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(54) Printer head for an ink-on-demand type ink-jet printer.

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Description

This invention relates to a printer head for an ink-on-demand type ink-jet printer in which ink droplets are squirted out each time a driving pulse is applied to an electromechanical transducer attached to one wall of an ink chamber.

Various types of ink-jet printers have been proposed as described in an article "Ink Jet Printing" by Fred J. Kamphoefner published in the "IEEE Transactions on Electron Devices, Vol. Ed—19, No. 4, April 1972, pp. 584—593. The ink-jet printer of ink-on-demand type is described in detail, for example, in the United States Patent No. 3,946,398 entitled "Method and Apparatus for Recording with Writing Fluids and Drop Projection Means Therefor" issued to E. L. Kyser et al, and the United States Patent No. 4,106,032 entitled "Apparatus for Applying Liquid Droplets to a Surface by using High Speed Laminar Air Flow to Accelerate the same" issued to M. Miura et al. In GB—A—1 551 990 there is described a printer head for an ink-on-demand type ink jet printer for squirting ink droplets on to a printing medium. This previously proposed printer head has a nozzle through which ink droplets are to be squirted, a supply passage for supplying ink from an ink tank, pressure exertion means for exerting pressure on the ink in accordance with an electric signal to squirt the ink droplets and fluid control means including two non-deformable valves which are disposed in the ink passage and can be solenoid operated.

In contrast to this known embodiment, the present invention is characterised by the features set out in claim 1.

In the conventional ink-on-demand type ink-jet printer, as shown in Fig. 1, a nozzle 104 and an ink feed port 105 communicate with a pressure chamber 103 which is filled with ink and which genertes a pressure pulse by deforming a wall 102 with electromechanical transducer means 101. The ink feed port 105 feeds the ink from an ink tank to the pressure chamber 103. When a pressure is not applied, the meniscus of the ink is formed at the end face of the nozzle 104 and balances with the pressure of the ink owing to the surface tension. A piezoelectric element is mainly employed as the electromechanical transducer means 101. The piezoelectric element is fastened to the wall 102. When a driving voltage is applied across two electrodes 106 and 107 from a voltage source 108, an internal stress incurvates the wall 102 arises in the piezoelectric element 101.

The formation of ink droplet is carried out as follows. When the wall 102 is curved inwardly of the pressure chamber 103 by applying the voltage to the piezoelectric element 101, the internal volume of the pressure chamber decreases, and ink within the pressure chamber is forced out of the pressure chamber. The ink pressure at this time squirts the ink from the nozzle 104. The ink pressure from the pressure chamber acts also on the ink feed port 105, and also an ink stream which returns from the ink feed port to the ink tank arises. Subsequently, when the voltage applied to the piezoelectric element 101 is returned to zero or a voltage of the opposite polarity is applied so as to render the deformation of the wall 102 of the pressure chamber null or to curve the wall outwardly of the pressure chamber, the internal volume of the pressure chamber increases, and the ink is drawn back into the pressure chamber. At this time, at the ink feed port 105, the ink is fed from the ink tank into the pressure chamber, while at the nozzle 104, the meniscus is retracted from the nozzle end into the nozzle. Subsequently, when the volume fluctuation in the pressure chamber has stopped, the meniscus retracted into the nozzle reverts to the nozzle end again under the action of the surface tension of the ink. With the transfer of the meniscus succeeding to the increase of the internal volume of the pressure chamber, the ink feed from the ink tank is continued at the ink feed port 105. At the time when meniscus has reverted to the nozzle end and has come to a standstill, the supply for the ink previously squirted from the nozzle 104 finishes off.

The droplet forming operation in the conventional ink-on-demand type ink-jet printer has involved several problems as stated hereunder. In the first place, the ink pressure generated by the deformation of the wall of the pressure chamber acts, not only on the nozzle portion, but also on the ink feed port, so that the loss of energy dissipated otherwise than the droplet formation is great. In order to squirt the ink droplets, accordingly, the volume change of the pressure chamber needs to be made large by applying high electric energy to the piezoelectric element. This has led to such problem as degradation in the characteristics of the piezoelectric element and lowering in the response rate of the droplet formation.

Secondly, there has been the problem that when the repetition period of the ink droplet formation is shortened, the volumes and flight speeds of the squirted ink droplets fluctuate. This is attributed to the fact that while the meniscus is being returned into the nozzle by the change of the internal volume of the pressure chamber after the ink droplet formation, the next droplet-formation operation starts, and that the position and transfer speed of the meniscus at the starting of the operation change depending upon the repetition period. In order to suppress such fluctuations of the characteristics, the reverting speed of the meniscus retracted into the nozzle needs to be increased. Since, however, the reversion of the meniscus is dependent upon the surface tension of the ink and the value of this surface tension is inherent in the ink material, it is subject to a limit to increase the reverting speed of the meniscus by making the surface tension great.

In the next place, there has been the problem that when the repetition period of the ink droplet formation is made still shorter, the volume of the ink droplet decreases, the droplet formation stopping eventually. This problem has been known to be also attributed to the limitation in the reverting speed of the meniscus retracted into the nozzle.

In the prior art, accordingly, the number of ink droplets to be formed within one second or the ink droplet frequency is at most 3KHz or so in a practical range, and the highest frequency with the fluctuations of the characteristics neglected is approximately 10KHz. The prior art has therefore been unsuitable for high-speed high-density printing.

An ink-jet printer head in which an ink passage on the ink feed side is constructed of a fluidic element in order to enhance the energy efficiency at the droplet formation, is disclosed in the United States Patent No. 3,848,118. The fluidic element has the effect that the flow resistance to an ink stream changes depending upon the direction of the ink stream, and it intend to enhance the energy efficiency at the droplet formation. Since, however, the fluidic element attains kind of rectification characteristic by utilizing physical properties inherent in fluids, there are such problems that the characteristic fluctuates depending upon the nature of the fluid used and that the ratio of the flow resistance changes responsive to the directions of the ink stream cannot be set large. Moreover, the fluidic element has been structurally complicated and has been attended with much difficulty in disposing it within the ink-jet printer heads.

An object of this invention is to provide a novel ink-jet printer head which solves the various problems in the prior art.

According to this invention, there is provided a printer head for an ink-on-demand type ink-jet printer for squirting ink droplets onto a printing medium, said printer head comprising: a nozzle for squirting said ink droplets; a supply passage for supplying ink in communication with an ink tank; pressure exertion means for exerting a pressure on said ink in accordance with an electric signal to squirt said ink droplets; and fluid control means having a valve which is deformed under the action of the ink pressure.

Other features and advantages of this invention will be apparent from the following description of preferred embodiments of this invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a cross-sectional view of a conventional ink-jet printer head;

Fig. 2 is a cross-sectional view of a first embodiment of this invention;

Figs. 3A, 3B, 4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 6C, 7A, 7B, 9A, 9B, 9C and 10 show various examples of a fluid control means used in the first embodiment;

Fig. 8 is a cross-sectional view of a second embodiment of this invention;

Figs. 11, 12A and 12B are diagrams useful for explaining the operation of the ink-jet printer head;

Figs. 13A, 13B, 13C, 14A, 14B, 16A, 16B, 16C, 16D and 16E are diagrams showing examples of the driving voltage to be applied to the ink-jet printer head and change in the pressure and the change in the capacity of the pressure chamber; and

Figs. 15 and 17 are block diagrams of the driving voltage forming means.

Referring to Fig. 2, the first embodiment of this invention includes an ink-jet printer head 10 which is constructed of a nozzle 14 for squirting ink, a supply passage 15 communicating with an ink tank (not shown) and for supplying the ink, a pressure chamber 13 filled with the ink, a piezoelectric element 11 fastened to a wall 12 of the pressure chamber, first fluid control means 21 disposed between the nozzle 14 and the pressure chamber 13, and second fluid control means 22 disposed between the pressure chamber 13 and the supply passage 15. When the ink passes through the fluid control means, a pressure loss occurs. Herein, the ratio of the pressure loss to the flow rate of the ink (hereinafter, referred to "flow resistance") changes depending upon the direction of the passing ink stream. The fluid control means 21 and 22 operates so that the flow resistance may become low under the action of the pressure of the ink in response to the ink stream in the direction of from the supply passage side toward the nozzle side, whereas the flow resistance may become high under the action of the ink pressure in response to the ink stream in the direction of from the nozzle side toward the supply passage side.

The formation of ink droplets in the ink-jet printer head 10 is carried out as follows: When the wall 12 is curved inwardly of the pressure chamber 13 by applying a voltage to the piezoelectric element 11 through electrodes 16 and 17 from a power source 18, the pressure owing to the wall 12 acts on the ink within the pressure chamber 13. As a result, the stream from the pressure chamber 13 toward the nozzle 14 acts on the first fluid control means 21 so as to render the flow resistance low, whereas the stream of the ink from the pressure chamber 13 toward the supply passage 15 acts on the second fluid control means 22 so as to render the flow resistance high. Therefore, the difference of the two flow resistances becomes large, the ink forced out of the pressure chamber flows out principally toward the nozzle side, and the ink droplet is squirted from the nozzle 14. Subsequently, when the voltage applied to the piezoelectric element 11 is returned to zero or voltage of the opposite polarity is applied so as to render the deformation of the wall 12 of the pressure chamber null or to curve the wall outwardly of the pressure chamber, the interval volume of the pressure chamber 13 increases and the pressure inside the pressure chamber 13 decreases. As a result, the stream from the nozzle 14 toward the pressure chamber 13 acts on the first fluid control means 21 to render the flow resistance high, whereas the ink stream from the supply passage 15 toward the pressure chamber 13 acts on the second fluid control means 22 to render the flow resistance low. In this case, accordingly, the ink flows principally from the supply passage 15 into the pressure chamber 13, and the extent to which the meniscus in the nozzle portion is retracted into the nozzle lowers.

