EUROPEAN QUALIFYING EXAMINATION 1995

PAPER A
ELECTRICITY / MECHANICS

This paper comprises:

INSTRUCTIONS TO CANDIDATES

You are to assume that you have received the annexed letter from your client including a description of an invention for which he wishes you to obtain a European patent together with references to the most pertinent prior art known to your client.

You should accept the facts given in the paper and base your answers upon such facts. Whether and to what extent these facts are used is your responsibility.

You should not use any special knowledge you may have of the subject-matter of the invention, but are to assume that the prior art given is in fact exhaustive.

Your task is to draft an independent claim (or claims) offering the applicant the broadest protection possible while at the same time having a good chance of succeeding before the EPO. In drafting your claim(s) you should bear in mind the need for inventive step over the prior art indicated, the requirements of the Convention, in particular as to the form of claims, and the recommendations made in the Guidelines for Examination in the EPO. Dependent claims should also be drafted so as to enable you to fall back upon them should the independent claim(s) fail and should be kept to a reasonable number.

You are also expected to draft an introduction, i.e. that part of the description which precedes the examples or the explanation of the drawings. The introduction should be sufficient to provide support for the independent claim(s). In particular, you should consider the advisability of mentioning advantages of the invention in the introduction.

You are expected to draft claims and an introduction for one European patent application only. This application should meet the requirements of the Convention as to unity. If you would in practise seek to protect further inventions by filing one or more separate applications, you should, in a note, clearly identify the subject-matter of the independent claim of such separate application(s). However, it is not necessary to draft the wording of the independent claim for the or each separate application.

In addition to your chosen solution, you may – but this is not mandatory – give, in a note, the reasons for your choice of solution, for example, why you selected a particular form of claim, a particular feature for an independent claim, a particular piece of prior art as starting point or why you rejected or preferred some piece of prior art. Any such note should however be brief.

It is assumed that you have studied the examination paper in the language in which you have given your answer. If this is not so, please indicate on the front page of your answer in which language you have studied the examination paper. This always applies to candidates who – after having filed such a request when enrolling for the examination – give their answer in a language other than German, English or French.

Client's Letter

We are a firm producing printers, in particular printers which suitable for use with Personal Computers (PCs). Printers in general can be divided into two groups: the first group consists of so-called impact printers which use what could be described as the hammer principle, whereas the second group consists of so called non-impact printers in which no direct strokes of characters or character elements onto the surface to be printed are performed. Examples of the first group are hammer, chain and needle printers, examples of the second group are electrophotographic printers (laser printers), thermo and ink jet printers.

A broadly applied printing principle which is used for both of the above groups of printers is the matrix printing principle. Matrix printers do not have fixed printing characters. Instead, they use a matrix grid in which dots are either set (printed) or left out (not printed) in order to produce a character to be printed. An example of an impact matrix printer is the well known needle printer in which a plurality of needles corresponds to the dots in the matrix grid. In most matrix printers, a printing head is moved across the surface to be printed and/or vice versa and the control electronics of the printer sets the correct dot or dots in the matrix grid at the correct moment. The advantage of matrix printers is that the character to be printed can be freely chosen within the matrix grid, which allows printing of self-designed characters or graphics.

Impact printers and therefore also matrix impact printers have considerable disadvantages: they are noisy, they make use of colour ribbons which tend to wear out irregularly, their maximum working frequency (and hence their printing speed) is limited and the mechanism of the printing head is sensitive, expensive to manufacture and difficult to service. For these reasons the trend in recent years has been away from impact printers towards impact printers.

Our invention is concerned with ink jet printers which have the following general working principle: liquid ink is ejected from a printing head having a plurality of tiny ink ejecting outlets or nozzles, the arrangement of which corresponds to the above-mentioned matrix grid. The ink is ejected from the outlets in the form of droplets towards the printing paper under the control of the printer electronics. This principle allows a higher density of the printing matrix than is possible with needle printers and therefore a higher printing resolution. Moreover, the printing itself is rapid and quiet, which aspect is of particular importance for PC applications.

Our invention is concerned in particular with the way in which the ink droplets are generated and in which they are ejected from the printing head.

Attached to this letter find enclosed a copy of Document I which describes a printing head for ink jet printers which was patented by our firm several years ago. Although this printing head works in a very satisfactory manner, the technology used therein nevertheless has some disadvantages which will be apparent when it is compared with our invention for which we ask you to prepare a European patent application.

Our invention is described hereafter with reference to the appended drawings. The basic working principle is explained with reference to Figs. 1 to 4, whereas Figs. 5 to 9 show five embodiments of the invention which are suitable for commercial application. In all the drawings corresponding parts carry the same reference numerals, a list of which is attached at the end of the present description. In the drawings:

Fig. 1 is a schematic exploded view of a printing device illustrating the basic working principle of the invention,

Fig. 2 is a perspective view of the device of Fig. 1,

Fig. 3 is a vertical cross-sectional view on an enlarged scale of the device of Figs. 1 and 2 along the line III-III of Fig. 2,

Figs. 4A to 4F depict a sequence of events involved in the production of an ink droplet,

Figs. 5A and 5B are disassembled and assembled views respectively of an "end-shooter" printing head (first embodiment),

Figs. 6A and 6B are disassembled and assembled views respectively of a "side-shooter" printing head (second embodiment),

Figs. 7 is a perspective view of another "side-shooter" printing head (third embodiment) and

Figs. 8 and 9 show in perspective cross-section two further "side-shooter" printing heads of the invention (fourth and fifth embodiments).

