(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 465 071 A2

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number : 91305676.8

(22) Date of filing : 24.06.91

(51) Int. Cl.[5] : B41J 2/05, B41J 2/005, B41J 2/135

(30) Priority : 24.06.90 US 557280

(43) Date of publication of application : 08.01.92 Bulletin 92/02

(84) Designated Contracting States : DE FR GB IT

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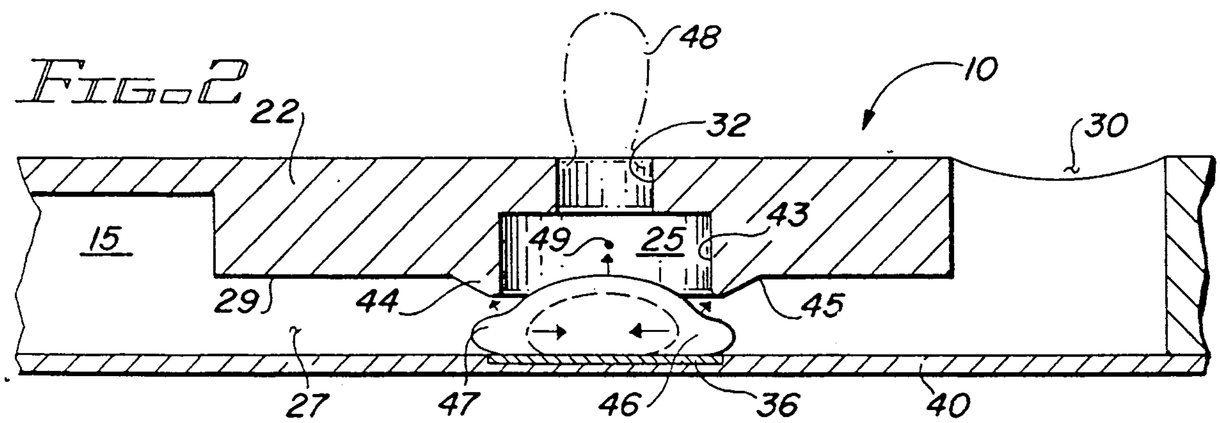
(54) **Ink jet print head.**

(57) A thermal drop-on-demand ink jet print head (10) has an array of heating elements (36) and near each heating element is a compression chamber (25). Each compression chamber is filled with ink from an ink reservoir (15) through an ink supply line (27) near a heating element. Each compression chamber further has an orifice (32) for ejecting ink drops (48). A dynamic valving effect is generated by configuring a protrusion (44) around the edge of the compression chamber which slightly reduces the flow area of the channel inlet. As a heating element is energized, a vapor bubble (46) of ink nucleates and grows rapidly on the heating element surface. The growth of the bubble increases the pressure in the compression chamber, pushing the ink through the orifice to eject an ink drop. Meanwhile, the formation of the growing bubble produces a dynamic valving action between the protrusion and the heating element surface, preventing a pressure leak through the ink supply line. This dynamic valving effect accelerates the bubble formation in the middle of the compression chamber, thereby creating large-size drops which eject with high speed. As the heating element is deenergized, the bubble collapses and a fast lateral pullback motion near the channel inlet enhances the replenishing of the compression chamber with ink, thereby improving the frequency response of the print head.

FIG. 2



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This invention relates to an ink jet print head and, more particularly, to a thermal ink jet print head which generates ink drops on demand under the control of electrical signals energizing a preselected set of heating elements.

Ink jet printing is well known in the art. An ink jet print head typically comprises an ink reservoir supplying ink to an array of ink chambers, and each ink chamber has an orifice and a mechanism to eject ink drops. The print head is electrically connected to and controlled by an output interface device. This output interface device and its associated print head can be implemented in a printer, a facsimile machine, a copier, a marking device, or other types of input/output or recording apparatus.

Ink jet printing is a technique which takes small quantities of ink from a reservoir, converts them into drops, and ejects the drops through the air to the printed medium. There are two major classes of ink jet printers often referred to as "continuous ink jet" and "drop-on-demand ink jet". A continuous ink jet printer ejects ink streams continuously with electrostatic or magnetic forces applied to guide the ink drops to the printed medium. A drop-on-demand ink jet printer, such as the thermal ink jet printers of this invention, uses a thin film heating resistor to dissipate heat in a small compression chamber filled with ink. A sudden vaporization of a small portion of the ink creates a fluid displacement and propels an ink drop to eject through a chamber orifice.

Major limitations of the prior art drop-on-demand systems have been (1) low drop production rate caused by the time delay required to refill the compression chamber; (2) pressure leak through the ink supply line which reduces the drop propelling force directing toward the orifice, resulting in small ink drops ejected with low speed; and (3) jet instability which produces drops of irregular sizes and/or space caused by "crosstalk" between neighboring chambers, i.e., interdependence and fluctuation of chamber internal energy between neighboring chambers.

Two prior art drop-on-demand ink jet printers implemented design changes in an attempt to overcome the above limitations.

Hara et al., Japanese published unexamined patent application 59-138460, filed August 8, 1984, describes a liquid jet recording apparatus having the heat-acting surface disposed on the bottom surface of each ink flowline. The vertically extending partition walls defining the flowline are configured to have non-constant flowline width in the vicinity of the heat-acting surface. Hara claims that the "indefiniteness" in the flowline width creates an imbalance of the liquid stream resistance and thereby causes a change of flowrate to enhance the refilling of the ink flowline after the emission of the ink. Hara's disclosure does not address the limitations caused by pressure leaks through the ink flowline to a common ink reservoir, nor does it resolve the "crosstalk" problem between adjacent chambers.