As apparent from the droplet forming operation described above, in the ink-jet printer head 10, the deformation of the pressure chamber 13 acts for squirting the ink droplet when the volume of the pressure chamber decreases, and it acts for supplying the ink when the volume to the pressure chamber increases. Therefore, the dissipation of energy onto the supply passage side at the ink droplet squirt as in the prior art lessens, and the energy efficiency is enhanced. Further, since the retraction of the meniscus into the nozzle at the ink supply lessens, the period of time required for the meniscus to revert to the nozzle end part is shortened. In addition, since the change of the internal volume of the pressure chamber by the piezoelectric element may be small on the same order as the volume of the ink droplet, the period of time for forming the droplet can be shortened in the extreme. Since excess electric energy need not be applied to the piezoelectric element, the degradations of the characteristics of the piezoelectric element are not incurred. Further, in the prior art, the ink supply is relied on the surface tension of the meniscus at the nozzle portion, whereas the ink is supplied from the supply passage owing to the increase of the internal volume of the pressure chamber and forcibly performs the ink supply by the use of the external energy such as electric energy, so that the ink supply for the high-speed droplet formation is possible. Thus, the ink-jet printing apparatus according to this invention has realized the droplet formation at very high speed.

The example employing the two fluid control means has been described above. However, even when two fluid control means are not conjointly used, the use of the means either between the pressure chamber and the nozzle or between the ink feed port and the pressure chamber is effective. In case of employing the means between the ink feed port and the pressure chamber, when the internal pressure of the pressure chamber is raised to extrude the ink, the ink flows out toward the nozzle portion and the supply passage. The fluid control means disposed on the supply passage side can be set so that the flow resistance thereof may become greater than that in the nozzle portion under the action of the ink pressure. As a result, most of the ink extruded from the pressure chamber is squirted from the nozzle. Subsequently, when the internal pressure of the pressure chamber is lowered to retract the ink into the pressure chamber, the ink flows in the pressure chamber from the nozzle portion and the supply passage. At this time, the fluid control means located on the supply passage side operates so that the flow resistance may decrease. The flow resistance in the supply passage can be set so as to become less than that in the nozzle portion. As a result, most of the ink flows from the supply passage into the chamber. In this manner, the ratios between the flow resistances in the nozzle portion and the supply passage in case of the extrusion and retraction of the ink from and into the pressure chamber are made different, whereby the same effect as in the first embodiment can be brought forth.

A similar effect is also attained in the case where the fluid control means is disposed between the pressure chamber and the nozzle. In this case, the flow resistance of the fluid control means is smaller under a high internal pressure than that under a low internal pressure. In order to intensify the effect of the fluid control means, it is desired to set the flow resistance of the fluid control means to be lower than that of the ink supply passage when the internal pressure is high, and to be higher than that of the ink supply passage when the internal pressure is low.

The stream of the ink in the on-demand type ink-jet printer head is always pulsatile, and the quantity of the ink which is passed through a valve by one pulsatile stream is as extremely small as approximately equal to at most the volume of the ink droplet. On the other hand, in order to enhance the rectification effect based on the operation of the valve, it is important that the volume of the space in which the valve moves is made sufficiently smaller than the quantity of the ink to pass through the valve.

Referring to Figs. 3A and 3B, in the first example of the fluid control means, a flat valve 301 made of an elastic member is arranged so as to cover an ink outflow port 302. The valve 301 is fixed in close contact with a valve seat 304 by means of a stationary portion 303. In the absence of the stream of the ink, also a movable portion 305 lies in close contact with a valve seat 306. Now, when a pressure which causes the ink flow upwardly from below the valve as shown by an arrow in Fig. 3B, has acted on the valve, the valve 301 is pushed up and the ink flows out through the opening 308 between the valve and the valve seat. Since the pressure loss at this time occurs mostly in the opening 308, the dimension of the overlap parts 309 of the valve and the valve seat needs to be made small so as to reduce the pressure loss. As the material of the valve, there can be used thin films of metals such as gold, nickel and stainless steel and various plastic films. For example, in case of employing a polyethylene terephthalate film, the movable portion 305 and the outflow port 302 of the valve are respectively made square with each side being 200 μm long and 180 μm long, and the length of the overlap part 309 is set to 10 μm. The valve is formed by punching from the polyethylene terephthalate film of 20 μm thick. The valve is fixed in such manner that the stationary portion 303 is pressed against the valve seat 304 by a fixing member 307.

The wall 12 of the pressure chamber 13 is made of a cold-rolled stainless steel plate of 0.4 mm thick. The piezoelectric transducer may be of NEPEC N-10 having dimensions of 2 mm×26 mm×0.4 mm. The piezoelectric transducer is fastened to the wall 12 with an epoxy type solventless thermosetting binder. As the nozzle 14, a hole which is 50 μm in diameter and 100 μm in length is formed by the electric discharge machining. The droplet formation is carried out by supplying the piezoelectric transducer with a pulse voltage which has a waveform corresponding to one wavelength of the cosine wave. As a result, the formation of an ink droplet having a diameter of about 100 μm and an initial velocity of about 2.4 m/sec is observed at a pulse width of 55 μsec and a peak voltage of 80 V. When the recurrence frequencies of the pulses is changed, the maximum value of the operating frequencies at which the fluctuations of the initial velocity of the droplet fall within 10% is 18 KHz. In addition, in case where the fluid control means is disposed on only either the nozzle side or the supply passage side, the operating frequency is about 12 KHz under the operating conditions mentioned above. On the other hand, in case where the ink-jet printer head of the same geometries is used without providing the fluid control means, the operating frequency for fulfilling the droplet velocity fluctuations of within 10% is at most only about 1.5 KHz. In order to form an ink droplet having a diameter of 100 μm, a peak voltage of about 9 V is necessary, and the initial droplet velocity is about 1.8 m/sec. From these results, it is apparent that the fluid control means according to this invention is very greatly effective for raising the operating speed of the ink jet and that it is effective for enhancing the energy efficiency in the droplet formation.

It is advantageous in the assemblage job to make the geometries of the valve as large as possible. In this case, however, the geometries must be limited to the range in which the volume of the moving space of the valve is smaller than the volume of the droplet. In addition, as the valve enlarges, also its thickness needs to be increased. For example, when the sides of square valve made of polyethylene terephthalate enlarged to 300 μm and 400 μm, the thicknesses of the valves needed to be made 35 μm and 75 μm, respectively. It has been confirmed that when the dimensions of the valve are further enlarged, the effect of the valve lowers abruptly.

The fluid control means in this invention has its one feature in exploiting the displacement of the valve owing to the ink pressure. In order to hold the reliability of the valve high, the displacement of the valve needs to be made within the elastic limit thereof. In case where the valve is displaced beyond the elastic limit, it is deformed and cannot return to its original closed state. With the cantilever valve as in the first example shown in Fig. 3, a pressure range in which the elastic limit is not exceeded is narrow. Therefore, it has sometimes been the case that an excess ink pressure acts to deform the valve at, for example, the initial charging of the ink-jet printer head with the ink.

Referring to Figs. 4A and 4B, a doughnut-shaped disc valve 401 made of an elastic member is fixed in close contact with a valve seat 404 by a stationary portion 403, and in the absence of the stream of the ink, also a movable portion 405 lies in close contact with a valve seat 406 so as to blockade an ink outflow port 402. Such valve is constructed of a components as shown in Fig. 4C. More specifically, the valve seats 404 and 406 are unitarily formed in a manner to have the annular outflow port 402 therebetween. The disc valve 401 formed with a hole in its central part is stacked on the valve seats, and a ring-shaped fixing member 407 is further stacked on the valve, to fix the valve.

When a pressure causing the ink to flow upwardly acts on the valve, the valve 401 is pushed up similarly to the cantilever valve in Fig. 3, the ink flows out through the opening 408 between the valve and the valve seats as shown in Fig. 4B. The deformation of the disc valve around the central hole thereof as in Fig. 4B includes an elongation in the circumferential direction of the central hole in addition to the same simple bending in the radial direction as in the cantilever valve of Fig. 3. Accordingly, the disc valve is more difficult of deformation than the cantilever valve and has its durability sharply enhanced against the action of intense pressure.

An example of the geometries of the fluid control means constructed by the use of a polyethylene terephthalate film will be given below. The doughnut-shaped disc valve 401 is formed by punching from the polyethylene terephthalate film 20 μm thick. The diameter of the central hole is set at 300 μm, and the outside diameter of the movable portion 405 of the valve 401 is set at 500 μm. The outside diameter of the valve seat 406 is set at 320 μm so that the length of the overlap parts 409 of the movable portion 405 and the valve seat 406 may become 10 μm. The fluid control means thus constructed is applied to the ink-jet printer head 10 shown in Fig. 2. As a result, the same effects as in the fluid control means shown in Fig. 3 has been confirmed.

In case of employing a gold foil as the material of the disc valve 401, the thickness of the valve needed to be as small as 5 μm when the diameter of the central hole and the outside diameter of the movable portion of the disc valve are set equal to those in the case of the polyethylene terephthalate film. In fabricating such thin disc valve, various microscopic machining techniques have been known. For example, according to the machining technique called "electroforming", an electrode in the flat shape of the disc valve is plated with gold up to a predetermined thickness in the vertical direction, whereby the disc valve of the gold foil can be formed.

The thickness of the valve must be made smaller as the elastic modulus of the material used is greater. For example, in case where the disc valve having the same geometries as those of the disc valve of the gold foil is made of stainless steel, the pressure for the droplet formation needs to be made approximately double that in the case of the gold foil. In order to perform the droplet formation under the same conditions, accordingly, the thickness of the stainless steel valve needs to be made smaller than 5 µm. The thin valve, however, has such problems that the handling is difficult and that thin foils are difficult to obtain in case of some materials.

