ABSTRACT

An ink printing apparatus has an ink recirculating system incorporated therein to supply ink to the printing nozzle and further includes an ink bottle or cartridge that is readily inserted in and removed from the system, the bottle serving as the primary ink supply. The system operates with a single pump and depends primarily on vacuum lines rather than high pressure lines.
INK RECIRCULATING SYSTEM FOR INK JET PRINTING APPARATUS

REFERENCES OF INTEREST


BACKGROUND OF THE INVENTION AND PRIOR ART

The Woods, et al. patent describes ink jet printing apparatus that is fairly representative of a synchronous pressure jet system. The present case makes use of the principles set forth in the Woods, et al. case for printing purposes and further enhances the Woods, et al. apparatus by an efficient ink supply and recirculating system. The Fillmore, et al. patent describes a servo system that is useful in the present system. The Phillips article describes an ink level detector that is useful in the present case. No other art is known that is particularly pertinent to the many features set forth in the present case.

SUMMARY OF THE INVENTION

As indicated in the Abstract, the present case concerns an ink recirculating system for ink jet printers making use of a readily removable ink bottle (cartridge) serving as the main source of ink in the system. This enables easy periodic replacement of the bottle upon depletion. Typically, the bottle, when positioned in its receptacle, serves as an integral part of the ink recirculating system enabling control of various conditions encountered during operation of the system such as pressure differentials, and the like. The system further incorporates filtration and screen units, valves, air bubble catchers, a single pump, a J-tube with a servo point, and an expansion chamber or reservoir primarily serving to accumulate excess ink during operation.

OBJECTS

A primary object of the present invention is to provide an ink recirculating system particularly useful in an ink jet printer environment and operating with high reliability and efficiency.

Another object of the present invention is to provide a system of this nature incorporating a removable ink bottle serving as the primary ink supply source and enabling periodic replenishment of the ink supply.

Still another object of the present invention is to provide a system of this nature incorporating facilities for determining when the ink supply needs replenishment.

Also, an object of the present invention is to provide structures wherein the primary reliance is on vacuum principles, rather than high pressure principles, thereby enabling more suitable placement of the components, such as the ink bottle, for optimum performance.

Another object of the present invention is to provide compensating or accommodating structures in order to compensate for or control pressure and vacuum differentials, temperature variances, and the like.

A further object of the present invention is to provide convenient servicing facilities for the system.

A still further object of the present invention is to provide a system of this nature wherein all recirculating requirements are met by a single pump.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of the preferred embodiment of the invention as illustrated in the accompanying drawings.

DRAWINGS

In the Drawings:

FIG. 1 illustrates an ink jet printing system incorporating a printer and having an associated magnetic card recording/reproducing unit with both line printing and character-by-character printing facilities.

FIG. 2 illustrates structures in the ink jet printer head assembly with an associated grating.

FIG. 3 illustrates several components of ink jet apparatus incorporating the ink recirculating system and including a power module, a print module, and document handling facilities.

FIG. 4 illustrates an ink bottle useful in the system of FIG. 3.

FIGS. 5a and 5b illustrate a needle used for penetrating the bottle shown in FIG. 4.

FIG. 6 is a diagram of an ink recirculating system in accordance with the present invention.

FIG. 7 shows a relief valve incorporated in bubble catcher structures shown in FIG. 6.

FIG. 8 illustrates a suitable bellows pump that may be used in the recirculating system of FIG. 6.

DETAILED DESCRIPTION

FIG. 1 illustrates an ink jet printing system incorporating a printer 1 with an associated magnetic card recording/reproducing unit 2. Card unit 2 is shown for convenience only since it is apparent that other kinds of storage units, recording/reproducing units, magnetic tape units and the like, may be used in the system. Printer 1 has the usual keyboard 3 which preferably is of the electrical type. Printer 1 incorporates an ink jet head assembly 4 arranged for travelling movement from left to right (and conversely) adjacent a document 7 to be printed in order to print lines of information on the document. Assembly 4 has an ink drop nozzle and an associated grating 8 for drop location purposes. Printer 1 may be provided with various control buttons 10, 11, 12 and 13 for automatic, line, word, and character printing, respectively. Other key buttons 15-18 concern mode selection, that is, record, playback, adjust, and skip, respectively. Printer 1 incorporates a left margin reed switch 30, a drop carrier return reed switch 31 and a right margin reed switch 32.