Lee et al., U.S. Patent 4,353,078, issued october 5, 1982, describes a drop-on-demand ink jet printer in which an electromechanical transducer is mounted adjacent to an ink cavity and an inlet chamber. The transducer is selectively energized in response to an electrical signal to reduce the volume in the ink cavity to eject one drop from the orifice. During the drop ejection, the transducer also substantially closes the flow path from the ink cavity to the inlet chamber. Lees patent shows a design improvement specifically for piezoelectric crystal (PEC) driven drop-on-demand ink jet devices which makes use of the on-demand vibration of the solid PEC walls on a print head which is typically larger than thermal ink jet devices. The transducer motion creates a mechanical force to effectuate ink compression. This external compressive force which was shown and applied in Lee's patent to overcome the above difficulties is, however, not available in a thermal drop-on-demand ink jet device. There still is a need in the art for a thermal bubble ink jet printer to overcome the above limitations.

For a thermal ink jet device, the formation of a vapor bubble of ink in a compression chamber creates a transitory pressure barrier at the boundary of the bubble with temporary higher pressure immediately inside the bubble boundary which pushes the bubble to expand outwardly. The dynamics of the bubble expansion and the pressure variations within the compression chamber as a function of time are functionally dependent upon the geometrical configuration of the chamber and the relative position of the heater, the orifice, and the channel inlet.

Therefore, it would be desirable to have a thermal ink jet device which can be configured such that during the bubble formation and ejection stage, the pressure boundary created by the bubble can be used as a valve which seals off and isolates the compression chamber. This results in all the internal energy produced by the bubble expansion being directed to the orifice for the creation of high-speed large ink drops and, meanwhile, since each compression chamber is hydraulically isolated, the "crosstalk" between the neighboring chambers is reduced.

Viewed from one aspect the present invention provides a thermal drop-on-demand ink jet print head comprising a substrate having a plurality of ink heating elements thereon, means defining a plurality of compression chambers for receiving ink each aligned with a respective one of said heating elements and each communicating with a respective orifice for ejecting ink drops, and means located near each said heating element and its associated compression chamber and arranged to generate a dynamic fluid valving action between said substrate and said compression chamber defining means when said heating element generates a vapor bubble of ink in said compression chamber.

Further aspects of the invention are set forth in the appended claims.

In a preferred form, the invention provides a thermal ink jet print head with an improved compression chamber configuration by disposing the chamber inlets near the heating elements and slightly reducing the flow area of the chamber inlets by forming a protrusion on the edge of the compression chambers. When a heater is energized, a vapor bubble of ink formed on the surface of the heater will first come into near contact with the protrusions and a dynamic fluid pressure valving action is generated which seals off the compression chamber, thereby preventing pressure leak and directing all mechanical force to the ejection of an ink drop through the orifice. After ejection of an ink drop, the electric current to the heater is terminated and the vapor bubble of ink begins to collapse. As the bubble collapses, an inverse pressure transition takes place. A higher pressure immediately outside the bubble exerts a compressive force. The ink in the channel inlet area which was previously sealed off during bubble expansion is now subject to greater compressive force because, unlike the inner portion of the compression chamber, the ink was stopped by a dynamic fluid valve and no outward momentum is to be overcome in the collapse motion. A greater pressure difference is therefore produced between the chamber inlet area and the middle portion of the chamber. This greater pressure difference accelerates the ink replenishment and shortens the response cycle of the print head.

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which:-

Fig. 1 is a top plan view of a thermal drop-on-demand print head embodying the present invention;

Fig. 2 is a section view taken along line 2-2 of Fig. 1 of the thermal drop-on-demand ink jet print head;

Figs. 3A-3D are diagrams showing the voltage pulse, the temperature at the surace of the heating element, and the pressure variations at two locations of the compression chamber as functions of time;

Fig. 4 is a top plan view of a thermal drop-on-demand print head with an alternative embodiment of the invention;

Fig. 5 is a side elevation view taken along line 5-5 of Fig. 4; and.

Fig. 6 is a schematic view of a thermal ink jet printer incorporating the present invention.

Referring first to Figs. 1 and 2, a printer apparatus comprises a print head 10, an ink supply means such as ink reservoir 15 which supplies ink to the print head, and a control means 20. Control means 20, typically an addressing electrode connected to a digital-stream input interface, controls print head 10 by providing voltage pulses to selectively energizing print head 10. Each voltage pulse provided to print head 10 produces one ink drop. A more full description of the voltage pulses as a function of time and the temperature and pressure responses are shown in Figs. 3A-3D and are explained in more detail later. Print head 10 comprises an orifice plate 22 having a compression chamber 25 formed therein. Ink reservoir 15 provides ink to compression chamber 25 through ink supply line 27. A vent 30 is placed near the chamber 25 to enhance the ejection of the ink drop. Compression chamber 25 and ink supply line 27 are not pressurized and are maintained at or near the atmospheric pressure under static conditions. Orifice plate 22 further has an orifice 32 which is in fluid communication with compression chamber 25. Aligned with chamber 25 is a heating element 36 formed on a substrate 40. Heating element 36 is typically a thin film resistor, and substrate 40 is typically a silicon plate. Heating element 36 is connected to control means 20 to receive voltage pulses. As shown in Fig. 2, an annular protrusion 44 is formed near the inlet to compression chamber 25 on orifice plate 22. When control means 20 sends a voltage pulse to energize heating element 36, a vapor bubble 46 nucleates and grows like a piston with primary motion displaced upward. The rapid growth of vapor bubble 46 pushes the ink on top toward the upper structures.