Referring to Fig. 5A and 5B, in the third example of the fluid control means, a valve 501 arranged in close contact with a valve seat 506 so as to cover an outflow port 502 is supported by fine supporting arms 510, and is fixed to the valve seat 506 by a stationary portion 503. As understood from Fig. 5C, the third example can be constructed by successively stacking the valve seat 506 having the outflow port 502 in its central part, a valve member 511 which is centrally located and in which the valve 501 to cover the outflow port is unitary with the peripheral stationary ring 503 through the fine supporting arm 510, and a fixing member 507. In response to the upward stream of the ink, the valve 501 is pushed up as shown in Fig. 5B and the ink flows out through the opening 508 between the valve and the valve seat 506. In the third example, the operation of the valve involves the flexures and elongation of the supporters 510, and the valve has its durability sharply enhanced against the action of intense pressure in comparison with the cantilever valve of Fig. 3. Moreover, since the displacement of the valve is based on the deformation of the supporter portion, the quantity of the displacement of the valve can be set larger than in the disc valve of Fig. 4, resulting in the advantage that the versatility of the selection of the valve material and the versatility of the design are sharply enhanced.

An example of the geometries in the case where a stainless steel sheet of 10 µm thick is used will be given below. In case of the configuration in which the disc valve 501 has four supporting arms 510 similarly to the valve member 511 shown in Fig. 5C, the outside diameter of the disc valve 501 is set at 200 µm, the width and length of the supporting arm are respectively set at 50 µm and 400 µm, the diameter of the ink outflow port 502 is set at 180 µm, and the length of the overlap parts of the disc valve 501 and the valve seat 506 is set at 10 µm. The fluid control means thus constructed may be applied to the ink-jet printer head shown in Fig. 2. As a result, the same effects as in the fluid control means shown in Figs. 3 and 4, has been confirmed. This example is highly practical because of the additional advantages that the stainless steel readily available can be used and that the outside dimensions can be set large.

While, in any of the fluid control means thus far described, the movable portion of the valve is arranged so as to lie in close contact with the valve seat at a standstill, such close-contact arrangement is not always necessary.

Referring to Figs. 6A and 6B, in the fourth example of the fluid control means, a disc valve 601 is fixed in close contact with a valve seat 604 by a stationary portion 603, and in the absence of the stream of the ink, a movable portion 605 lies in a position separate from a valve seat 606 and the parts of the ink before and behind the valve communicate. However, when a pressure acts to cause the ink to flow downwardly, as shown in Fig. 6B, the valve 601 flexes and comes into contact with the valve seat 606, and it acts to prevent the stream of the ink.

On the other hand, under the action of a pressure causing the ink to flow upwardly as shown in Fig. 6C, the valve 601 flexes upwards and the ink flows out upwards through the opening 608 between the valve and the valve seat. In this manner, to the end of attaining the rectification effect of permitting the ink to flow in one direction, it is not always necessary that the valve and the valve seat lie in close contact at a standstill.

In case of employing a doughnut-shaped disc valve which has been actually made of a polyethylene terephthalate film of 20 µm thick and in which the diameter of the central hole is 300 µm and the outside diameter of the movable portion is 500 µm, the quantity of flexure of the valve under the ordinary droplet-forming conditions is readily calculated within the scope of the fundamental knowledge of the material strength and is found to be approximately 3 µm. A stationary rectification effect is accordingly achieved when the spacing between the valve and the valve seat at the standstill is up to 3 µm or so. Needless to say, the fact that the valve and the valve seat need not always lie in close contact at the standstill is applicable, not only to the cases of employing the doughnut-shaped disc valves, but also to the fluid control means shown in Figs. 3 and 5.

When, in the fourth example, the spacing between the valve and the valve seat at the standstill is increased beyond the quantity of flexure of the valve, the ink comes to flow also in the opposite direction, and the rectification effect weakens gradually. However, in a range in which the spacing between the valve and the valve seat is not very great as compared with the quantity of flexure of the valve, the flow resistance can be greatly changed depending upon the direction of the ink stream, and hence, a satisfactory function can be exercised as the fluid control means. There are considered as the flow resistance an inertial resistance and a viscous resistance which are based on the ink stream, and a loss term in the part in which the sectional shape of the flow passage changes. The viscous resistance becomes the greatest with respect to the steady flow after the valve has flexed a fixed amount. As a basic characteristic concerning viscous fluids, it has been known that the viscous resistance is proportional to d^{-3} with respect to the spacing d

between the valve and the valve seat. Accordingly, in case where, for example, the spacing between the valve and the valve seat at the standstill is set at 8 µm for a valve flexure quantity of 3 µm, the flow resistance changes about 10 times in dependence on the direction of the ink, and a satisfactory function can be achieved as the fluid control means. The fluid control means as thus far described in which the ink stream in the opposite direction is not perfectly cut off but the flow resistance changes greatly in dependence on the direction of the ink stream, is readily performed in such a way that the spacing between the valve and the valve seat in each of the examples shown in Figs. 3, 4 and 5 is much greater than the quantity of flexure of the valve.

The above-mentioned structures in which the valve and the valve seat are separated at the standstill have an important advantage from the viewpoint of practical use. At the standstill, the ink meniscus is formed at the end face of the nozzle of the ink-jet printer head, and a liquid component in the ink in the nozzle portion is continually vaporizing. Now, in case where the fluid control means is disposed between the pressure chamber and the supply passage and where the ink passages before and behind the fluid control means are separated from each other by the valve, the ink in the nozzle decreases and the meniscus is retracted into the nozzle. When the retraction of the meniscus arrives at the pressure chamber, the air is introduced into the pressure chamber and a stable droplet formation can no longer be executed. In contrast, when the ink passage parts before and behind the fluid control means are communicating even at the standstill, the ink is supplied from the supply passage side to the extent that the ink in the nozzle portion has decreased due to the vaporization of the liquid component, and hence, the ink meniscus is always kept at the nozzle end face.

As the fluid control means whose flow resistance changes depending upon the direction of the ink stream, there will now be described one having a valve structure somewhat different from those of the examples described above. The fifth example of the fluid control means shown in Figs. 7A and 7B is constructed of a wall member 35 defining a flow passage of the ink, a plate member 31 provided with an aperture, a spacer 32, a film 33 which can be deformed by the pressure of the ink, and a frame member 34 which has a frame for securing the film and whose outer side is a penetration portion. The bore of the plate member 31 is made smaller than the diameter of the film. The film 33 may be made of sheets of metals such as gold and stainless steel, films of plastics, etc. The ink flows from the passage 36 to the passage 40 through the aperture 37, the opening 38 between the plate member 31 and the film 33, and the penetration portion 39 of the frame member 34. When the ink flows from the passage 40 to the passage 36, it passes in the reverse order.

The operation will now be described. When the pressure has become higher on the side of the passage 36 than on the side of the passage 40, the ink begins to move from the passage 36 toward the passage 40. At this time, letting P_1, P_2, P_3 and P_4 denote respective pressure in or on the passage 36, the surface of the film 33 facing the aperture 37, the penetration portion 39 and the passage 40, the relationship among the pressures is represented by

$$P_1 > P_2 > P_3 > P_4$$

Therefore, a pressure difference of (P_2-P_4) arises between both the surfaces of the film 33, and the film curves downwards. Therefore, the gap width of the opening enlarges, and the flow resistance of this part decreases. For this reason, when the ink flows from the passage 36 toward the passage 40, the overall flow resistance of this flow passage decreases.

In contrast, when the pressure of the passage 40 is higher and the ink flows in the opposite direction, the relationship of the pressure of the respective portions becomes

$$P_1 < P_2 < P_3 < P_4$$

Therefore, the film 33 curves upwards conversely to the foregoing, the gap width of the opening 38 decreases and the flow resistance increases. For this reason, the overall flow resistance of the flow passage increases. Thus, the flow passage whose flow resistance changes depending upon the direction of the ink stream can be provided, and a high-speed ink-jet printer head may be provided by employing it as the fluid control means.

In order to intensify the effects by making the change of the flow resistance dependent upon the direction of the ink stream great, it is desirable that the ratio $k=d_2/d_1$ between the gap width d_1 of the opening 38 and the width d_2 of the deformation of film 33 is close to 1 (unity). The magnitude of the ratio between the flow rates dependent upon the direction of the stream becomes

$$\left(\frac{1+k}{1-k}\right)^3,$$

under an identical pressure. For example, the material of the film is polyethylene terephthalate of 10 µm thick, the diameter of the film is 400 µm, and the gap width of the opening 38 is 10 µm. Then, supposing the pressure difference between the front and rear of the film is 0.5 atmosphere, k=0.5 is obtained and the ratio of the flow rates becomes about 60.

Referring to Fig. 8, in the second embodiment of this invention, the fluid control means is arranged between the ink feed port and the pressure chamber in the conventional ink-jet printer head shown in Fig. 1. As the fluid control means, a passage 42 having a fixed gap width is disposed between an ink feed port 41 and a pressure chamber 103, the wall of the passage on one side is provided with a hole communicating with the pressure chamber, and a film 43 is fastened to a part of the passage 42. As the film, the sheet of a metal, plastic or the like can be employed as mentioned above.

In operation, when a voltage is applied to a piezoelectric element 101 to curve the wall 102 of the pressure chamber 103 inwards, internal pressure of the pressure chamber rises. Then, the film 43 curves to reduce the gap width of the passage 42. Therefore, the flow resistance of the passage 42 increases, and most of the ink extruded from the pressure chamber is squirted from the nozzle 104. Subsequently, when the voltage is returned to its original value, incurving wall 102 undergoes a force which restores it to its original position, and hence, the pressure of the pressure chamber becomes lower than the external pressure. Therefore, the film 43 returns onto the pressure chamber side conversely to the foregoing, and the flow resistance of the passage 42 decreases. For this reason, most of the ink to flow into the pressure chamber is applied through the passage 42. Accordingly, the quantity of the retracted ink is smaller than the quantity of the squirted ink in the nozzle portion, the period of time in which the retracted meniscus return to the nozzle end is shortened, and it is permitted to shorten the period of the ink droplet formation.