The magnetic card unit 2 has a load slot 25 and a track indicator 26. Also provided on unit 2 is a card eject button 27, a track stepdown button 28 and a track stepup button 29 for relocating the scanning transducer with respect to the various tracks on the card.

Referring to FIG. 2, various structures incorporated in a representative head assembly 4 are illustrated. This includes a pump 40 for directing ink from an ink supply conduit 41 through a crystal 42 and nozzle 43. Crystal 42 is energized, that is, pulsed at high frequencies in order to produce drops. The rate of impulsing crystal
3,929,071

3

42 may be in the range of 100 kiloHertz for example. Ink drops are emitted from nozzle 43 and pass through a charge electrode 44 for variable charging in accordance with the output of a charge amplifier to deflect the drops in a column an amount representing the vertical height of the drop location in any given character. As illustrated, the letter capital “S” designated 50 comprises a number of vertical columns 51. The printing is such that a sequence of vertical columns, each comprising a plurality of drops, such as 40 in number, is propelled from nozzle 43 toward document 7 (see FIG. 1) for the printing of the character involved. If drops are not required for printing, they are directed to a gutter 53 for passage back to the ink supply, as will be subsequently described. A pair of deflection plates 60 and 61 is positioned in the path of travel of the drops leaving the charge electrode 44. A constant high potential is applied across plates 60 and 61 and this, in cooperation with the variable charge on the individual drops, determines the amount of deflection as the drops are directed toward document 7. Grating 8 in this instance is shown as being positioned horizontally rather than vertically as in FIG. 1, but the positioning is immaterial.

INK JET PRINTER ASSEMBLY

Referring to FIG. 3, certain details of an ink jet printer like the printer of FIG. 1 are shown. It is noted that a keyboard is not shown in FIG. 3. Typically, a printer of this nature incorporates document handling facilities 70 having a platen 71 for supporting a document to be printed. When in use, the document handling facilities 70 are positioned in proximity to the print module 73 and more especially the ink jet head assembly 4 in order to print characters on document 7, not shown in FIG. 3. Carrier 5 supports head assembly 4 for movement from left to right and conversely in order to print information on the document mounted on platen 71, as previously described. Of particular interest in FIG. 3 is the ink bottle (cartridge) 100, further shown in detail in FIGS. 4 and 6. Bottle 100 is mounted on power module 75 which includes a drive motor 80 interconnected by various clutches and drive assemblies 81 through cables 82 and 83, for example, to drive carrier 5 back and forth during printing.

Further associated with print module 73 are electronic modules 86 and 87. A filter, filter B, is also illustrated in FIG. 3.

Not all of the components of the ink recirculating system according to the present invention are shown in FIG. 3, but they are illustrated in other drawings, such as FIG. 6. As an example, the supply and return lines between bottle 100 and head assembly 4 are not shown in FIG. 3. Of particular interest is that all of the components on the power module 75, FIG. 3, remain relatively stationary during printing operations. This contrasts with other components associated with head assembly 4 which are mounted for movement on print module 73. Greater stability of the ink supply in bottle 100 is achieved by having such separation of the components. This is further illustrated in FIG. 6. Components above and to the right of line 200 move during printing operations while those below and to the left of line 200 remain relatively stationary.

INK BOTTLE

FIG. 4 illustrates bottle 100 in greater detail. It is also shown in cross-section in FIG. 6. The bottle consists of a blow-molded, polypropylene, cylindrical shell. Typical dimensions are: height 4.1 inches and outside diameter 2.6 inches; shell thickness approximately 0.045 inches. The bottle is stoppered with an RTV silicone rubber plug that has needle-puncturable septums 90 and 91. The bottle is arranged for alignment in a bottle receptacle 142, FIG. 3, and has a projection 103 arranged for actuation of a cut-off valve 102, FIG. 6. The capacity of the bottle is 6.9 ounces of ink, however, the fill volume is actually 6 ounces and only 4 of the 6 ounces are actually used. Two ounces are discarded with the used bottle. Bottle 100 is equipped, near the base, with two embossed copper adhesive tape plates 105 and 106, which interface with a level detect circuit using capacitive electrical principles to detect the ink level within the bottle. Reference is made to the Philips article.