As shown in Fig. 1, the area of compression chamber 25 is defined by dotted circle 43, protrusion 44 is defined by the area between dotted circles 43 and 45, and the area of heating element 36 is defined by dotted square 48. As shown in Figs. 1 and 2, heating element 36 preferably has an area slightly larger than the cross-section of compression chamber 25. Consequently, heating element 36 extends into the ink supply line 27 under protrusion 44 at the inlet area to compression chamber 25. Vapor bubble 46 generated on the surface of heating element 36 is typically larger than the dimension of heating element 36, depending on the amplitude of the voltage provided by control means 20. There is a substantial area of bubble surface extending outside compression chamber 25. Since annular protrusion 44 is closer to heating element 36 than the top wall 29 of orifice plate 22, the growth of bubble 46 feels the effect of protrusion 44 first. A squeeze film phenomenon is effectuated which generates a localized, transient, high-pressure valving action immediately next to the annular protrusion 44.

Fig. 3 depicts the pressure variations at point 47 and point 49 as shown in Fig. 2. Point 47 is located immediately under annular protrusion 44, and point 49 is located right on top of bubble 46. The pressure variations at points 47 and 49 are shown as functions of time in Figs. 3A and 3B, and the temperature at the surface of heating element 36 and the voltage pulses provided by control means 20 as functions of time are shown in Figs. 3C and 3D. As show in Figs. 3C and 3D, the temperature at the surface of heating element 36, i.e., T36, rises to its peak temperature right after the voltage pulse provided to heating element 36, i.e., V36, is removed. The ink in compression chamber 25 begins to nucleate and vapor bubble 46 is formed. As shown in Fig. 3B, a very sharp initial pressure rise at point 47, i.e., P47, is effectuated because vapor bubble 46 first comes into near contact with protrusion 44. This high-pressure rise becomes a dynamic valving action which asserts a force pushing the ink to the middle portion of compression chamber 25. It accelerates the pressure rise near point 49, i.e., P49. This dynamic valving action near protrusion 44 seals off compression chamber 25 temporarily, preventing mechanical energy leak to ink supply line 27, and thereby impedes the growth of vapor bubble 46 at the periphery and accelerates the growth at the middle of compression chamber 25, thereby ejecting an ink drop 48 through orifice 32 with larger drop size and higher speed.

As the voltage pulse is removed, vapor bubble 46 collapses. The bubble collapses faster laterally along the surface of heating element 36 than at the top of the bubble and ink interface in the middle portion of compression chamber 25. The change in bubble surface motion, i.e., away from the top structure and collapsing laterally, causes immediate removal of the dynamic valving action near protrusion 44. The fast lateral collapse motion of bubble 36 enhances the inflow of ink from ink supply line 27 and reduces the time required to refill compression chamber 25. This refilling process is a dynamic one which is effectuated by a sharp pressure decrease and a negative low pressure near protrusion 44 as shown by the variation of P47 in Fig. 3B. The chamber replenishment, with the aid of the low pressure at point 47, is faster than that produced by a capillary action. A shorter response time and higher frequency capability is accomplished by use of this improved design.

The present embodiment has therefore resolved the difficulties encountered by the prior art. The dynamic valving action produced in the compression chamber during bubble formation not only directs more force toward ejection of the ink drops, thereby producing larger ink drops ejected with higher speed, but it also seals off the ink chamber and reduces the hydraulic crosstalk between the neighboring chambers. Furthermore, the faster lateral pullback near the chamber inlets during bubble collapse produced by a greater pressure difference accelerates the ink replenishment of the chamber, whereby a print head with a short response time and high-frequency printing is achieved by the present invention.

An alternative embodiment of the print head which implements the dynamic valving action design in the ink compression chamber is shown in Figs. 4 and 5. The print head comprises a substrate 55 oriented on an X-Y plane where an array of heating elements 58 parallel to the Y-axis are formed. A barrier layer 60, having an array of compression chambers 62, overlies the substrate. Each of the compression chambers 62 is aligned with a heating element 58. An array of orifices 66 parallel to the Y-axis can either be formed on the side surface of barrier layer 60 or, alternatively, an orifice plate 64 oriented parallel to the Y-Z plane is perpendicularly connected to substrate 55 and barrier layer 60, and an array of orifices 66 is then formed on orifice plate 64. Each orifice 66 is aligned with a compression chamber 62 so that orifice 66 is in fluid communication with compression chamber 62. As shown in Fig. 5, a protrusion 70 is formed on the barrier layer 60 near the inlet of compression chamber 62 above heating element 58. As control means 72 selectively sends a voltage pulse to energize heating element 58, a vapor bubble of ink 74 is formed on the surface of heating element 58. As shown in Figs. 4 and 5, the area of heating element 58 preferably is slightly larger than that of the top surface of compression chamber 62. The rapid growth of the bubble pushes the fluid upward. Because protrusion 70 is closer to heating element 58, the "squeeze film" effect caused by the protrusion generates a temporary valving action near point 76 immediately under the protrusion. This dynamic valving action temporarily seals off compression chamber 62, thus preventing mechanical energy from leaking through ink supply line 78, and forcing the growth of the bubble toward orifice 66. The more efficient use of the heating energy provided by heating element 58 using this improved compression chamber design generates an ink drop 88 of larger size and ejects it with higher speed.

