's state of collapse and eventually increases to the point that no more ink can be drawn therefrom, even though ink in the reservoir is not exhausted.)

The capillary system suffers with environmental excursions. If the ambient temperature increases, or if the ambient pressure decreases, the air trapped inside the ink reservoir expands. This expansion drives ink from the reservoir and out the

printhead nozzles where it may contact the user.

Consequently, it is an object of the present invention to provide an ink jet ink reservoir that overcomes these drawbacks of the prior art.

It is a more particular object of the present invention to extend the pressure and temperature range over which a volumetrically efficient ink jet ink reservoir can operate without leaking.

According to one embodiment of the present invention, an ink jet print head is provided with an ink reservoir having two portions: a fixed volume portion and a variable volume portion. The fixed volume portion can be a rigid chamber. The variable volume portion can be a flexible bladder in a wall of the rigid chamber. Due to volumetric efficiency considerations, the fixed volume portion is desirably larger than the variable volume portion.

Beneath the reservoir is a catchbasin operated at ambient pressure into which ink can be pressure driven from the reservoir through a small coupling orifice. The coupling orifice serves both to convey ink from the reservoir into the catchbasin and to convey fluid (ink or air) from the catchbasin back into the reservoir, depending on the pressure differential. (Due to its occasional role of introducing air into the reservoir, the orifice is sometimes termed a "bubble generator.")

In normal operation, the partial vacuum left in the reservoir when ink is ejected out the print nozzles first causes the flexible bladder portion of the reservoir to collapse. After a certain amount of ink is ejected from the reservoir, the partial vacuum reaches a point at which it draws air into the reservoir from the catchbasin through the small bubble generator orifice. The orifice is sized to begin this bubbling action at a desired underpressure - 1.25 KPa (five inches of water) in the illustrated embodiment. Thereafter, as printing continues, the additional underpressure caused by the continued ejection of ink is regulated by the introduction of a corresponding volume of air through the bubble generator orifice.

If the ambient temperature rises, causing the air in the reservoir to expand (or if the ambient pressure diminishes, with similar effect), the bladder starts to restore and expand towards its uncollapsed state so as to contain the additional reservoir volume. In so doing, the bladder continues to exert the bladder restorative force on the ink, maintaining the pressure in the reservoir below ambient to keep the ink in the pen.

In the foregoing case of rising temperature (or decreasing ambient pressure), the bladder restorative force continues to keep the reservoir at a pressure slightly below ambient until the reservoir volume has increased to fully inflate the bladder. At this point, the bladder can no longer serve as a volumetric accumulator and ink is forced to flow

through the bubble generator orifice into the catchbasin. (Ink is not driven out through the print nozzle orifices because these orifices are substantially smaller than the bubble generator orifice. Consequently, they require a higher reservoir pressure to drive ink therethrough. This higher pressure is generally never reached because the bubble generator orifice acts to relieve the reservoir pressure before the higher pressure can be attained.)

When the ambient temperature thereafter falls, causing the air pressure in the reservoir to diminish (or when the ambient pressure rises, or when ink is ejected from the reservoir by printing, all with similar effect), ink is drawn from the catchbasin by the pressure differential until it is exhausted. Thereafter, the bladder collapses until the partial vacuum in the reservoir is sufficient to draw air through the orifice from the catchbasin, as described above.

While the foregoing description has focused on a very particular embodiment of an ink jet pen according to the present invention, the invention can more generally be described as including:

- a) an ink reservoir;
- b) a print head for ejecting ink from the reservoir and thereby leaving a negative pressure therein;
- c) a first pressure control mechanism for limiting the negative pressure in the ink reservoir by controllably introducing replacement fluid (i.e. air or ink) thereto; and
- d) a second pressure control mechanism for limiting the negative pressure in the ink reservoir by changing the volume thereof.

The foregoing and additional objects, features and advantages of the present invention will be more readily apparent from the following detailed description, which proceeds with reference to the accompanying drawings.

Fig. 1 is a side sectional view of an ink jet print head according to one embodiment of the present invention.

Fig. 2 is a front sectional view of the print head of Fig. 1.

Fig. 2A is an enlarged detail showing a bubble generator orifice in the print head of Fig. 2.