In each of the various examples of the fluid control means as stated above in which the flow resistance changes depending upon the direction of the ink stream, the change of the flow resistance is the sum of the fixed value independent of the direction of the ink stream and a value varying under the action of the valve. Accordingly, the flow resistance can also be changed in dependence on the direction of the ink stream in such a way that an auxiliary ink passage having a fixed flow resistance is disposed jointly with the fluid control means which has previously been illustrated in Figs. 3, 4 and 5 and which has the complete rectification action. For example, Fig. 9 shows another example of the fluid control means in which auxiliary ink passages penetrating at all times are respectively provided in the valve seats in the three kinds of fluid control means shown in Figs. 3, 4 and 5. Fig. 9 shows the case where the valve is open under the action of the ink pressure and where the ink is flowing upwards. In order for such fluid control means to exercise a satisfactory function in the ink-jet head, the flow resistance to the ink passing through opening 908 between a valve 901 and a valve seat 906 needs to become sufficiently lower than the flow resistance of the auxiliary ink passage 912.

A still another example of the fluid control means is shown in Fig. 10, in which the parts of the ink passage covered by the valve and the valve seat, as shown in Figs. 3, 4 and 5, are communicated by an auxiliary passage which is provided so as to bypass the valve and the valve seat. In this case, the flow resistance to the ink passing through the opening 908 between the valve 901 and the valve seat 906 needs to be sufficiently lower than the flow resistance of the auxiliary ink passage 912.

The driving voltage to be applied to the piezoelectric transducer 11 or 101 will be described. When the driving voltage is applied to the piezoelectric transducer, a pressure is generated in accordance with its voltage value ϕ or with a quantity of deflection, and the magnitude of the pressure can be approximated as follows:

$$P=A(\phi-\phi_o)+B(V-V_o) \qquad (1)$$

Here, A and B are constants that are determined by the dimension and material of the piezoelectric oscillation plate, P is the pressure, ϕ is the voltage, ϕ_o is the initial voltage, V is the capacity of the pressure chamber and V_o is the capacity of the pressure chamber when $\phi=\phi_2$ and $P=0$.

As can be understood from the equation (1), the pressure occurring on the piezoelectric oscillation plate increases in proportion to the amplitude $(\phi-\phi_o)$ of the impressed voltage. When the voltage is applied to the piezoelectric oscillation plate, the pressure occurs in accordance with the equation (1) and the ink is caused to flow out from the pressure chamber. As the capacity of this pressure chamber decreases, the pressure also decreases progressively and when a predetermined voltage ϕ_a is kept being applied, the pressure approaches zero. In this instance, the capacity of the pressure chamber progressively approaches the saturation value $Va(P=0)$. The behaviour of the capacity change in this case is shown in Figure 11a. In the drawing, symbols *b* and *c* represent the behaviours when other voltages ϕ_b and ϕ_c are applied, respectively. Incidentally, the relation between these voltages is $\phi_a<\phi_b<\phi_c$. It can be understood from this drawing that the deflection quantity of the capacity becomes greater with an increasing amplitude of the voltage. It can also be understood that the time required for deflection can be shortened by increasing the amplitude of the voltage if a predetermined capacity change is to be effected by this oscillation plate. It will be assumed the case in which the capacity is to be changed from V_o to V_a. As shown in Figure 11, when ϕ_a is impressed, the time required for deflection theoretically becomes infinite, and when the voltage increases to ϕ_b and then to ϕ_c, the time required for deflection becomes shorter to T_b and T_c, respectively.

Next, deflection will be considered when a pulse voltage is applied to this piezoelectric oscillation plate. The width of this driving pulse is related with an ink droplet formation characteristic. In the ink jet head such as shown in Figure 2, behaviour of the droplet formation will be considered by changing the width of the driving pulse. In this case, when the pulse width becomes greater and exceeds a predetermined width, the volume and initial speed of the ink droplet become constant irrespective of the pulse width. This is because the deflection of the pressure chamber reaches the saturation value in Figure 11. However, in this pulse width, a large number of sub-droplets, that are called "satellite", of ink are formed in addition to the main ink droplet and cause recording problems. Furthermore, the time required for the deflection to attain its maximum becomes about 0.2 msec in ordinarily available ink jet recording heads in this pulse width. In other words, if such a pulse width is employed, it is not possible to obtain a high ink droplet-forming frequency. Accordingly, as a practical driving pulse is used one that shortens the application time and finishes the pulse application before the deflection attains its maximum. By use of such a pulse, the formation of the satellites can be eliminated, and the repetition frequency of the driving pulse can be enhanced since the pulse width is narrow.

Figure 12B shows the behaviour of the change in the capacity of the pressure chamber when the driving pulse having a pulse width, at which the capacity of the pressure chamber does not attain the maximum deflection quantity, such as shown in Figure 12A, is employed. In this drawing, V_o represents the initial capacity and V_1 does the saturation value when ϕ_1 is impressed. When the impressed voltage reaches ϕ_1 from ϕ_o, the capacity of the pressure chamber so changes as to asymptotically approach the saturation value V_1 and becomes V_2 at the time t_1 of finish of the ϕ_1 application. The deflection quantity of the pressure chamber capacity from V_o is smaller than the deflection quantity up to the saturation value V_1.

Next, when the impressed voltage is returned to ϕ_o, the capacity of the pressure chamber so changes from V_2 as to asymptotically approach the saturation value V_o when ϕ_o is impressed. Here, the time during which the pulse is impressed will be compared with the time required for the capacity of the pressure chamber to return to V_o after the finish of the pulse application. The relation between the time required for predetermined deflection and the impressed voltage is already described with reference to Figure 11. Since the saturation is not yet attained, the deflection when the voltage is impressed from ϕ_o to ϕ_1 corresponds to the case when the capacity of the pressure chamber changes from V_o to V_a as ϕ_b or ϕ_c is impressed, as shown in Figure 11. On the other hand, when the voltage is returned from ϕ_o to ϕ_1, the behaviour corresponds to that of the case when ϕ_a is impressed in Figure 11 because the capacity of the pressure chamber asymptotically approaches V_o at the voltage ϕ_o from V_2.

Accordingly, it can be understood that the voltage changes from ϕ_o to ϕ_1 and the time required for the pressure chamber capacity to return from V_2 to V_o when the voltage is returned from ϕ_1 to ϕ_o becomes greater than the time required for the one to change from V_o to V_1. If the ink droplet is formed by use of such a driving waveform as shown in Figure 12A, therefore, its repetition frequency becomes high, and if the application time of the driving pulse and the repetition frequency approach each other, a succeeding voltage is applied before the deflection of the pressure chamber is not capable of returning its initial value V_o.

If there is any initial deflection as given by the aforementioned equation (1) when the succeeding voltage pulse is applied, the pressure generated by the pressure chamber becomes smaller even if the same voltage is impressed. For this reason, the velocity of the jetted ink droplet and the volume of the droplet decrease. The decreases in the ink droplet velocity and the ink droplet volume may presumably be attributed to the slow action of the pressure chamber capacity in returning to its initial value. On the basis of this assumption, the present invention contemplates to enhance the ink droplet forming a frequency by making it possible for the capacity of the pressure chamber to return to its initial value within a shorter period of time.

Figure 13A shows an example of the driving pulse in accordance with the present invention. The waveform is so arranged that it first changes from ϕ_1 to ϕ_1 at the time of jetting of the ink and when the deflection of the pressure chamber is to be returned to its initial state, it is set to ϕ_2 having an amplitude in the opposite direction to ϕ_1 with respect to ϕ_o before the voltage is returned to ϕ_o and is then allowed to return to ϕ_o. The mode of change in the capacity of the pressure chamber when this driving waveform is applied is shown in Figure 13B. As the impressed voltage changes from ϕ_o to ϕ_1 and attains the stage in which the ink droplet is about to be jetted, the capacity of the pressure chamber exhibits the same change as in Figure 12B. Next, when the impressed voltage changes from ϕ_1 to ϕ_2, a pressure is generated, which pressure is greater than one when the impressed voltage changes from ϕ_1 to ϕ_o. Accordingly, the capacity of the pressure chamber so changes as to asymptotically approach from V_2 to V_3 which is greater than the initial value V_o. This is the same mode of change when the pressure chamber capacity changes with a varying application voltage in Figure 11. Hence, the capacity of the pressure chamber reaches the initial value V_o more quickly than when the voltage is simply returned to ϕ_o. The impressed voltage is returned from ϕ_2 to ϕ_o when the capacity of the pressure chamber reaches V_o. Though the application time of ϕ_2 in this description is the time required for the pressure chamber capacity to return to V_o, some increases or decreases of the application time may be effected in practice in consideration of the force of inertia of the ink or the like. This application time of ϕ_2 varies in accordance with the magnitude of $|\phi_1-\phi_2|$ and when this absolute value is great, the application time becomes short, and it becomes greater as the value $|\phi_1-\phi_2|$ is small and asymptotically approaches $|\phi_1-\phi_o|$, as can be appreciated clearly from the explanation with reference to Figure 11.

The driving waveform shown in Figure 13A consists of two pulses continuously combined with each other, the former being for forming the ink droplet and the latter, for shortening the returning time of the capacity of the pressure chamber. However, other driving waveforms may be employed, as well, such as one consisting of two spaced-apart pulses as shown in Figure 13C.