The voltage pulse provided to heating means 58 by control means 72 is terminated when an ink drop 88 is ejected from the orifice 66. Rapid cooling in compression chamber 62 causes bubble 74 to collapse. The collapse motion near protrusion 70 at location 76 is faster than at the inner portion of the compression chamber which is closer to orifice 66 because, unlike the bubble collapse near the orifice, the bubble collapse near location 76 does not have to overcome an outward bubble growth momentum. The dynamic valving action is quickly removed, and the effect of having a greater compressive pressure near the chamber inlet at location 76 than at the inner portion of the compression chamber accelerates the refilling of the ink through the ink supply line 78.

In summary, the dynamic valving effect achieved by implementing the disclosed invention in the compression chamber of a thermal ink jet print head produces larger ink drops ejecting with higher speed. The hydraulic "crosstalk" between the neighboring chambers is reduced because each chamber is isolated by the dynamically formed valving action. In addition, the increased ink replenishment rate enables the print head to produce ink drops at higher frequency with improved stability.

There is a wide range of print head designs based on the characteristics of the ink being used, the processes applied to the substrate to form the thin film heating elements, and techniques used in producing the compression chambers and orifices. A number of print heads were made based on the embodiments as shown in Figs. 1 and 4 having 40 orifices operating at frequencies up to 11 KHz. The size of the ink drops was measured at 2.7 mils in diameter and they were ejected at a velocity of approximately 600 in/sec with exceptional stability. The hydraulic crosstalk effects are measured by comparing the drop ejection speeds of a single chamber without crosstalk and that of a multichamber print head with improved design, as shown in Figs. 1 and 2. The differences of ejection speeds characterizing the chamber crosstalk measured on these heads are typically under one percent, while a print head of the prior art with a similar design generally has a crosstalk ranging between 3-5 percent.

Fig. 6 is a perspective view of a typical thermal ink jet printer which incorporates a print head according to the present invention. This thermal ink jet printer comprises housing 90, and reciprocating carriage assembly 92 which is mounted on guide rails 94 fixed in housing 90. Carriage assembly 92 carries print head 96, including a matrix array of individual ink compression chambers and orifices connected to a common ink reservoir. Print head 96 incorporates the improvements taught by this invention. Carriage assembly 92 is mounted on, and makes reciprocal motions along, guide rails 94. Print head 96 ejects ink drops onto paper 98 when carriage assembly 92 is traveling and paper 98 is held stationary. Paper 98 is then stepped a fixed distance and carriage assembly 92 is moved to a different position, and print head 96 ejects ink drops onto paper 98 in a coordinated manner under the control of a printer controller (not shown). The printer controller also receives a stream of digital signals from an input/output interface device which is not shown here to selectively energize a predesignated set of heating elements located in print head 96.

It is well recognized among those who are skilled in the art that besides the printer as shown in Fig. 6, the improved print head as taught by this invention can be incorporated in a variety of apparatus such as copiers, facsimile machines, markers, and other types of output or recording systems. The benefits of a stable and large ink drop printing with short response time and high-frequency capabilities can all be realized by incorporating this improved print head in the above apparatus.

It will thus be seen that this invention, at least in its preferred forms, provides an improved thermal drop-on-demand print head which produces high-speed large ink drops at a higher rate while maintaining the production of ink drops with uniform size and spacing; and furthermore provides an improved thermal drop-on-demand print head wherein the replenishment of the ink chamber is accelerated by generating a greater pressure difference between the chamber inlet and the middle portion of the chamber, whereby a shorter response time and higher frequency printing are achieved by the improved print head.

While the preferred embodiments of the present invention have been illustrated in detail, it should be apparent that modifications and adoptions to those embodiments may occur to one skilled in the art without departing from the scope of the present invention as set forth in the following claims.

Claims

1. A thermal drop-on-demand ink jet print head comprising:

   a substrate;

   a plurality of heating elements for heating ink drops, said heating elements disposed on said substrate;

   an orifice plate having a plurality of orifices for ejecting ink drops, overlying and connected to said substrate, said orifice plate defining in conjunction with said substrate a plurality of compression chambers for receiving ink, each of said compression chambers aligned with a respective heating element;

   each of said orifices being in fluid communication with a respective compression chamber; and

   means for generating a dynamic fluid valving action located near each respective heating element and its associated compression chamber, wherein said generating means produces a dynamic fluid valving action between said substrate and said orifice plate when said heating element generates a vapor bubble of ink in said compression chamber.

2. The thermal drop-on-demand ink jet print head of claim 1, wherein said valving action generating means comprises a protrusion formed on said orifice plate.

3. The thermal drop-on-demand ink jet print head of claim 2, wherein said heating element has an area extending to its associated compression chamber inlet.

4. A thermal drop-on-demand ink jet print head comprising:

a substrate;

a plurality of heating elements for heating ink drops, said heating elements disposed on said substrate;

a barrier layer overlying and connected to said substrate;

said barrier layer defining in conjunction with said substrate a plurality of compression chambers for receiving ink, each of said compression chambers aligned with a respective heating element;

for each of said compression chambers, said barrier layer further defining in conjunction with said substrate a respective orifice for ejecting ink drops, said orifice being in fluid communication with said compression chamber; and

means for generating a dynamic fluid valving action located near each respective heating element and its associated compression chamber, wherein said means produces a dynamic fluid valving action between said substrate and said barrier layer when said heating element generates a vapor bubble of ink in said compression chamber.