Fig. 3 is a chart illustrating ink reservoir underpressure as a function of ejected ink volume for the print head of Figs. 1 and 2.

Fig. 4 is a side sectional view of an ink jet print head according to another embodiment of the present invention.

Fig. 5 is a side sectional view of an ink jet print head according to still another embodiment of the present invention.

Fig. 6 is a side sectional view of an ink jet print head according to yet another embodiment of the present invention.

Referring to Figs. 1 and 2, an ink jet print head according to one embodiment of the present

invention includes an ink reservoir 12 having two portions. The first portion 14 is of fixed volume and is formed by rigid walls 16, 18, 20, 22, 24, etc. The second portion 26 is of variable volume and comprises a flexible bladder 27 mounted behind an opening in one of the rigid walls.

Extending downwardly from the fixed volume portion 14 is a well 28 with a print head 30 at the bottom thereof. Ink from the reservoir 12 is drawn through a filter 32 and into the print head 30 from which it is ejected towards the printing medium by thermal or piezoelectric action, as is well known in the art.

Also in the bottom portion of well 28 is a small orifice 36 (Fig. 2) that couples the ink reservoir 12 to a catchbasin 38 positioned at the bottom of the assembly. Orifice 36 serves both to permit ink to pass from the reservoir 12 into the catchbasin 38 and to permit fluid (air or ink) to pass from the catchbasin into the reservoir, depending on the pressure difference between the two regions. (As noted earlier, this orifice 36 is sometimes termed a bubble generator orifice due to its occasional role in introducing air bubbles into the reservoir.) The size of the bubble generator orifice 36 is selected to be larger than the size of the print nozzle orifice so that, in over pressure conditions, ink will preferentially flow out the bubble generator orifice 36 instead of out the print nozzles. However, the bubble generator orifice 36 is small enough that the ink's surface tension prevents it from being gravitationally driven therethrough - there must be a driving pressure differential. In the illustrated embodiment, the bubble generator orifice diameter is - 0.198 mm (0.0078 inches) and the print nozzle diameter is 0.051mm (0.0020 inches). Catchbasin 38, to which the bubble generator orifice 36 leads, is vented to atmospheric pressure by a vent 40 located in the upper sidewall of the catchbasin, beneath the platform 24 in which the bladder 26 is mounted.

In operation, the reservoir 12 is initially filled with ink through an opening 42 which is thereafter sealed with a plug 44. When the pen is first printed, ink ejected from the print head leaves a corresponding partial vacuum or underpressure in the reservoir 12 which causes the flexible bladder 27 to begin collapsing. The collapsing of the bladder reduces the reservoir volume and thus slows the rate at which the partial vacuum builds with continued ejection of ink.

Despite the bladder's moderating action on reservoir pressure, the underpressure nonetheless continues to increase with continued ejection of ink. This increase continues until the pressure differential between the ink reservoir 12 and the vented catchbasin 38 is sufficient to pull a bubble of air through the bubble generator orifice 36 and into the

reservoir. This bubble of air replaces a volume of ink that has been ejected from the reservoir and thereby relieves part of the partial vacuum in the reservoir. Thereafter, continued ejection of ink will not further collapse the bladder 27 but will instead draw in additional bubbles of air through the bubble generator 36. The bubble generator thus acts as a pressure regulator that controllably introduces air into the reservoir so as to prevent the reservoir pressure from fully attaining ambient.

Fig. 3 is a chart illustrating the relationship between the reservoir underpressure and the ejected ink volume. Before any ink is ejected from the reservoir, the reservoir may be at a slight underpressure by reason of the restorative force of the flexible bladder pulling on the ink in the reservoir. As printing begins, the underpressure builds slowly as the bladder collapses, as shown by the solid curve. (If there was no flexible bladder present to moderate the underpressure, it would increase much more rapidly, as shown by the dashed curve labelled "A".)