Though the foregoing embodiment uses a rectangular driving waveform for the ease of description, the present invention is not limited in particular to such a waveform. Namely, it is possible to use a waveform in which a predetermined time constant is applied to the rise and fall of the pulse, a triangular wave, a sine wave, a trapezoidal wave, and so forth. Namely, after the voltage for jetting the ink droplet is applied, the voltage is not merely returned to its initial value ϕ_o, but a voltage of an amplitude in the opposite direction to the voltage pulse for jetting the droplet is applied to the initial potential ϕ_o so that the capacity of the pressure chamber is capable of more rapidly returning to its initial value V_o. Hence, the waveform for this purpose is not limitative, in particular.

It is possible to use, for example, one period of a sine wave as the driving waveform such as shown in Figure 14A. In this waveform, the phase of the sine wave is so adjusted that when one period of the driving waveform finishes, the capacity of the pressure chamber returns to its initial value V_o, as shown in Figure 14B, in this waveform, too, the capacity of the pressure chamber returns to its initial state more rapidly than a waveform devoid of such a voltage that is lower than ϕ_o and is applied to the above-mentioned waveform.

The driving waveform in accordance with the present invention can be synthesized by generally known methods. Figure 16 shows a representative of circuits for forming the driving waveform such as shown in Figure 13A. In the drawing, when a trigger pulse for forming the ink droplet is applied to a mono-multiple vibrator 211, there is produced a rectangular pulse 212. This pulse width determines the ϕ_1 application time of the driving pulse. The pulse 212 is applied to a second mono-multiple vibrator, which is triggered by the rear end of the pulse and generates a rectangular pulse 214. The pulse width of this pulse determines the ϕ_2 application time of the driving pulse. The rectangular pulses 212 and 214 are subjected to the amplitude adjustment by an amplitude control circuit 215 and are then applied to positive and negative input terminals of a differential amplifier 216, thereby yielding a driving signal 217.

Another driving waveform in accordance with the present invention will further be described. Figure 16A shows an example of the driving waveform and Figure 16B shows an example of a compensating waveform. Driving waveforms of the present invention synthesized from these waveforms are shown in Figures 16C, 16D and 16E. Figure 17 shows an example of the circuit for forming these driving waveforms. In Figure 17, when a trigger 210 signal is applied to a driving waveform forming circuit 218, a waveform such as shown in Figure 16A is produced as the output. This trigger signal 10 is also applied to a delay circuit 219 and is applied to a compensating waveform forming circuit 219 after the passage of a predetermined time, thereby yielding the waveform such as shown in Figure 16B. These outputs are applied to an amplitude control circuit 221 and are then synthesized by a synthesizing circuit such as a differential amplifier 222. In accordance with the delay time determined by the delay circuit 219, there are obtained a waveform composed of two mutually overlapping waveforms such as shown in Figure 16C, two continuous waveforms such as shown in Figure 16D and two spaced-apart waveforms such as shown in Figure 16E. When the ink jet printer is actuated by any of these waveforms, the force of returning the deflected piezoelectric oscillation plate to its original state becomes great by applying, after the formation of the ink droplet, a voltage having an amplitude in the opposite direction with respect to the voltage applied at the time of jetting the ink droplet and consequently, the returning time to the original state becomes shorter. The delay time is selected in accordance with the signal response characteristic of the piezoelectric oscillation plate of the ink jetter printer to be employed and with the amplitude of the signal so that the time required for the capacity of the pressure chamber to return to its original state is shortened.

As described in the foregoing, in accordance with the present invention, a voltage having an amplitude in the opposite direction to the driving voltage for jetting the ink with respect to the initial voltage is applied to the piezoelectric oscillation plate in order to allow the capacity of the pressure chamber to immediately return to its initial state after jetting of the ink. According to this arrangement, the velocity and size of the ink droplet do not change even if the repetition frequency for forming the ink droplet is increased, and there can thus be obtained an ink jet printer having a high printing speed and high printing quality.

Claims

1. A printer head for an ink-on-demand type ink-jet printer for squirting ink droplets onto a printing medium, said printer head comprising:

a nozzle (14) communicating with a pressure chamber (13) for squirting said ink droplets;

a supply passage (15) for supplying ink from an ink tank to said pressure chamber;

pressure exertion means (11, 12) for exerting a pressure on said ink in said pressure chamber in accordance with an electric signal (at 18) to squirt said ink droplets; and

fluid control means;

characterised in that said fluid control means (21, 22) is a valve which, in order to vary its flow resistance, is deformable under the action of the ink pressure and is disposed either between said pressure chamber (13) and said nozzle (14) or between said pressure chamber and said supply passage (15), and that said control means (21, 22) further operate in such a way that in the first alternative the flow resistance of said fluid control means is smaller than that in the supply passage (15) under a high internal pressure of said pressure chamber and greater than that in the supply passage under a low internal chamber pressure, whereas in the second case the flow resistance of said control means is higher than that in the nozzle portion (14) under a high internal chamber pressure and smaller than that in said nozzle portion under a low internal chamber pressure.

2. A printer head as claimed in claim 1, characterised in that a fluid control means (21 and 22) is disposed both between the supply passage (15) and said pressure chamber (13) and between said pressure chamber (13) and said nozzle (14) as well.

3. A printer head as claimed in claim 1 or 2, characterised in that said or each fluid control means comprises an elastic valve for covering the supply passage and/or the said nozzle portion, said elastic valve being deformed under the action of the ink pressure to open or close said ink passage.

4. A printer head as claimed in claim 3, characterised in that said or each fluid control means further comprises an auxiliary ink passage having a fixed flow resistance and shunted to said elastic valve, the flow resistance thereof, in its open valve position, being lower than said fixed flow resistance.

5. A printer head as claimed in claim 1, characterised in that the valve includes a deformable flat member supported by a stationary member and covering an opening extending through said member, that a portion of the periphery of the flat member is fixed, and that the remaining portion of the member is freely movable in response to the ink pressure so as to open or close the opening.

6. A printer head as claimed in claim 1, characterised in that the valve includes a deformable flat member which is fixed along its periphery and has at least one opening at an inside portion thereof, which inside portion of the flat member is supported by a supporting member having at least one opening at a position not corresponding to the opening in the flat member, so that both openings communicate with each other when the flat member is deformed in response to the ink pressure.

7. A printer head as claimed in any one of claims 1 to 6, characterised in that the pressure exerting means comprises means responsive to drive pulses for selectively compressing and releasing the ink chamber.

8. A printer head as claimed in claim 7, characterised in that the drive pulse comprises a first pulse of one polarity for driving the chamber into the compression and a second pulse of opposite polarity for driving the chamber into a release of the compression.

9. A printer head as claimed in claim 8, characterised in that the pressure exerting means comprises means for selecting a delay time between the first and second driving pulses in order to control the formation of the droplets.

Revendications

1. Tête d'imprimante pour imprimante à jet d'encre du type à encre sur demande pour projeter des gouttelettes d'encre sur un support d'impression, la tête de l'imprimante comprenant:

- un ajutage (14) communiquant avec une chambre de pression (13) pour projeter les gouttelettes d'encre;
- un canal d'alimentation (15) pour fournir de l'encre à partir d'un réservoir d'encre à la chambre de pression;
- un moyen d'exercise de pression (11, 12) pour exercer une pression sur l'encre dans la chambre de pression en conformité avec un signal électrique (à 18) pour projeter les gouttelettes d'encre; et
- un moyen de commande de fluide;

caractérisée en ce que le moyen de commande de fluide (21, 22) est une valve qui, dans le but de faire varier sa résistance à l'écoulement, peut se déformer sous l'action de la pression d'encre et est disposée soit entre la chambre de pression (13) et l'ajutage (14) soit entre la chambre de pression et le canal d'alimentation (15), et en ce que le moyen de commande (21, 22) fonctionne en outre d'une façon telle que dans la première alternative la résistance opposée à l'écoulement par le moyen de commande de fluide est inférieure à celle dans le canal d'alimentation (15) sous une pression interne élevée de la chambre de pression et supérieure à celle dans le canal d'alimentation sous une pression interne faible de la chambre, alors que dans le second cas, la résistance opposée à l'écoulement par le moyen de commande est supérieure à cell dans la partie à ajutage (14) sous une pression interne élevée de la chambre et inférieure à celle dans la partie à ajutage sous une pression interne faible de la chambre.

2. Tête d'imprimante selon la revendication 1, caractérisée en ce qu'un moyen de commande de fluide (21 et 22) est disposé à la fois entre le canal d'alimentation (15) et la chambre de pression (13) et entre la chambre de pression (13) et l'ajutage (14).

3. Tête d'imprimante selon la revendication 1 ou la revendication 2, caractérisée en ce que ledit ou chaque moyen de commande de fluide comprend une valve élastique pour recouvrir le canal d'alimentation et/ou la partie à ajutage, la valve élastique étant déformée sous l'action de la pression d'encre de manière à ouvrir ou fermer le canal d'encre.

4. Tête d'imprimante selon la revendication 3, caractérisée en ce que ledit ou chaque moyen de commande de fluide comprend en outre un canal auxiliaire d'encre ayant une résistance fixe à l'écoulement et shunté par rapport à la valve élastique, sa résistance opposée à l'écoulement, dans sa position d'ouverture de valve, étant inférieure à la résistance fixe à l'écoulement.

5. Tête d'imprimante selon la revendication 2, caractérisée en ce que la valve comprend un élément plat déformable supporté par un élément fixe et recouvrant une ouverture s'étendant à travers l'élément, en ce qu'une partie de la périphérie de l'élément plat est fixe, et en ce que la partie restante de l'élément est mobile librement en réponse à la pression d'encre de manière à ouvrir ou fermer l'ouverture.