5. The thermal drop-on-demand ink jet print head of claim 4, wherein said dynamic valving action means further comprises a protrusion formed on said barrier layer near said compression chamber.

6. The thermal drop-on-demand ink jet print head of claim 4, wherein said heating element has an area extending to its associated compression chamber inlet.

7. A thermal drop-on-demand ink jet print head comprising:

a substrate;

an array of heating elements for heating ink drops, said heating elements disposed on said substrate;

said substrate oriented on an X-Y plane in a three-dimensional right-hand X-Y-Z coordinate system;

said array of heating elements distributed parallel to said Y-axis;

a barrier layer overlying and connecting said substrate;

said barrier layer defining in conjunction with said substrate an array of compression chambers for receiving ink, each of said compression chambers being aligned with a respective heating element;

an orifice plate oriented parallel to said Y-Z plane having an array of orifices oriented parallel to said Y-axis for ejecting ink drops in a direction substantially parallel to said X-axis connected perpendicularly to said substrate and said barrier layer, each of said orifices being in fluid communication with a respective compression chamber; and

means for generating a dynamic fluid valving action located near each respective heating element and its associated compression chamber, wherein said means produces a dynamic fluid valving action.

8. The thermal drop-on-demand ink jet print head of claim 7, wherein said valving action means generating means further comprises a protrusion formed on said barrier layer near said compression chambers.

9. The thermal drop-on-demand ink jet print head of claim 7, wherein said heating element has an area extending to its associated compression chamber inlet.

10. A thermal drop-on-demand ink jet print head responsive to a print head controller comprising:

a substrate;

a plurality of heating elements disposed on said substrate coupled to, controlled and electrically energized by said print head controller;

an orifice plate having top and bottom surfaces, a plurality of orifices for ejecting ink drops disposed on said top surface, said bottom surface overlying and connected to said substrate;

said bottom surface defining in conjunction with said substrate a plurality of compression chambers for receiving ink from an ink reservoir through an ink supply line, each of said compression chambers aligned with a respective heating element;

each of said orifices being in fluid communication with a respective compression chamber; and

a perimeter protrusion formed on said bottom surface of said orifice plate defining the outer ridge of said compression chambers reducing the cross-sectional flow area of said ink supply line adjacent to the inlet area of said compression chamber;

whereby said heating element is energized and a vapor bubble of ink is formed and expanded, the liquid vapor interface of said vapor bubble coming into near contact with said perimeter protrusion generating a dynamic fluid valve preventing pressure leaks from said compression chamber to said reservoir through said ink supply line, and reducing the hydraulic crosstalk between adjacent compression chambers.

11. A thermal drop-on-demand ink jet print head in response to a print head controller comprising:

a substrate;

a plurality of heating elements disposed on said substrate coupled to, controlled and energized by said print head controller;

a barrier layer having a top and a bottom surface overlying said substrate;

said bottom surface of the barrier layer connected to said substrate;

said bottom surface of the barrier layer having cavities which define in conjunction with said substrate a plurality of compression chambers for receiving ink from an ink reservoir through an ink supply line, each of said compression chambers aligned with a respective heating element;

for each of said compression chambers, said bottom surface of the barrier layer further defining in conjunction with said substrate a respective orifice for ejecting ink drops, said orifice being in fluid communication with said compression chamber; and

a protrusion formed on said bottom surface of the barrier layer near the inlet area of said compression chambers reducing the cross-sectional flow area of said ink supply line at the chamber inlet;

whereby as said heating element is energized and a vapor bubble of ink is formed and expanded, said vapor bubble coming into contact with said protrusion and the liquid vapor interface near the chamber inlet acting as a dynamic fluid valve preventing a pressure leak from said compression chamber to said ink reservoir through said ink supply line, and reducing the hydraulic crosstalk between adjacent compression chambers.

12. An apparatus to impress a graphic image by thermally ejecting ink drops onto a print medium comprising:

a controller receiving electrical signals indicative of a character to be printed and generating corresponding signals to cause ink impression;

a print head electrically connected to and responsive to said controller; and

a housing supporting said controller and said print head providing a print medium transport mechanism to supply print medium adjacent to said print head;

said print head further comprising:

a substrate;

a plurality of heating elements for heating ink drops, said heating elements disposed on said substrate;

an orifice plate having a plurality of orifices for ejecting ink drops overlying and connected to said substrate, said orifice plate defining in conjunction with said substrate a plurality of compression chambers for receiving ink, each of said compression chambers aligned with a respective heating element;

each of said orifices being in fluid communication with a respective compression chamber; and

means for generating a dynamic fluid valving action located near each respective heating element and its associated compression chamber, wherein said generating means produces a dynamic fluid valving action between said substrate and said orifice plate when said heating element generates a vapor bubble of ink in said compression chamber.