As the ejected ink volume increases, the curve may become somewhat irregular, due to the non linear behavior of the bladder as it folds onto itself while collapsing. At the point labelled "B", the underpressure is sufficient to start pulling bubbles through the bubble generator orifice 36 and the underpressure thereafter stabilizes around this "bubble pressure" 1.25 KPa or 5 inches of water in the illustrative embodiment). The underpressure drops suddenly each time a bubble is introduced and then increases back up towards the bubble pressure with continued ejection of ink. When the bubble pressure is again reached, another bubble is introduced and the underpressure falls again. The process continues until the reservoir is exhausted of ink. (Line "C" in Fig. 3 represents the underpressure that would occur if the bubble generator was omitted. As can be seen, the underpressure would rise rapidly and would soon prevent the ejection of ink from the pen.)

While ejection of ink is the principle mechanism causing reservoir underpressure to vary, it is not the only one. Environmental factors, such as ambient pressure and temperature, also play a role. For example, if the ambient pressure outside the reservoir increases, the reservoir underpressure (i.e. its partial vacuum relative to ambient) increases as well. Similarly, if the ambient temperature decreases, the air inside the reservoir contracts according to the ideal gas laws, causing a corresponding reduction in net reservoir volume and with it a corresponding increase in the reservoir underpressure. In both cases, the bladder and bubble generator orifice act as described earlier to counteract these changes in reservoir underpressure and regulate the underpressure near the de-

sired value.

Environmental factors can also tend to decrease the reservoir underpressure (i.e. bring the ink pressure up towards, or even above ambient pressure). This can occur, for example, if the ambient pressure falls or if the ambient temperature rises. In such cases, the bladder restores and expands towards its non-collapsed state to relieve the increased pressure and counteract this effect. In so doing, it continues to exert the bladder restoring force on the ink to hold it in the reservoir.

If the ambient pressure continues to fall, or if the ambient temperature continues to rise, the bladder will continue to exert its restorative force on the ink and maintain it below atmospheric pressure until the bladder becomes fully inflated. Thereafter, further increases in ink pressure will drive ink through the bubble generator 36 and into the catchbasin 38.

At this point the bladder 27 is fully expanded and the catchbasin 38 contains ink. When conditions thereafter change and the reservoir underpressure increases (i.e. by ejection of ink from the reservoir, by an increase ambient pressure, or by a decrease in ambient temperature), the pen 10 draws ink through the bubble generator 36 into the reservoir 12 from the catchbasin 38. Note that the pen in this circumstance operates differently than when the catchbasin contains only air. When the catchbasin contains only air and the underpressure increases, the underpressure is moderated by a collapse of the bladder. If the catchbasin contains ink, however, the underpressure is moderated by drawing ink into the reservoir from the catchbasin. The difference is attributed to the higher pressure differential required to pull a bubble of air into the ink-filled reservoir than to pull more ink. The air bubble has surface tension that must be overcome before it can bubble into the reservoir. The ink from the catchbasin does not.

Continued ejection of ink from the reservoir (or environmental change that tends to increase underpressure) continues to draw ink from the catchbasin into the reservoir until the ink in the catchbasin is exhausted. Thereafter, the situation is similar to that before the pen has been used - the catchbasin is dry and the bladder is fully expanded. Further ejection of ink from the pen (or corresponding environmental change) causes the bladder to collapse. In its collapsed (or partially collapsed) state, the bladder exerts a restorative force on the ink which maintains the pressure in the reservoir below ambient. The bladder continues to collapse with further ejection of ink until the bladder restorative force (i.e. the reservoir underpressure) reaches the point at which air bubbles are drawn through bubble generator 36. The process thereafter continues substantially as described

earlier, with a bubble introduced through the bubble generator orifice 36 each time the reservoir underpressure exceeds the bubble pressure.

From Fig. 2 it can be seen that the bubble generator orifice 36 leading to the catchbasin is not at the lowest point of the catchbasin. However, the catchbasin is desirably formed of plastic that causes the ink thereon to bead in an upright geometry under the force of its own surface tension. This permits the orifice 36 to drain the catchbasin substantially completely despite its elevation above the catchbasin floor. The location of the orifice near the corner 46 of the catchbasin also aids in complete ink withdrawal since the ink tends to collect in this corner into which it was introduced.