The full bottle, being sealed, has the capability of developing internal pressure when heated or exposed to an ambient pressure lower than the ambient pressure at the time of filling. The lowest fill pressure for a rigid bottle to still retain zero pressure differential on the plug at 7850 feet of elevation above sea level and 140°F is 6.5 pounds per square inch absolute (psia). However, since the deflection of the stopper makes the bottle less than rigid, the fill pressure needed to accommodate the pressure increase and still retain zero pressure differential across the plug is 9.8 psia. The bottles are filled at 9.0 psia. Another benefit is derived from the reduced bottle pressure in that when frozen at −40°F, no rupture or distortion of the bottle results. The bottle has been frozen upright, inverted, and on its side with no adverse reactions to the shell, plug or assembly. The ink expansion is amply contained.

When the ink bottle 100 has been depleted to 2 ounces of residual ink and is ready to be replaced with a new bottle, it is important not to allow any air to get into the ink system while removing the bottle, especially air in the pump inlet, or supply line. This is accomplished by cutoff valve 102 which closes the inlet line 104a upon removal of bottle 100.

As indicated, about 4 ounces of ink are used from each ink bottle 100. Typically, this represents four million characters of printing and an expected use of perhaps 20 bottles per year in the ink jet printer. FIGS. 5a and 5b illustrate one of the needles, such as needle 110 for example. Each needle comprises a sharp tip, such as tip 110a, for easy penetration of the septum. Circulation of ink through the needle is by means of a cross-drilled aperture 110b connected to a passage 110c.

STRUCTURAL CHARACTERISTICS OF INK RECIRCULATING SYSTEM

The ink recirculating system, FIG. 6, consists of bottle 100 mounted on power module 75 and connected by hoses 104a-g to pump 116 and nozzle 125 that are mounted on carrier 5. This is the input side of the system and further includes bubble catchers 120 and 122, capillary tube 151, main valve 154 and filters A, B, and C. The return side of the system includes gutter 53, J-tube 115, hoses 113a and 113b and screen element 117.

Circulation is as follows. Ink 116 from bottle 100 is drawn through needle 111, hoses 104a and 104b, filter A in bubble catcher 120, through hose 104c into another bubble catcher 122 and then by hose 104d to pump 116 which provides pressure to the nozzle 125.
Ink then passes through hose 104e, capillary tube 151, hose 104f, filter B, and hose 104g to main valve 154 which is turned on and off to control flow. Thereafter ink goes from valve 154 by conduit 155, filter C, and conduit 156 to nozzle 125. The function of main valve 154 is to prevent ink from dribbling out of nozzle 125 and contaminating other machine elements. Ink from the nozzle which is not used in printing is directed into gutter 53 where it gravity flows downward at 126 to elbow 115a of J-tube 115. From this point the ink is drawn into bottle 100 through hose 113a, screen 117 and hose 113b, needle 110 and standpipe 128 which extends on the inside almost to the top of bottle 100. Screen 117 is provided between hoses 113a and 113b for additional filtration and strains out relatively large particles thus insuring that there are no contaminants in the return line to bottle 100. Screen 117 is typically a flat stainless steel plate in the range of 0.01 inch with apertures of comparable size drilled through it.

The ink is drawn into the return line by the vacuum created when the ink is drawn out of the bottle by the pump 116. When the amount of ink removed from the bottle reaches the amount directed into gutter 53, the ink level in elbow 115a will go down below 110 establishing a bubble of air to enter hose 113b, thus compensating for the ink used in printing. During constant temperature operation, the ink level will automatically servo about the elbow, only allowing enough air to enter the system to compensate for the ink used in printing. A reservoir 133 is interconnected to J-tube 115 by two small openings 134 and 135, one at the top and one at the bottom of the reservoir. Reservoir 133 provides a place for ink to accumulate if temperature expansion of air in bottle 100 is at the same rate as ink removal from the bottle. In this case, no suction is created in the bottle to draw the returning ink into the bottle and it will accumulate in the J-tube 115 and reservoir 133. Reservoir 133 is sized such that it will accommodate the largest amounts of ink possible over the temperature range expected. The reservoir is filled with a material 140, such as open-cell foam, to prevent sloshing of ink during movement of carrier 5. As indicated, bottle 100 moves into a receptacle 142 shown in FIG. 3, which guides the bottle on and off of needles 110 and 111.