6. Tête d'imprimante selon la revendication 1, caractérisée en ce que la valve comprend un élément plat déformable qui est fixe le long de sa périphérie et comporte au moins une ouverture à une partie intérieure, cette partie intérieure de l'élément plat étant supportée par un élément de support ayant au moins une ouverture à une position ne correspondant pas à l'ouverture de l'élément plat, de sorte que les deux ouvertures communiquent l'une avec l'autre lorsque l'élément plat est déformé en réponse à la pression d'encre.

7. Tête d'imprimante selon l'une quelconque des revendications 1 à 6, caractérisée en ce que le moyen exerçant une pression comprend un moyen répondant à des impulsions de commande pour sélectivement comprimer et libérer la chambre d'encre.

8. Tête d'imprimante selon la revendication 7, caractérisée en ce que l'impulsion de commande comprend une première impulsion d'une polarité pour mettre la chambre en compression et une seconde impulsion de polarité opposée pour amener la chambre à libérer la compression.

9. Tête d'imprimante selon la revendication 8, caractérisée en ce que le moyen exerçant une pression comprend un moyen pour sélectionner un retard entre les première et seconde impulsions de commande de manière à commander la formation des gouttelettes.

Patentansprüche

1. Druckkopf für einen Tintenstrahldrucker mit durch ein Auslösesignal gesteuerter Tintenstrahlerzeugung zum Herausspritzen von Tintentröpfchen auf ein Druckmedium, wobei der Druckkopf folgende Bestandteile aufweist:

Eine Düse (14), die mit einer Druckkammer (13) in Verbindung steht, um die Tintentröpfchen herauszuspritzen, einen Versorgungskanal (15) zum Züfuhren von Tinte aus einem Tintenbehälter in die Druckkammer, eine Druckaufbaueinrichtung (11, 12) zum Aufbauen eines Drucks auf die Tinte in der Druckkammer in Abhängigkeit von einem elektrischen Signal (bei 18), um die Tintentröpfchen herauszuspritzen, und eine Fluidsteuereinrichtung, dadurch gekennzeichnet, daß die Fluidsteuereinrichtung (21, 22) ein Ventil ist, das zum Variieren seines Strömungswiderstandes durch den Tintendruck verformbar und entweder zwischen der Druckkammer (13) und der Düse (14) oder zwischen der Druckkammer und dem Versorgungskanal (15) angeordnet ist, und daß die Steuereinrichtung (21, 22) derart arbeitet, daß bei der ersten Alternative der Strömungswiderstand der Fluidsteuereinrichtung kleiner ist als der in dem Versorgungskanal (15) unter einem hohen Innendruck der Druckkammer und größer ist als der in dem Versorgungskanal unter einem niedrigen Kammerinnendruck, während bei der zweiten Alternative der Strömungswiderstand der Steuereinrichtung höher ist als der in dem Düsenabschnitt (14) bit hohem Kammerinnendruck und kleiner ist als der in dem Düsenabschnitt bei niedrigem Kammerinnendruck.

2. Druckkopf nach Anspruch 1, dadurch gekennzeichnet, daß eine Fluidsteuereinrichtung (21 und 22) sowohl zwischen dem Versorgungskanal (15) und der Druckkammer (13) als auch zwischen der Druckkammer (13) und der Düse (14) angeordnet ist.

3. Druckkopf nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die oder jede Fluidsteuereinrichtung ein elastisches Ventil aufweist, um den Versorgungskanal und/oder den Düsenabschnitt abzudecken, wobei das elastische Ventil aufgrund des Tintendrucks verformt wird, um den Tintenkanal zu öffnen oder zu schließen.

4. Druckkopf nach Anspruch 3, dadurch gekennzeichnet, daß die oder jede Fluidsteuereinrichtung ferner einen Hilfstintenkanal aufweist, der einen festen Strömungswiderstand aufweist und zum elastischen Ventil parallel geschaltet ist, dessen Strömungswiderstand in der offenen Ventilstellung geringer ist als der feste Strömungswiderstand.

5. Druckkopf nach Anspruch 1, dadurch gekennzeichnet, daß das Ventil ein verformbares, flaches Element aufweist, das durch ein stationäres Element abgestützt wird und eine sich durch das Element erstreckende Öffnung abdeckt, daß ein Umfangsabschnitt des flachen Elements feststehend ist und daß der verbleibende Abschnitt des Elements in Abhängigkeit von Tintendruck frei beweglich ist, um die Öffnung zu öffnen oder zu schließen.

6. Druckkopf nach Anspruch 1, dadurch gekennzeichnet, daß das Ventil ein verformbares, flaches Element aufweist, das an seinem Umfang befestigt ist und mindestens eine Öffnung an einem Innenabschnitt aufweist, wobei der Innenabschnitt des flachen Elements durch ein Stützelement abgestützt ist, das mindestens eine Öffnung an einer Stelle aufweist, die nicht der Öffnung des flachen Elements entspricht, so daß beide Öffnungen miteinander in Verbindung stehen, wenn das flache Element aufgrund des Tintendrucks verformt ist.

7. Druckkopf nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß die den Druck ausübende Einrichtung eine auf Treiberpulse

ansprechende Einrichtung aufweist, um die Tintenkammer selektiv zu komprimieren und zu entlasten.

8. Druckkopf nach Anspruch 7, dadurch gekennzeichnet, daß der Treiberpuls einen ersten Puls der einen Polarität, um die Kammer in den Kompressionszustand zu überführen, und einen zweiten Impuls mit entgegengesetzter Polarität enthält, um die Kammer in einen entlasteten Zustand zu überführen.

9. Druckkopf nach Anspruch 8, dadurch gekennzeichnet, daß die Druckaufbauvorrichtung eine Einrichtung zum Auswählen einer Verzögerungszeit zwischen dem ersten und dem zweiten Treiberpuls aufweist, um die Tröpfchenbildung zu steuern.

Fig.1.

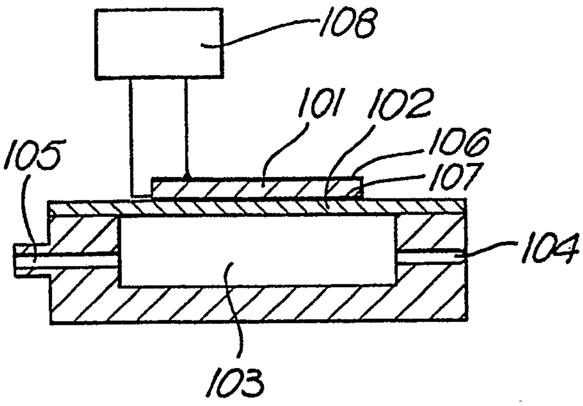


Fig.2.

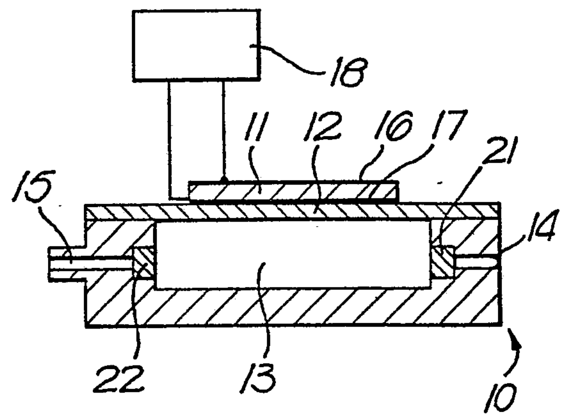


Fig.3A.

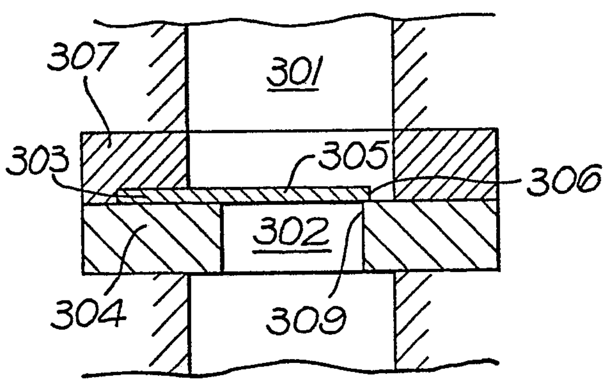


Fig.3B.

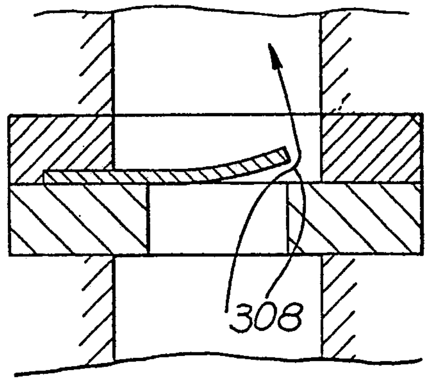


Fig.4A.

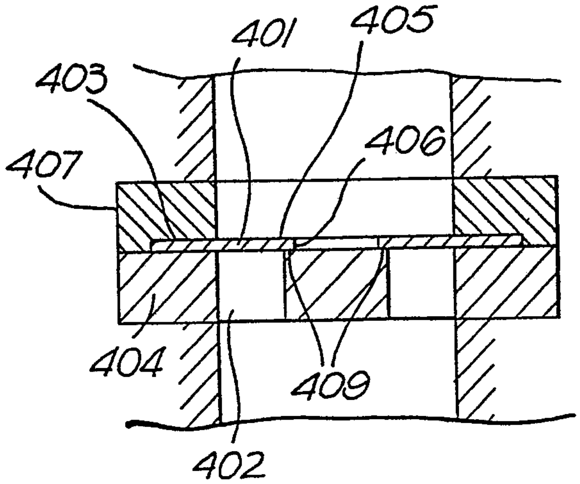


Fig.4B.