From the foregoing discussion, it will be recognized that one important requirement is to design the bladder 27 (i.e. its material and geometry) so that its restorative pressure is between the bubble pressure and the ambient pressure. That is, the bladder should be designed to collapse over a range that includes partial vacuums of between zero and five inches of water. If the bladder does not operate in this range, it will be ineffective in regulating reservoir pressure since the bubble generator would always act to relieve any excessive reservoir underpressure before the bladder was prompted to collapse. In the illustrated embodiment, the bladder 27 is formed of ethylene propylene diene monomer having a thickness of 0.61mm (0.024 inches) and a radius of curvature of 1.46mm (0.451 inches).

In the preferred embodiment, the bladder is not permitted to assume its fully hemispherical shape. Such a geometry resists collapsing. Instead, the bladder is dimpled, either during fabrication or by a dimpling finger 48 (Fig. 1). By this arrangement, the bladder can begin collapsing immediately as the underpressure increases, and does not require a high initial underpressure as would a hemispherical bladder before it begins its collapse.

Figs. 4 through 5 illustrate alternative embodiments of the present invention. In the Fig. 4 embodiment, the variable volume portion of the reservoir is formed by a bag 50. Bag 50 has an end piece 52 positioned therein and is urged towards a fully open position by a spring 54. The spring 54 is biased between the bag end piece 52 and a spring boss 56 in the top of the reservoir. Operation of the Fig. 4 embodiment is substantially identical to that of the Figs 1-2 embodiment except that the reservoir underpressure is a more linear function of ejected ink volume since the irregular collapsing of a hemispherical bladder is avoided.

Fig. 5 shows another embodiment similar to Figs. 1,2 and 4 but employing a rolling diaphragm 58 as the variable volume portion of the reservoir. The rolling diaphragm again behaves substantially

linearly in response to increases in reservoir underpressure.

Fig. 6 shows yet another embodiment of the present invention. In this embodiment the variable volume portion of the reservoir is positioned above, rather than below, the fixed volume portion. The variable volume portion here includes a rolling diaphragm 60 in combination with a piston 62, a fitment 64 and a spring 66.

In operation, the reservoir 12 is initially filled with ink and the piston 62 is forced to a fully upward position by spring 66, thereby fully stretching diaphragm 60. As ink is ejected from the pen, the reservoir underpressure increases. As the underpressure increases, the piston 62 travels downwardly, with very little friction, until it finally stops in contact with a bottom platform 68. Further ejection of ink from the reservoir causes air to enter the reservoir through the bubble generator 36 to regulate the reservoir underpressure. This air accumulates.

Again, temperature and altitude changes (exogeneous effects) may act on the pen, causing the reservoir underpressure to diminish. When this occurs, the piston 62 moves vertically upward, acted on by the now unbalanced air pressure over piston force and the spring force. This movement causes the pen to reestablish a new underpressure equilibrium, just slightly less than the prior condition. This process can continue until the piston/diaphragm/spring components reach their original uppermost vertical position.

If desired, the pen of Fig. 6 can be equipped with a ball check valve 70 to prevent the inadvertent introduction of air into the reservoir. It will be recognized that if the pen (or the printer in which it is mounted) is inverted, ink will flow away from the bubble generator orifice 36 and may permit air to freely enter the reservoir, reducing underpressure to zero. This, in turn, may cause a small amount of ink to flow out the pen's printing orifices. The unrestricted introduction of air to the reservoir also defeats the pen's temperature and elevation compensation capabilities by permitting the piston/diaphragm assembly to return to the original, extended position, with an air volume in the reservoir.

To prevent these undesirable conditions, a ball check 72 falls to a seat 74 provided near the location of the bubble generator whenever the pen is inverted, thereby effectively sealing the bubble generator and preserving the reservoir underpressure. When the pen is returned to the normal position, the ball falls from the seat and permits normal underpressure regulation to resume. Although shown in just this Fig. 6 embodiment, the ball check valve 70 can be used in any form of the invention.

Finally, the pen of Fig. 6 is shown as including absorbent foam 76 in the catchbasin. This foam captures and retains any ink driven to the catchbasin by exogenous effects and prevents any ink from flowing out the air vent. At the same time, and at all times, the absorbent foam allows air to pass freely between the vent and the bubble generator, thereby ensuring normal underpressure regulation. This foam can be used in any embodiment and is a last resort to keep ink off of the user.