Other structural characteristics of interest are as follows. Filter A may be formed of woven stainless steel pleated mesh. It's purpose is to clean out small particles that might stop up pump 116 and filter A is designed to last the life of the machine. Filter B simply provides further filtration following pump 116. Filter C is positioned in close proximity to nozzle 125 to prevent nozzle clogging. Ordinarily, contaminants are held on the various filters during the life of the machine.

Bubble catcher 120 serves to keep filter A from becoming air-locked. As ink is pulled from bottle 100, the pressure differentials form minute air bubbles in the stream which will tend to accumulate on the left side of filter A, FIG. 6, and block flow of the stream. To prevent this, the upper portion 120a of bubble catcher 120 is provided. Thus, bubbles 121 are able to rise in the ink and accumulate in the upper section of portion 120a. A similar function is performed by bubble catcher 122. Bubble catchers 120 and 122 are provided with valves 160 and 161, respectively, that enable periodic servicing of the bubble catchers by relief of the air bubbles trapped in the bubble catchers. A typical air valve for this purpose is illustrated in FIG. 7 as comprising a valve seat 165 against which the valve disk 166 and resilient element 168 are spring loaded by means of spring 167. Connection of a hose on port 170 and establishment of a vacuum during servicing procedures overcomes tension of spring 167, enabling valve disk 166 and element 168 to move to the right in FIG. 7 and release air from the bubble catcher.

Considering cutoff valve 102, this valve is provided between bottle 100 and filter A to compensate for conditions established in bubble catcher 120, hose 104b, bubble catcher 122; and pump 116. This is provided since the air in the top of bubble catcher 120, for example, is at a vacuum about the same level as in the pump supply line 114. In the absence of a cutoff valve 102, the vacuum in bubble catcher 120 would be relieved by air being drawn into needle 111 upon removal of bottle 100 from receptacle 142. The next time a bottle 100 were to be removed, the air volume present in bubble catcher 120 would be even bigger than the previous time, this being a cumulative process that becomes more pronounced upon each bottle replacement. To avoid this, cutoff valve 102 prevents air from going into line 104b. Valve 102 effectively closes before needles 110 and 111 are removed from bottle 100. When a fresh bottle 100 is installed, its needle 111 enter the bottle and then cutoff valve 102 opens.

Considering pump 116, the details of its construction are illustrated in FIG. 8. Any suitable pump can serve the intended function but in this case the pump is a bellows pump. Referring to FIG. 8, ink enters through hose 104d and is discharged through hose 104e. The pump assembly includes flapper valves 180 and 181, a pump bellows 182, a return spring 183 and a solenoid port 184, all suitably mounted together in support member 186-190.

Considering main valve 154, FIG. 6, this valve is provided to avoid dribbling of ink following shut-down and during startup. Associated with main valve 154 is a by-pass member 162 having an air vent 163. By-pass member 162 connects main valve 154 to reservoir 133. This connection to air vent 163 is provided since in some cases when ink accumulates high enough in J-tube 115, thus filling reservoir 133, top opening 134 could acquire a film of ink, disturbing the pressure conditions. In some cases not enough positive pressure could be created sufficient to break through the ink film over openings 134, thus allowing ink in J-tube 115 to accumulate higher than normal and to sloss out of gutter 53, and causing a malfunction. Provision of air vent 163 enables air to pass out of vent 163 or J-tube 115, whichever proves to be more convenient under the conditions at the moment.

**OPERATION**

A representative operation of the system is as follows. Bottle 100 is shoved into needles 110 and 111. The initial vacuum in bottle 100 draws ink dry from gutter 53 and by way of lines 113a and 113b through screen 117. This also pulls air through the return line in most cases which will result in atmospheric pressure being established in bottle 100.