13. An apparatus to impress a graphic image by thermally ejecting ink drops onto a print medium comprising:

a controller receiving electrical signals indicative of a character to be printed and generating corresponding signals to cause ink impression;

a print head electrically connected to and responsive to said controller; and

a housing supporting said controller and print head providing a print medium transport mechanism to supply print medium adjacent to said print head;

said print head further comprising:

a substrate;

a plurality of heating elements for heating ink drops, said heating elements disposed on said substrate;

a barrier layer overlying and connected to said substrate;

said barrier layer defining in conjunction with said substrate a plurality of compression chambers for receiving ink, each of said compression chambers aligned with a respective heating element;

for each of said compression chambers, said barrier layer further defining in conjunction with said substrate a respective orifice for ejecting ink drops, said orifice being in fluid communication with said compression chamber; and

means for generating a dynamic fluid valving action located near each respective heating element and its associated compression chamber, wherein said means produces a dynamic fluid valving action between said substrate and said barrier layer when said heating element generates a vapor bubble of ink in said compression chamber.

14. A method to impress a graphics image to a print medium by ejecting a plurality of ink drops from a plurality of compression chambers coupled to an ink reservoir onto said print medium, comprising the steps of:

(a) supplying ink from a reservoir to said compression chambers;

(b) selectively providing thermal energy to said compression chambers to generate a vapor bubble of ink within each of said compression chambers;

(c) utilizing the surface energy in the region of the interconnection between said reservoir and said compression chamber to produce a dynamic fluid valving action during the formation of said vapor bubble of ink to prevent vapor leakage into the reservoir;

(d) ejecting ink drops from said energized compression chambers through orifices whereby collapsing said vapor bubbles and removing said dynamic fluid valving action; and

(e) utilizing the removal of said dynamic fluid valving action during the bubble collapse to produce a greater compressive pressure in said compression chambers, whereby accelerating the replenishment of said compression chambers.

15. The method to impress a graphics image to a print medium by ejecting a plurality of ink drops contained in a plurality of compression chambers onto said print medium according to claim 14, wherein said step (c) further comprising the step of:

utilizing said dynamic fluid valving action to isolate each of said compression chambers, whereby the hydraulic crosstalk between adjacent compression chambers is reduced.