The above-described arrangements provide a variety of advantages over the prior art. Principal among these is the extended pressure and temperature range over which the ink reservoirs can hold ink in the pen. As an added benefit, these arrangements permit the catchbasins to be used to store part of the initial load of ink, thereby increasing volumetric efficiency. Finally, these designs permit essentially all of the ink to be used for printing, since none is caught in a tightly collapsed bladder. (Any ink that remains in the bladder 27 of Fig. 1 can be dislodged by tilting the pen so the ink can flow into the well 28 from which it can be printed.)

Having described and illustrated the principles of our invention with reference to a preferred embodiment and several variations thereof, it should be apparent that the invention can be modified in arrangement and detail without departing from such principles. For example, while the invention has been illustrated with reference to a vent in the upper side of the catchbasin, other vent geometries, such as a chimney extending upwardly from the floor of the catchbasin as shown in Fig. 6, could alternatively be used. Similarly, while the invention has been illustrated with reference to a bubble generator orifice coupling the reservoir to the catchbasin, a variety of other valve mechanisms, such as the check valve disclosed in U.S. Patent 4,677,447, could be substituted therefor.

Claims

1. An ink jet printing apparatus having an ink reservoir (12); and a print head (30) for ejecting ink from the reservoir, and second pressure control means (27) for controlling the negative pressure in the ink reservoir between a predetermined lower threshold value and an upper threshold value by changing the volume of the ink reservoir; the apparatus characterized in that it further comprises first pressure control means (36, 38) for regulating the negative pressure in the ink reservoir by controllably introducing replacement fluid therein when the negative pressure exceeds the upper threshold value of said second pressure control means.



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Fig. 6 shows yet another embodiment of the present invention. In this embodiment the variable volume portion of the reservoir is positioned above, rather than below, the fixed volume portion. The variable volume portion here includes a rolling diaphragm 60 in combination with a piston 62, a fitment 64 and a spring 66.

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The above-described arrangements provide a variety of advantages over the prior art. Principal among these is the extended pressure and temperature range over which the ink reservoirs can hold ink in the pen. As an added benefit, these arrangements permit the catchbasins to be used to store part of the initial load of ink, thereby increasing volumetric efficiency. Finally, these designs permit essentially all of the ink to be used for printing, since none is caught in a tightly collapsed bladder. (Any ink that remains in the bladder 27 of Fig. 1 can be dislodged by tilting the pen so the ink can flow into the well 28 from which it can be printed.)

Having described and illustrated the principles of our invention with reference to a preferred embodiment and several variations thereof, it should be apparent that the invention can be modified in arrangement and detail without departing from such principles. For example, while the invention has been illustrated with reference to a vent in the upper side of the catchbasin, other vent geometries, such as a chimney extending upwardly from the floor of the catchbasin as shown in Fig. 6, could alternatively be used. Similarly, while the invention has been illustrated with reference to a bubble generator orifice coupling the reservoir to the catchbasin, a variety of other valve mechanisms, such as the check valve disclosed in U.S. Patent 4,677,447, could be substituted therefor.

Claims

1. An ink jet printing apparatus having an ink reservoir (12); and a print head (30) for ejecting ink from the reservoir, and second pressure control means (27) for controlling the negative pressure in the ink reservoir between a predetermined lower threshold value and an upper threshold value by changing the volume of the ink reservoir; the apparatus characterized in that it further comprises first pressure control means (36, 38) for regulating the negative pressure in the ink reservoir by controllably introducing replacement fluid therein when the negative pressure exceeds the upper threshold value of said second pressure control means.