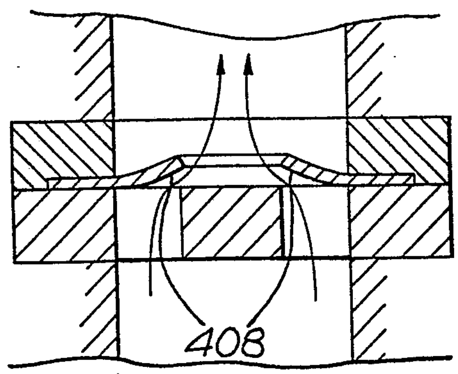


Fig.4C.

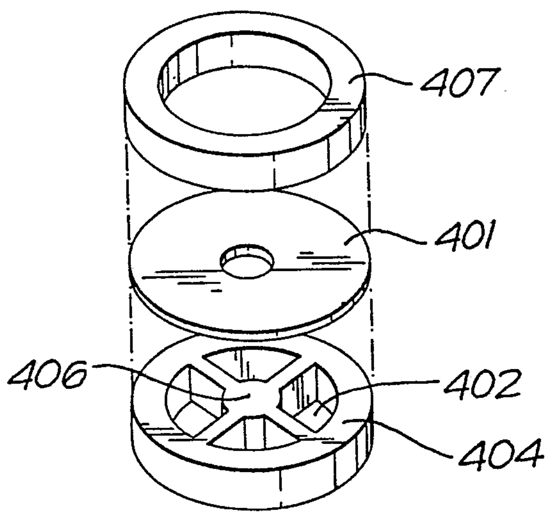


Fig.5A.

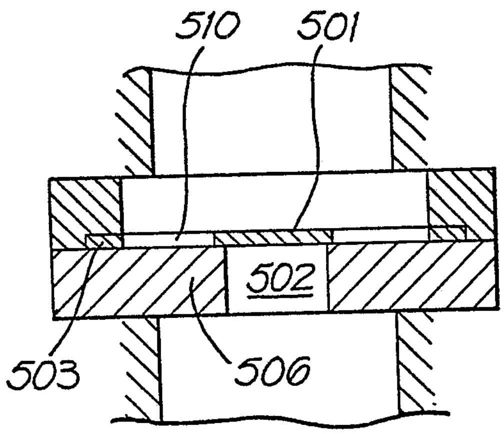


Fig.5B.

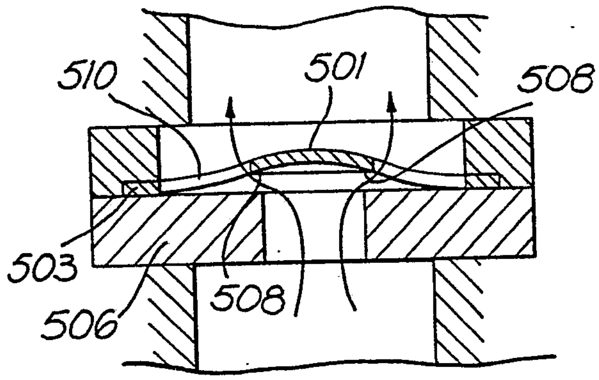


Fig.5C.

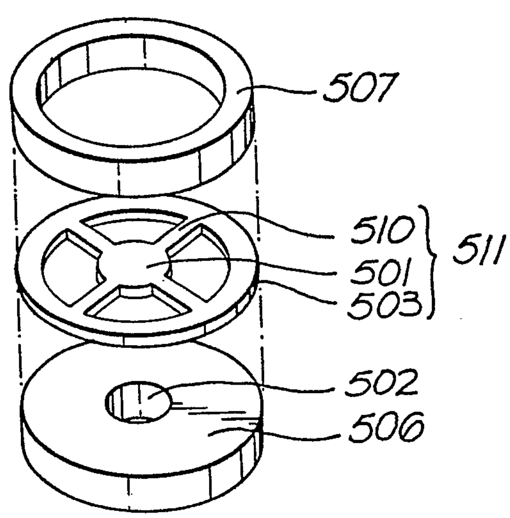


Fig.6A.

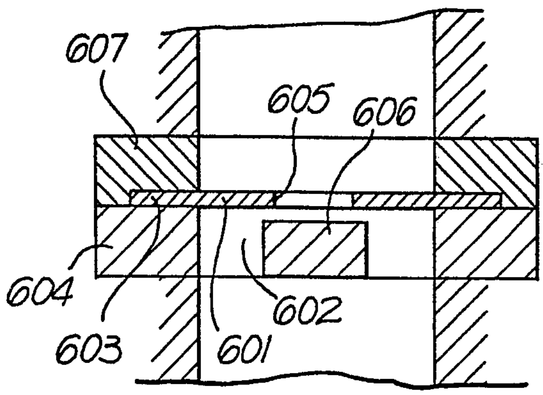


Fig.6B.

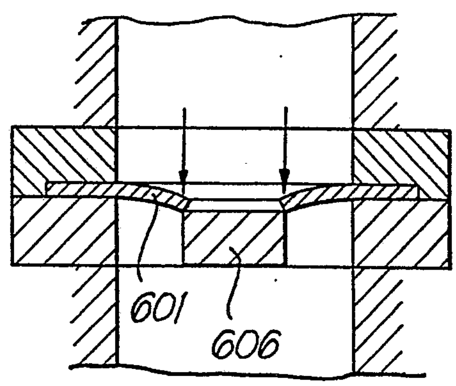
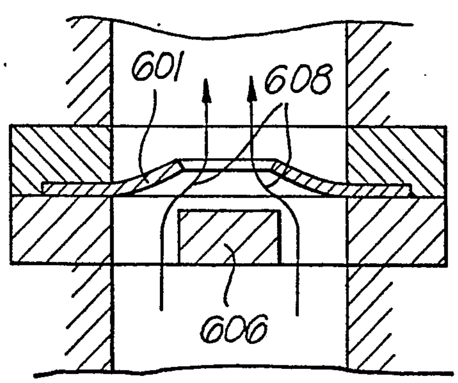


Fig.6C.



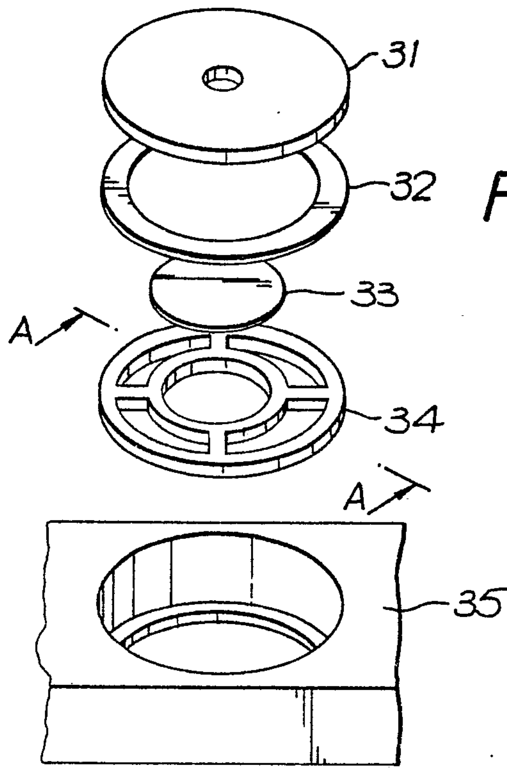


Fig. 7A.

Fig. 7B.

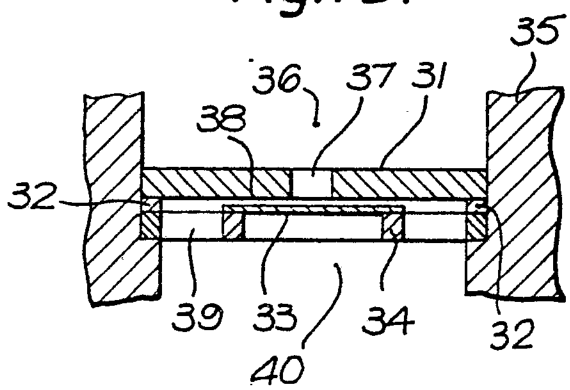


Fig. 8.

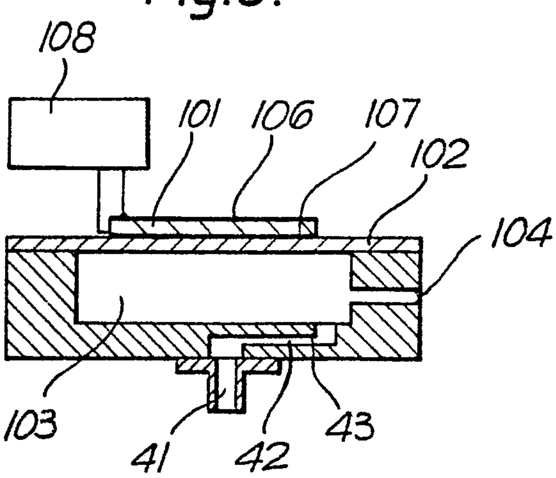


Fig.9A.

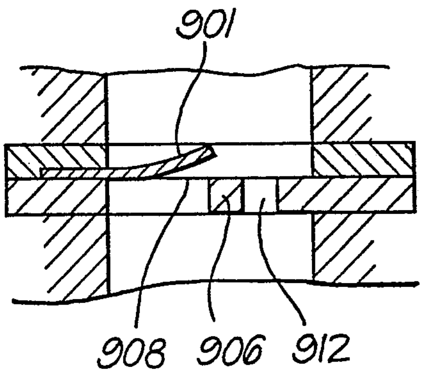


Fig.9B.

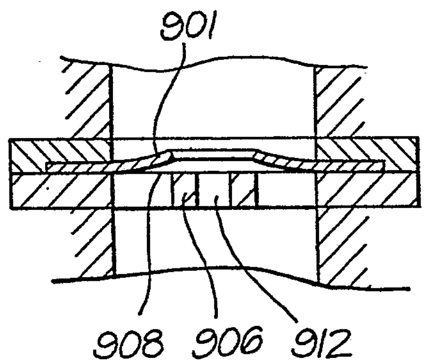


Fig.9C.