Subsequently, pump 116 begins operation and valve 154 opens. At this point, no vacuum exists in the return lines comprising lines 113a and 113b. However, vacuum will be established when ink falls in gutter 53 to the bottom portion of J-tube 115 and fills up to the servo point 115b of J-tube 115. When this occurs, no further air can reach bottle 100 and vacuum conditions are initiated in bottle 100. Vacuum continues to build
up in bottle 100 and in about 30 seconds from turn-on time, the flow of ink in the return lines 113a and 113b and in the pump lines 104a – 104d will reach approximate equilibrium. Also, ink in the J-tube will tend to back-up and flow into reservoir 133 during this 30 second period. Such conditions and ink levels are maintained until printing begins.

As ink flows during printing to gutter 53, it falls toward servo point 115b. If pump 116 draws more ink from bottle 100 than there is flowing into the return line, then the ink level at servo point 115b will drop and air will pass through to ink bottle 100. This will tend to relieve the vacuum slightly in bottle 100, thereby slowing the flow rate back to bottle 100 and allowing the level at servo point 115b to rise back up again. Thus, servo point 115b is the only point at which air is permitted to return to bottle 100.

In the overall structural configuration, it is mandatory that servo point 115b be located lower than reservoir 133. To enable gravity flow of ink to the servo point, it is necessary that an air vent be maintained to the servo point 115b location by keeping the J-tube 115 and gutter 53 unobstructed.

The aforementioned conditions prevail throughout operation until pump 116 is turned off near the end of printing. It is noted that ink is pumped continuously from turn-on to turn-off of valve 154. After valve 154 turns off, ink continues to flow in the gutter return lines 113a and 113b. This occurs due to the vacuum created in bottle 100 which tends to pull ink on through the return line until equilibrium is reached.

One consideration in the system that needs to be taken into account is the fact that the relationships are such that the top of return needle 110 should be maintained higher than the highest point of ink expected to exist in J-tube 115 or reservoir 133 in order to avoid ink spilling out of the system in the event of removal of bottle 100. To fully prevent this, an optional cut-off valve 192 may be provided. If this is done, the height of needle 110 is unimportant.

A point of interest is that the vacuum in bottle 100 mainly depends upon the differential between standpipe 128 in bottle 100 and servo point 115b which, in a typical case may be 4.0 inches of mercury and the pressure drop in the return lines 113a and 113b. In any case, the operating vacuum in bottle 100 is somewhat less than 20.0 inches of mercury.

Another point of interest is that as ink is consumed from bottle 100, the concentration tends to increase due to its having been in contact with the air from nozzle 125 to gutter 53 and with the air in J-tube 115 and in reservoir 133, for example. As concentration increases, viscosity tends to increase and pump 116 is no longer able to maintain the customary pressures required to allow the ink to break up into drops for printing or return to gutter 53. A suitable servo system, such as that described in the Fillimore, et al patent, may be provided to increase pump pressure as these conditions occur in order to maintain pump drive at a suitable level during operation.

Disposing of the ink bottle when the level of ink reaches about 2 oz. avoids difficulties due to the ink becoming overly concentrated.

As a modification, it may be desirable to incorporate additional filtration structures in bottle 100 itself. In this case, throwing bottle 100 away disposes of the contaminants caught by the bottle filter, as well.

The foregoing arrangements establish a highly efficient system for supplying ink to an ink jet printer apparatus.

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the spirit and scope of the invention. What is claimed is:

1. Ink recirculating apparatus, comprising:
   ink supply means, said ink supply means providing a predetermined quantity of ink for said apparatus;
   a utilization device, said utilization device having an input side and an output side and intervening portions thereof open to atmospheric pressure;
   an ink supply line interconnected between said ink supply means and the input side of said utilization device;
   an ink return line interconnected between the output side of said utilization device and said ink supply means;
   pump means interposed in said ink supply line for establishing a predetermined supply pressure to said utilization device and to concurrently establish a predetermined range of vacuum in said ink supply means;

2. The apparatus of claim 1, further comprising:
   a receptacle incorporated in said ink supply means; and
   an ink supply bottle arranged for insertion in and removal from said receptacle.

3. The apparatus of claim 2, further comprising:
   a supply needle incorporated in said receptacle and arranged for transmission of ink to said ink supply line;
   a return needle incorporated in said receptacle and arranged for transmission of ink from said return line;
   a standpipe incorporated in said bottle may be provided. If this is done, the height of needle 110 is unimportant.