2. The ink jet printing apparatus of claim 1 in which, for deviations in negative pressure in the ink reservoir (12) below a threshold value, the first pressure control means (36, 38) is inoperative.
3. The ink jet printing apparatus of claims 1 or 2 in which the second pressure control means comprises a member (27) movable in response to the pressure in the reservoir (12).
4. The ink jet printing apparatus of claim 3 in which the movable member (27) includes biasing means (54) tending to increase the volume of the reservoir (12).
5. The ink jet printing apparatus of claim 4, wherein the movable member comprises a flexible bladder (27) or diaphragm (58).
6. The ink jet printing apparatus of claim 4, wherein the movable member comprises a spring actuated, flexible bag (50).
7. The ink jet printing apparatus of claims 4 or 5, wherein the movable member comprises a spring actuated piston (62).
8. The ink jet printing apparatus of any preceding claim further comprising means (36) for expelling fluid from the reservoir when the negative pressure in the reservoir (12) is less than the lower threshold value of the second pressure control means (27).
9. The ink jet printing apparatus of claim 8 in which the first pressure control means comprises: a catchbasin (38); means (40) coupling the catchbasin to ambient pressure; means defining an orifice (36) establishing a fluid path through which the ink reservoir (12) can draw fluid from the catchbasin in response to pressure differentials therebetween; and pressure regulator means (36) for limiting the flow of fluid from the catchbasin into the ink reservoir so as to prevent the pressure in the ink reservoir from fully attaining ambient pressure.
10. The ink jet printing apparatus of claim 9 further comprising: orifice means (36) for establishing a fluid path through which ink can be dispelled from the reservoir (12) to the catchbasin (38) when a sufficient pressure differential exists therebetween; and wherein the movable member changes the volume of the ink reservoir and is operative over a first range of reservoir pressures for relieving pressure in the reservoir to prevent ink from being driven through the

orifice means to the catchbasin by pressures in said range.

11. The ink jet printing apparatus of claim 10 in which the movable means (27) includes means responsive to the pressure in the ink reservoir (12) to change the volume thereof.
12. The ink jet printing apparatus of any of claims 8 to 11 in which the first pressure control means (36,38) includes valve means (70) for preventing the unrestricted introduction of fluid into the reservoir (12) if the apparatus becomes inverted.
13. A method of operating an ink jet pen that includes a reservoir (12) for containing ink and a second pressure control means (27) for regulating the negative pressure in the reservoir (12), comprising the steps: regulating the negative pressure in the reservoir between a minimum threshold value and a maximum threshold value of the second pressure control means (27) by varying the volume of the reservoir (12); and regulating the negative pressure in the reservoir (12) when its negative pressure is above the maximum threshold value of the second pressure control means (27) by introducing fluid into the reservoir.
14. The method of claim 10 which further comprises the step of regulating pressure of the reservoir (12) when it is below the minimum threshold value of the second pressure control means (27) by transferring ink from the reservoir to a catchbasin (38).

Patentansprüche

1. Tintenstrahldruckvorrichtung mit einem Tintenreservoir (12) und einem Druckkopf (30) zum Auswerfen von Tinte aus dem Reservoir und einer zweiten Steuervorrichtung (27) zum Steuern des Unterdrucks im Tintenreservoir zwischen einem vorbestimmten unteren Schwellwert und einem oberen Schwellwert durch Verändern des Volumens des Tintenreservoirs, dadurch gekennzeichnet, daß eine erste Drucksteuervorrichtung (36, 38) zum Regulieren des Unterdrucks im Tintenreservoir durch gesteuertes Einspeisen von Verdrängungsflüssigkeit in dieses vorgesehen ist, wenn der Unterdruck den oberen Schwellwert der zweiten Drucksteuervorrichtung überschreitet.
2. Tintenstrahldruckvorrichtung nach Anspruch 1, bei der im Falle von Schwankungen des Unterdrucks im Tintenreservoir (12) unterhalb eines



Schwellwertes die erste Drucksteuervorrichtung (36, 38) nicht arbeitet.