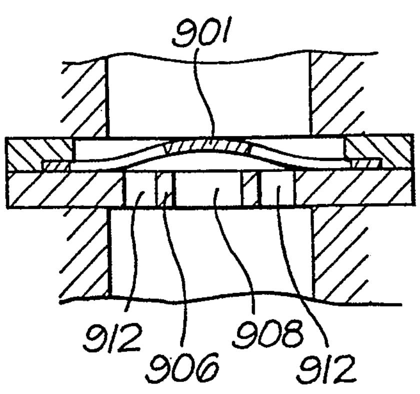


Fig.10.

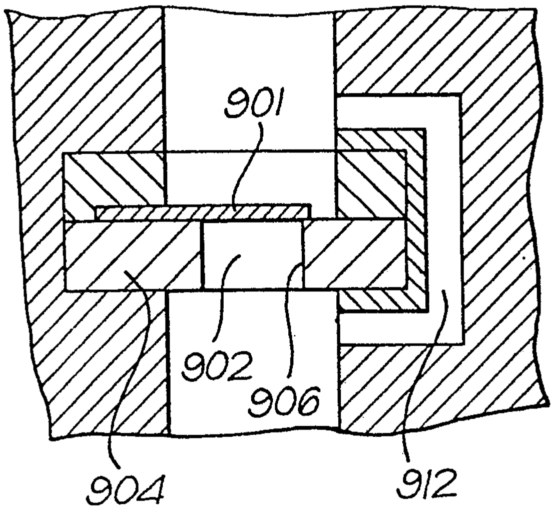


Fig.11.

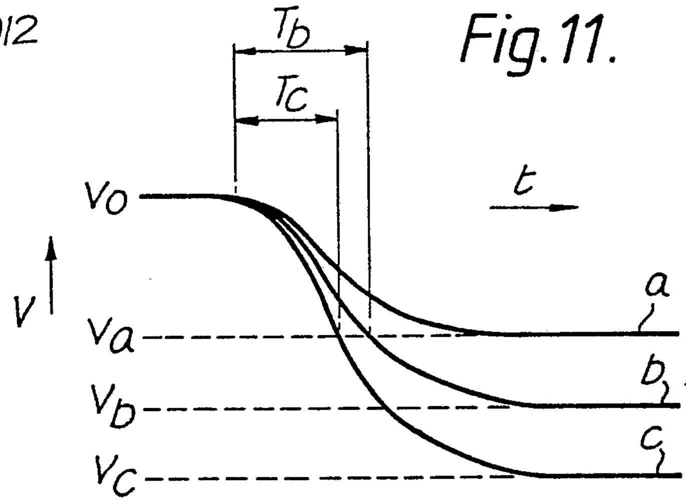


Fig.12.

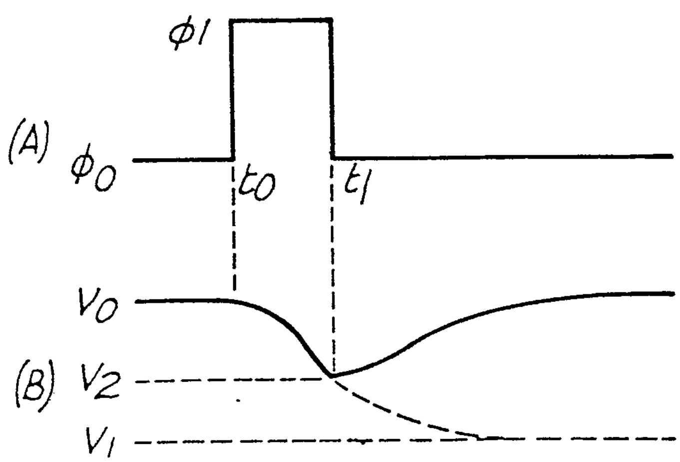


Fig. 13.

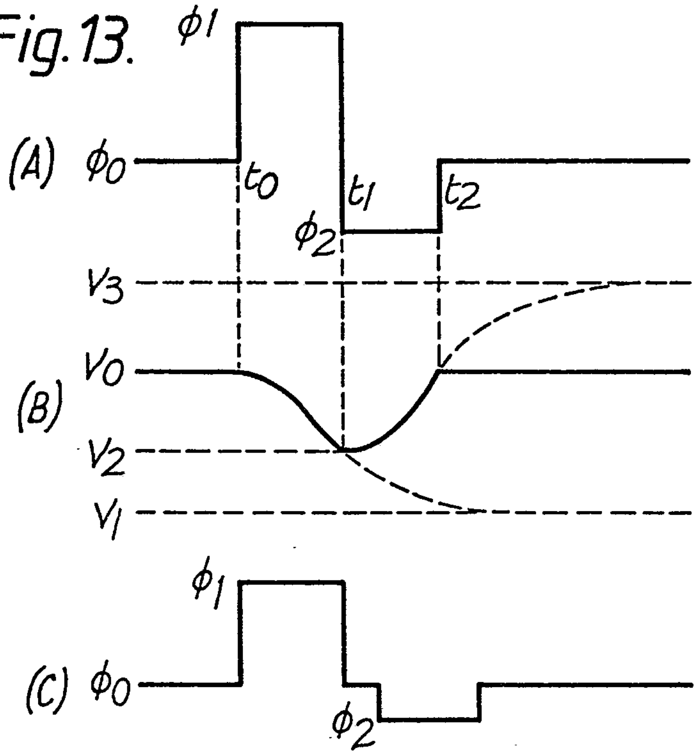


Fig. 14

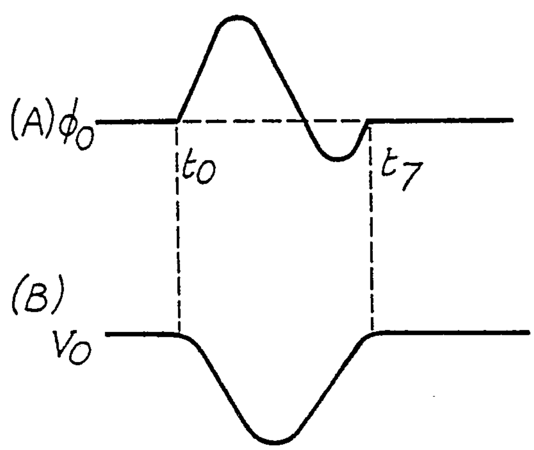


Fig. 15.

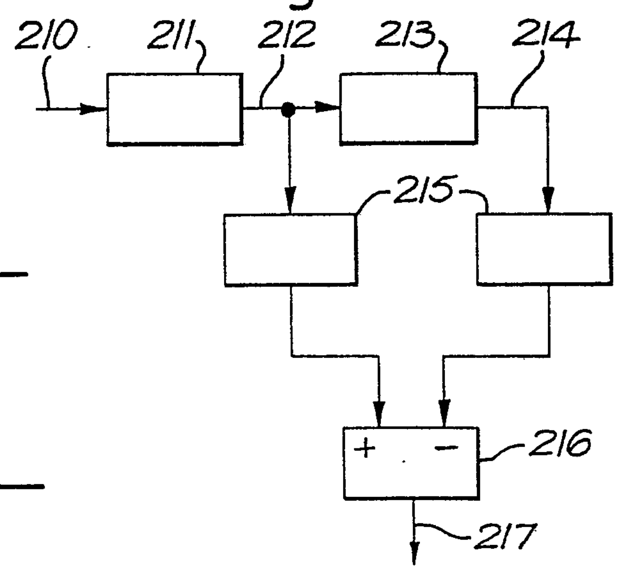


Fig.16.

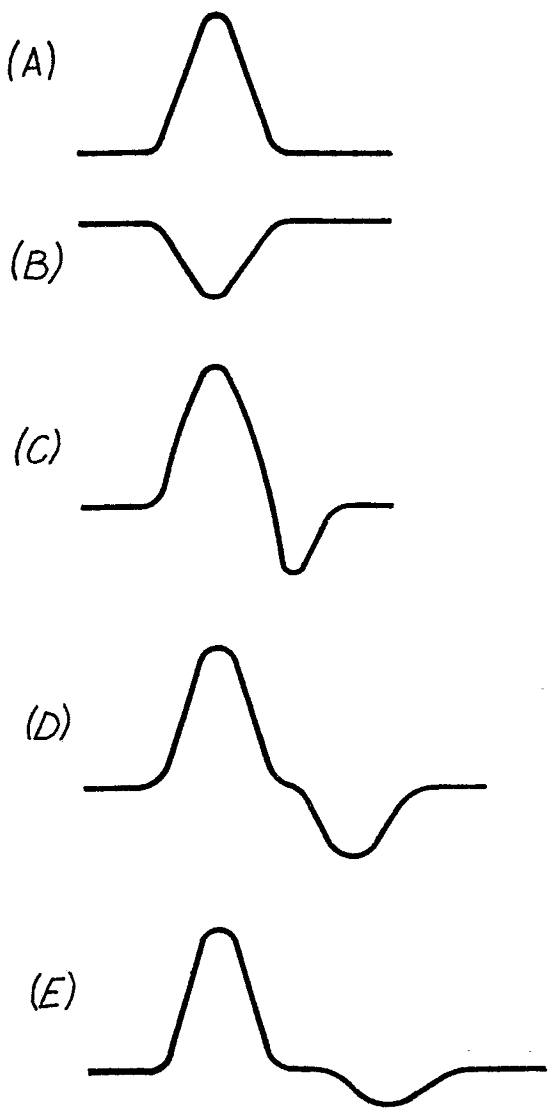


Fig.17.