4. The apparatus of claim 2, further comprising:
   a cut-off valve incorporated in said supply line between said ink supply means and said pump means; and
   means for operating said cut-off valve to on condition upon insertion of an ink bottle into said receptacle and to further operate said cut-off valve to off condition upon removal of said bottle from said receptacle.

5. The apparatus of claim 4, further comprising:
   projection means incorporated on said ink bottle and positioned for operation of said cut-off valve as an ink bottle is inserted in and removed from said receptacle.

6. The apparatus of claim 2, further comprising:
   sensor means for sensing the depletion of ink in said bottle to a predetermined level; and
advisory means actuated by said sensor means to indicate a depleted condition of ink in said bottle so that said bottle may be replaced with a replacement bottle containing a fresh supply of ink.

7. The apparatus of claim 2, wherein:
said ink bottle is filled at a predetermined pressure in order to establish an initial vacuum in said apparatus upon insertion of said bottle in said system.

8. The apparatus of claim 1, further comprising:
a bellows pump incorporated in said pump means.

9. The apparatus of claim 1, further comprising:
first filtration means incorporated in said supply line between said ink supply means and said pump means.

10. The apparatus of claim 9, further comprising:
second filtration means incorporated in said supply line between said pump means and said utilization device.

11. The apparatus of claim 1, further comprising:
a main valve means incorporated in said supply line between said pump means and said utilization device for controlling turnon and turnoff of ink to said utilization device.

12. The apparatus of claim 1, further comprising:
an ink housing interconnected in said ink supply line, said housing incorporating a bubble catcher portion for accommodating air bubbles occurring during passage of ink through said housing; and filtration means incorporated in said housing.

13. The apparatus of claim 12, further comprising:
a second housing, said second housing being incorporated in said ink supply line, and said second housing incorporating a bubble catcher portion.

14. The apparatus of claim 13, further comprising:
vent means incorporated in said housing members enabling relief of air bubbles during servicing operations.

15. The apparatus of claim 1, further comprising:
screen means incorporated in said return line for filtration purposes.

16. The apparatus of claim 15, further comprising:
an optional cut-off valve incorporated in said return line between said screen and said ink supply means.

17. The apparatus of claim 1, further comprising:
a J-tube incorporated in said fluid servo means, and positioned for collection of ink from the output side of said utilization device, said J-tube having an elbow portion for accumulation of ink on the return side of said apparatus, said elbow portion serving as a servo point for passage of ink and maintenance of said predetermined range of vacuum in said ink supply means.

18. The apparatus of claim 17, further comprising:
an ink reservoir integrally associated with said J-tube, said ink reservoir being of sufficient capacity to accommodate excess ink accumulating in said J-tube during operation of said system and due to changes in temperature, and the like.

19. The apparatus of claim 18, wherein:
said J-tube has an upper portion open to the atmosphere thereby enabling relief of pressure differentials in said reservoir.

20. The apparatus of claim 19, further comprising:
an additional vent means interconnected with said reservoir, said additional vent means enabling relief of pressure differentials in an auxiliary manner in relation to said J-tube.

21. The apparatus of claim 1, further comprising:
an ink jet head assembly, said ink jet head assembly comprising an ink nozzle and an ink gutter, said ink nozzle serving as the input side of said utilization device and said ink gutter serving as the output side of utilization device.

22. The apparatus of claim 21, further comprising:
a J-tube member integral with said gutter means, said J-tube having an elbow portion and arranged for accumulation of ink in said elbow portion, said elbow portion serving as a servo point in said apparatus.

23. The apparatus of claim 22, further comprising:
a reservoir integrally formed with said J-tube, said reservoir being arranged to accumulate excess ink from said J-tube during operation of said apparatus.

24. The apparatus of claim 23, further comprising:
baffling material such as open cell foam incorporated in said reservoir to prevent sloshing of ink in said reservoir.

25. The apparatus of claim 1, further comprising:
a first relatively stationary module for retaining said ink supply means during operation of said apparatus; and

a second relatively movable module for accommodating said pump means and said fluid servo means.

26. The apparatus of claim 25, further comprising:
power means including a motor and drive means on said first module; and

ink jet printing means including an ink jet head assembly and carrier mounted for movement on said second module, said carrier accommodating said pump means and said fluid servo means.

* * * * *