3. Tintenstrahldruckvorrichtung nach Anspruch 1 oder 2, bei der die zweite Drucksteuervorrichtung ein abhängig vom Druck im Reservoir (12) bewegliches Bauteil (27) umfaßt. 5
4. Tintenstrahldruckvorrichtung nach Anspruch 3, bei der das bewegliche Bauteil Spannmittel (54) aufweist, welche bestrebt sind, das Volumen des Reservoirs (12) zu erhöhen. 10
5. Tintenstrahldruckvorrichtung nach Anspruch 4, bei dem das bewegliche Bauteil eine flexible Blase (27) oder Membran (58) umfaßt. 15
6. Tintenstrahldruckvorrichtung nach Anspruch 4, bei der das bewegliche Bauteil einen federbetätigten flexiblen Beutel (50) umfaßt. 20
7. Tintenstrahldruckvorrichtung nach Anspruch 4 oder 5, bei der das bewegliche Bauteil einen federbetätigten Kolben (62) umfaßt. 25
8. Tintenstrahldruckvorrichtung nach einem der vorangehenden Ansprüche, bei der Mittel (36) zum Austragen von Fluid aus dem Reservoir vorgesehen sind, wenn der Unterdruck im Reservoir (12) kleiner als der untere Schwellwert der zweiten Drucksteuervorrichtung (27) ist. 30
9. Tintenstrahldruckvorrichtung nach Anspruch 8, bei der die erste Drucksteuervorrichtung umfaßt: ein Auffangbecken (38); Kuppelmittel zum Anschließen des Auffangbeckens an den Umgebungsdruck; Mittel zum Bilden einer Öffnung (36), welche einen Fluid-Pfad herstellt, durch welchen das Tintenreservoir (12) Fluid aus dem Auffangbecken abhängig von der Druckdifferenz zwischen dem Reservoir und dem Auffangbecken saugen kann; und einen Druckregulator (36) zum Begrenzen der Fluidströmung aus dem Auffangbecken in das Tintenreservoir derart, daß der Druck im Tintenreservoir nicht vollständig den Umgebungsdruck erreichen kann. 35 40
10. Tintenstrahldruckvorrichtung nach Anspruch 9, bei der Öffnungsmittel (36) zum Herstellen eines Fluidpfades vorgesehen sind, über welchen Tinte aus dem Reservoir (12) zum Auffangbecken (38) ausgetrieben werden kann, wenn dazwischen ein ausreichender Differenzdruck herrscht; und bei dem das bewegliche Bauteil das Volumen des Tintenreservoirs verändert und bewirkt, daß über einen ersten Bereich von Reservoirdrücken Druck im Reservoir

entlastet wird, um zu verhindern, daß Tinte aus den Öffnungsmitteln in das Auffangbecken durch Drücke in diesem Bereich ausgetrieben wird.

11. Tintenstrahldruckvorrichtung nach Anspruch 10, bei der das bewegliche Bauteil (27) auf den Druck im Tintenreservoir (12) reagierende Mittel umfaßt, um das Volumen des Tintenreservoirs zu verändern.
12. Tintenstrahldruckvorrichtung nach einem der Ansprüche 8 bis 11, bei der die erste Drucksteuervorrichtung (36, 38) eine Ventilvorrichtung (70) zum Verhindern des ungedrosselten Eindringens von Fluid in das Reservoir (12) aufweist, wenn die Vorrichtung umgekehrt wird.
13. Verfahren zum Betreiben eines Tintenstrahlschreibers mit einem Reservoir (12) für Tinte und einer zweiten Drucksteuervorrichtung (27) zum Regulieren des Unterdrucks in dem Reservoir (12) mit den folgenden Schritten: Regulieren des Unterdrucks im Reservoir zwischen einem minimalen Schwellwert und einem maximalen Schwellwert der zweiten Drucksteuervorrichtung (27) durch Verändern des Volumens des Reservoirs (12); und Regulieren des Unterdrucks im Reservoir (12), wenn der Unterdruck den maximalen Schwellwert der zweiten Drucksteuervorrichtung (27) überschreitet, und zwar durch Einführen von Fluid in das Reservoir.
14. Verfahren nach Anspruch 13, umfassend den weiteren Schritt des Regulierens des Reservoirs (12) wenn dieser unterhalb des minimalen Schwellwertes der zweiten Drucksteuervorrichtung (27) liegt, und zwar durch Überführen von Tinte aus dem Reservoir in ein Auffangbecken (38).

Revendications

1. Un appareil d'impression à jet d'encre comportant un réservoir d'encre (12) ; et une tête d'impression (30) pour éjecter de l'encre hors du réservoir, ainsi qu'un second moyen de commande de pression (27) pour commander la dépression dans le réservoir d'encre entre un seuil inférieur prédéterminé et un seuil supérieur par modification du volume du réservoir d'encre : l'appareil étant caractérisé en ce qu'il comprend en outre un premier moyen de commande de pression (36,38) pour régler la dépression dans le réservoir d'encre en introduisant de façon contrôlable du fluide de remplacement dans celui-ci quand la dépression



dépasse le seuil supérieur dudit second moyen de commande de pression.