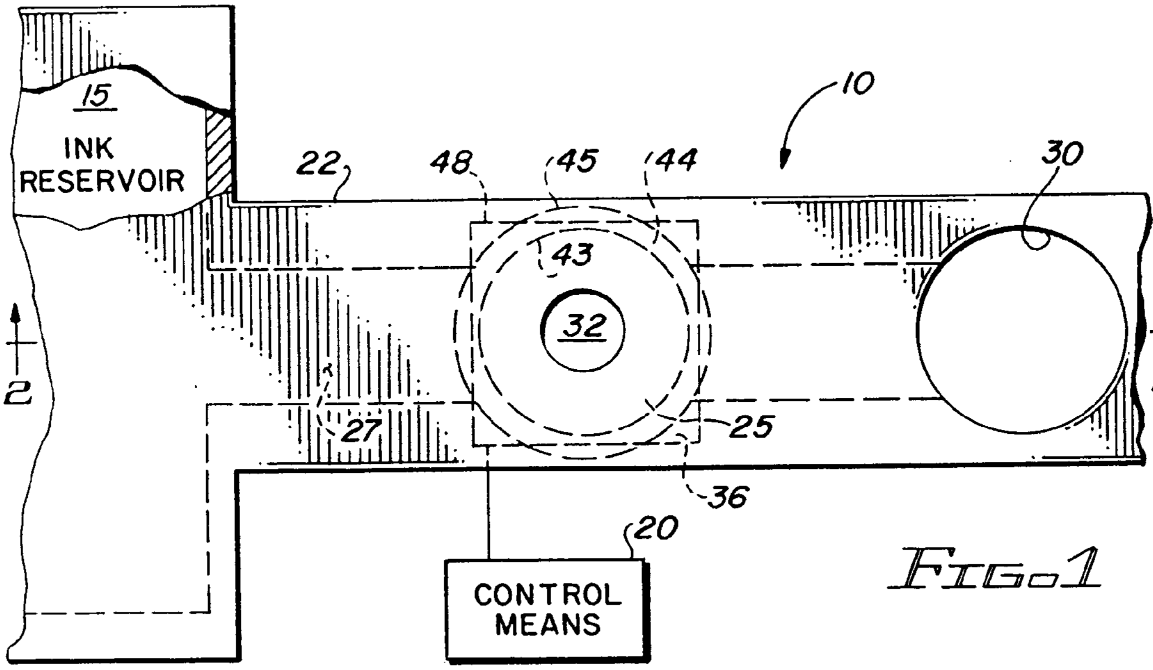


FIG. 1

FIG. 2

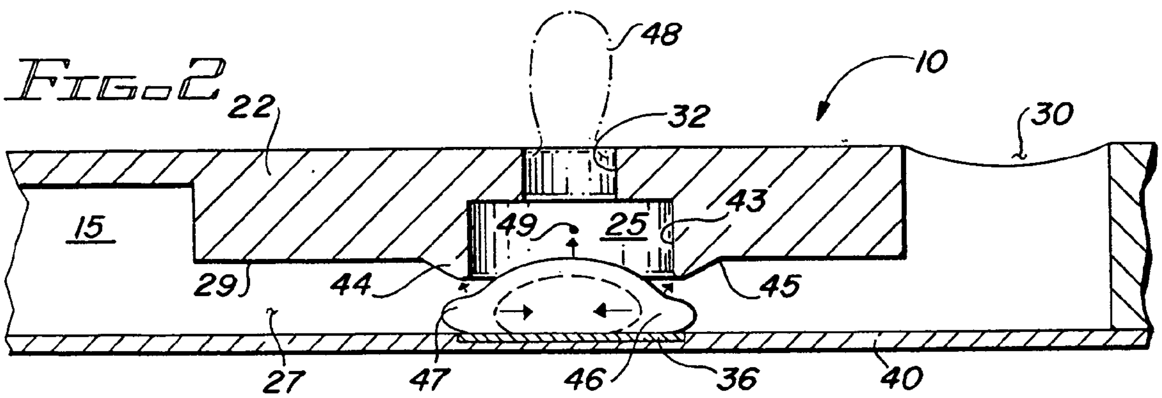


FIG. 4

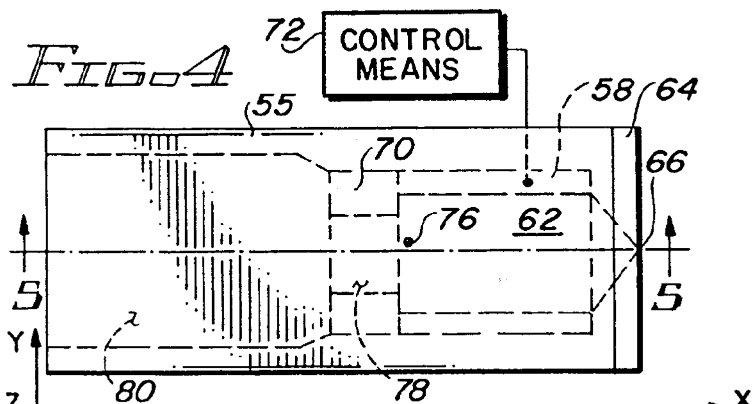
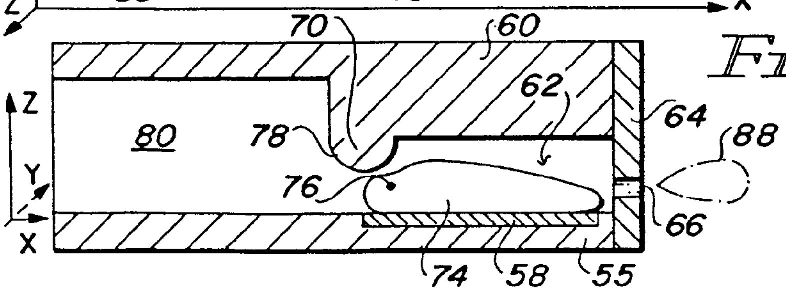