2. L'appareil d'impression à jet d'encre selon la revendication 1, dans lequel, lors d'écarts de dépression dans le réservoir d'encre (12) en dessous d'une valeur de seuil, le premier moyen de commande de pression (36,38) est sans effet.
3. L'appareil d'impression à jet d'encre selon une des revendications 1 ou 2, dans lequel le second moyen de commande de pression comprend un élément (27) déplaçable en réponse à la pression régnant dans le réservoir (12).
4. L'appareil d'impression à jet d'encre selon la revendication 3, dans lequel l'élément mobile (27) comprend un moyen de poussée (54) ayant tendance à augmenter le volume du réservoir (12).
5. L'appareil d'impression à jet d'encre selon la revendication 4, dans lequel l'élément mobile comprend une vessie flexible (27) ou un diaphragme (58).
6. L'appareil d'impression à jet d'encre selon la revendication 4, dans lequel l'élément mobile comprend un sac flexible (50) actionné par ressort.
7. L'appareil d'impression à jet d'encre selon les revendications 4 ou 5, dans lequel l'élément mobile comprend un piston (62) actionné par ressort.
8. L'appareil d'impression à jet d'encre selon une quelconque des revendications précédentes, comprenant en outre un moyen (36) pour expulser du fluide du réservoir quand la pression négative dans le réservoir (12) est plus petite que le seuil inférieur du second moyen de commande de pression (27).
9. L'appareil d'impression à jet d'encre selon la revendication 8, dans lequel le premier moyen de commande de pression comprend : une cuvette collectrice (38) ; un moyen (40) reliant la cuvette collectrice à la pression ambiante ; un moyen définissant un orifice (36) établissant un trajet de fluide par l'intermédiaire duquel le réservoir d'encre (12) peut aspirer (20) du fluide à partir de la cuvette collectrice en réponse à des différences de pressions existant entre eux ; et un moyen formant régulateur de pression (36) pour limiter l'écoulement de fluide de la cuvette collectrice vers le réservoir d'encre

de façon à empêcher la pression dans le réservoir d'encre d'atteindre complètement la pression ambiante.

- 5 10. L'appareil d'impression à jet d'encre selon la revendication 9, comprenant en outre : un moyen formant orifice (36) pour établir un trajet de fluide par l'intermédiaire duquel de l'encre peut être transférée du réservoir (12) dans la cuvette collectrice (38) quand une différence de pression suffisante existe entre eux ; et dans lequel l'élément mobile change le volume du réservoir d'encre et opère dans une première gamme de pressions de réservoir pour réduire la pression dans le réservoir afin d'empêcher l'encre d'être entraînée à travers le moyen formant orifice vers la cuvette collectrice sous l'effet de pressions rentrant dans ladite gamme.
- 10 11. L'appareil d'impression à jet d'encre selon la revendication 10, dans lequel le moyen mobile (27) comprend un moyen répondant à la pression régnant dans le réservoir d'encre (12) pour changer son volume.
- 15 12. L'appareil d'impression à jet d'encre selon une quelconque des revendications 8 à 11, dans lequel le premier moyen de commande de pression (36,38) comprend un moyen formant soupape (70) pour empêcher l'introduction non limitée de fluide dans le réservoir (12) si l'appareil prend une position inversée.
- 20 13. Un procédé de commande d'une tête d'impression à jet d'encre qui comprend un réservoir (12) pour contenir de l'encre et un second moyen de commande de pression (27) pour régler la pression négative dans le réservoir (12), procédé comprenant les étapes consistant à : régler la dépression dans le réservoir entre un seuil minimal et un seuil maximal du second moyen de commande de pression (27) par variation du volume du réservoir (12) ; et régler la dépression dans le réservoir (12) quand sa dépression est plus grande que le seuil maximal du second moyen de commande de pression (27) par l'introduction de fluide dans le réservoir.
- 25 14. Le procédé selon la revendication 13, qui comprend en outre l'étape consistant à régler la pression du réservoir (12) quand elle est inférieure au seuil minimal du second moyen de commande de pression (27) par transfert d'encre du réservoir jusque dans une cuvette collectrice (38).
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