FIG. 5



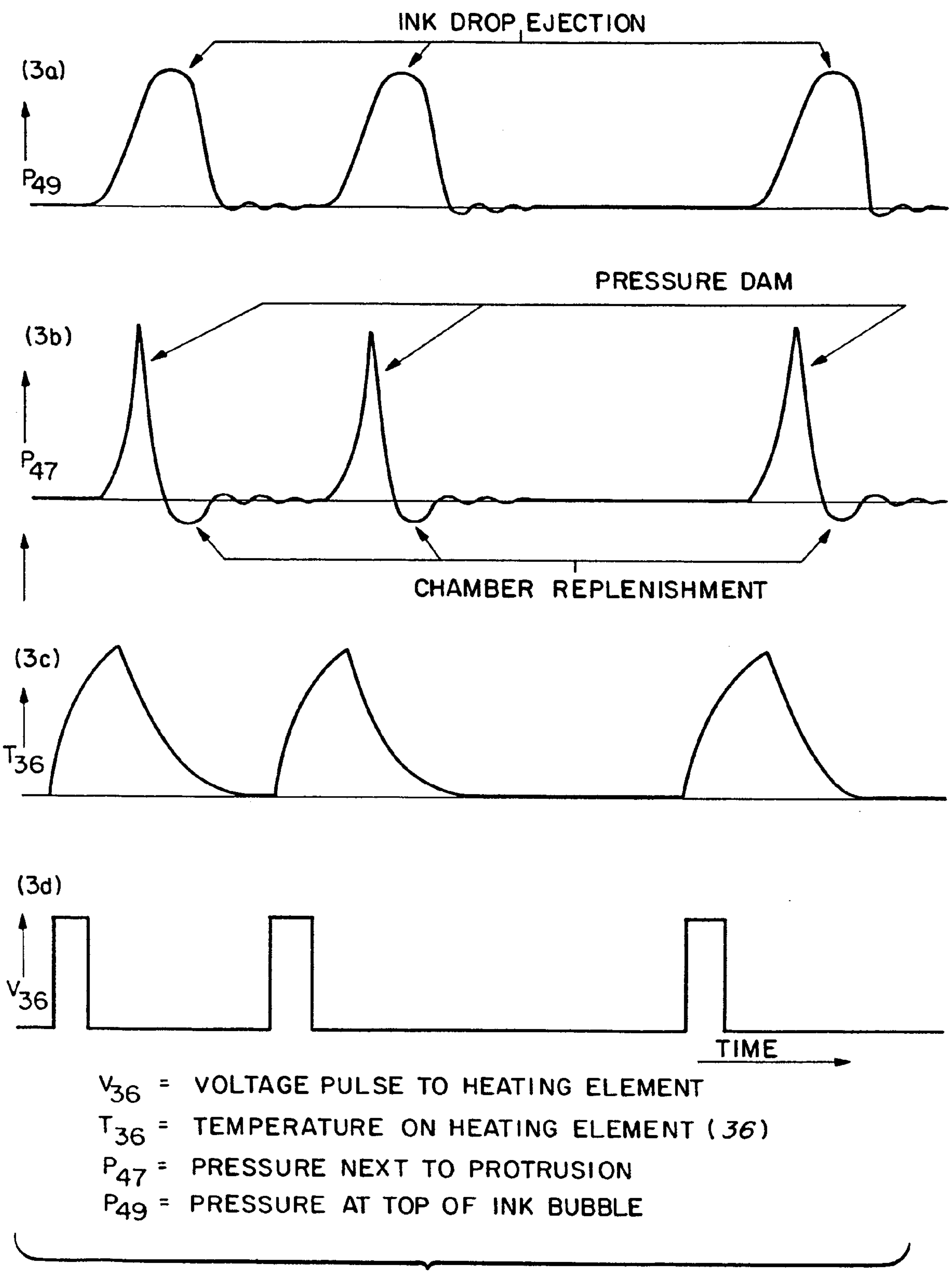

INK DROP EJECTION
(3a)
P49
PRESSURE DAM
(3b)
P47
CHAMBER REPLENISHMENT
(3c)
T36
(3d)
V36
TIME
V36 = VOLTAGE PULSE TO HEATING ELEMENT
T36 = TEMPERATURE ON HEATING ELEMENT (36)
P47 = PRESSURE NEXT TO PROTRUSION
P49 = PRESSURE AT TOP OF INK BUBBLE

FIG. 3

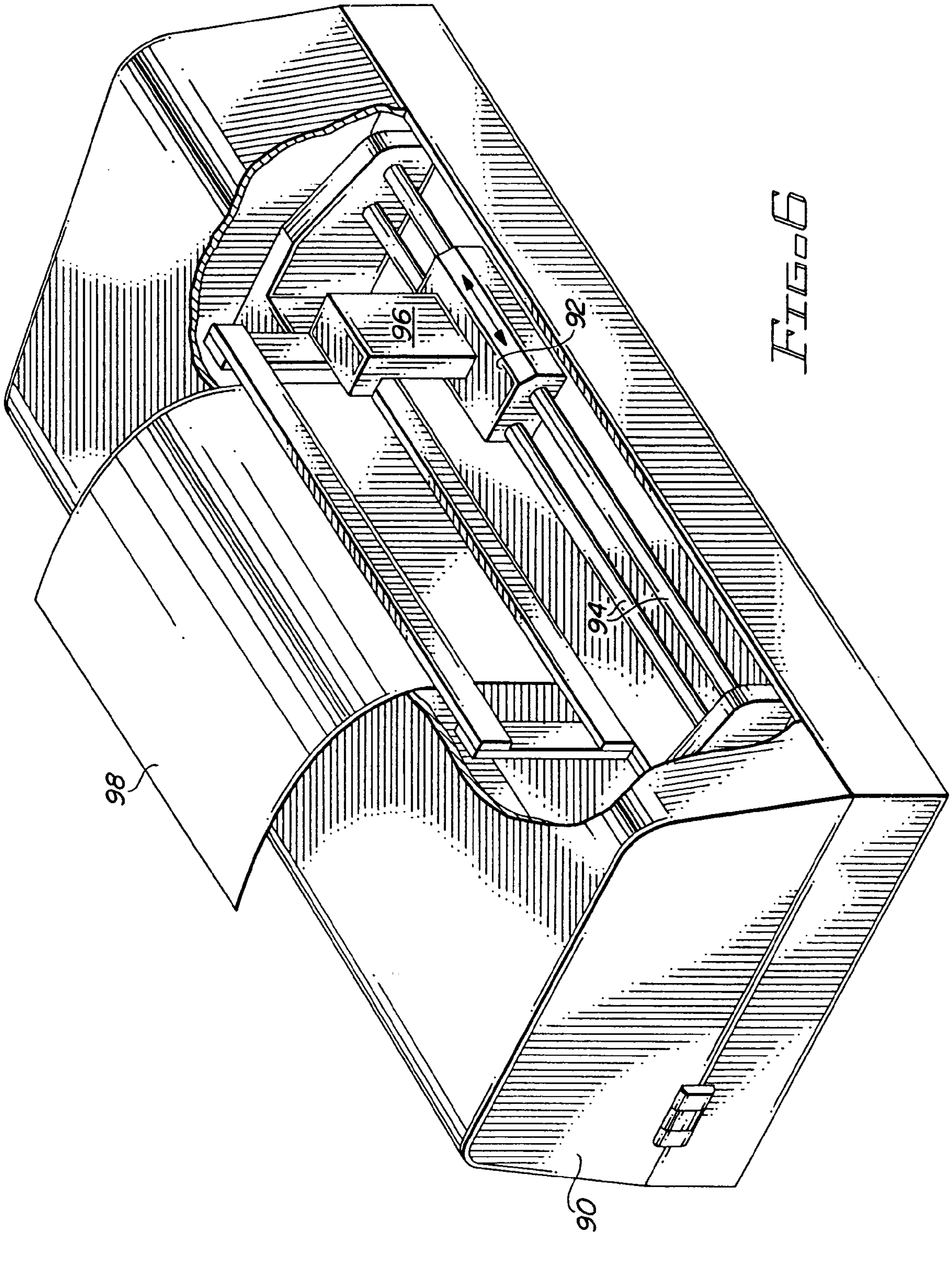


Fig-6