Figs. 1 and 2 show an ink jet printing device having a single ink ejecting outlet. Part of one surface of a substrate 1 of electrically nonconducting material is covered with a thin film metallization layer 2. This is a metal layer which is extremely thin and which is applied by evaporation of a metal under a vacuum onto the substrate, masks being used to create metallization patterns on the substrate. The thin film metallization layer is configured to provide a narrow nonconducting strip 3 of width D1 of 75 μm (= 0.075 mm) and a conducting strip of width D2 of 75 μm. This conducting strip - due to its limited cross-sectional area of conducting material - creates an electrical resistor 4 in metallization layer 2. Alternatively, the resistor can be cr by a different material which may also be applied by evaporatio In a typical configuration, the resistor 4 is located at a distance D3 of 150 µm from an edge of the substrate 1. Fixed to the upper surface of the metallization layer 2 is a capillary block 5, typically made of glass, having an ink supply passage in the form of a capillary channel 6 with an inlet 7 and an outlet 8. The channel 6 is about 75 µm x 75 µm in cross-section and corresponds in width to the nonconducting strip 3.

Behind the capillary block 5 and on top of the substrate 1 is a wall 9 (depicted schematically only) for holding ink in a reservoir 10 (see Fig. 2). The channel 6 draws ink by capillary action from the reservoir 10 to the outlet 8. As can be seen in Fig. 2, the printing device has two electrodes 11 and 12 which are attached to the metallization layer 2 for applying a voltage pulse across the resistor 4. Fig. 3 shows the relative configurations of the ink 13, the capillary block 5, the resistor 4 and a surface 14 to be printed. In operation, the distance D4 between the outlet 8 and the surface 14 is of the order of 0.75 mm.

Figs. 4A to 4F show in cross-sectional view a sequence of events during one cycle of operation of the printing device. When a voltage pulse is applied to the electrodes 11 and 12, the current flowing through the resistor 4 has a sufficient heating effect to superheat the ink and thereby to create a vapour bubble 15 over the resistor 4 as shown in Fig. 4A. The vapour bubble expands rapidly as shown in Fig. 4B. By controlling the electrical energy supplied to the resistor 4, the size of the vapour bubble 15 is determined. Care must be taken to ensure that the total amount of energy absorbed by the ink is not so great as to expel vapour from the outlet 8. The momentum imparted to the ink from the vapour bubble expansion in the direction of the outlet 8 acts to propel a droplet of ink out of the channel 6. The vapour bubble then begins to collapse back as shown in Fig. 4C. After the ink droplet has left the outlet 8, as shown in Fig. 4D, the vapour bubble pletely collapses back on or near its starting location, vol no longer being applied to the resistor 4. The ink begins to refill the channel 6 by capillary action (Fig. 4E) and the ink droplet subsequently lands on the surface to be printed (not shown). Fig. 4F shows the channel 6 filled to its original condition, ready for the next cycle. Printing is accomplished by successively applying voltage pulses to the resistor 4 in an appropriate sequence, while the printing device and the surface to be printed are moved relative to each other so as to create the desired printing pattern.

In the above explanation of the basic working principle of the invention, the preferred ink supply by capillary action has been used. It should however be noted that any other suitable kind of ink supply could be provided. For example, the ink in the reservoir could be under a slight overpressure. This also applies to the embodiments to be described below.

Comparing the printing device described above which constitutes a basic printing head with the printing head disclosed in Document I it is observed that:

- The present device is much easier to manufacture and is therefore cheaper. With the principle described above, it is even possible to integrate the printing head into a disposable ink cartridge which, when empty, is replaced. The printing head of the invention does not have the complicated flow paths present in the printing head of Document I which - because of the size of the pump chambers which is determined by the size of the piezoelectric crystals - have to get narrower downstream of the pump chamber to increase the printing resolution.
- The present device requires less space since it is relatively thin. It is possible to form a stack comprising several of the devices described above, whereby several dots can be printed at the same time, the distance between the outlets of neighbouring devices determining the printing resolution.

- Due to the absence of pump chambers and other portions h relatively large diameters in the flow path, the ink supply i the printing head according to the invention can - as already mentioned above - be carried out by means of capillary action.
- The vapour bubble is preferably generated in the vicinity of the outlet, so that the impedance to flow of the ink towards the outlet is very low in comparison with that towards the reservoir and no fluid diodes have to be provided to guarantee ink flow in the desired direction.
- The working frequency and hence the printing speed are higher, since the vibration frequency of the piezoelectric crystals is limited.

It is to be mentioned here that the voltage U applied to the resistor and the resistance value R of the resistor both determine the current I flowing through the resistor. The relationship is the following: $I = U/R$ (Ohm's Law). Typical values in practice are: $U = 1.5$ V (Volt) and $R = 3\ \Omega$ (Ohm) resulting in a current of $I = 0.5$ A (Ampère). A typical pulse duration is 5 μs (5×10^{-6} s).

The pulses to be applied to the resistor are not generated in the printing head, which usually is exchangeable or even of the single-use type but by suitable control electronics provided in the printer.

Figs. 5A and 5B show an ink jet printing head according to a first commercial embodiment of the invention. The printing head has a plurality of outlets which create a one column printing matrix. The so-called "end-shooter" printing head shown in Figs. 5A and 5B comprises a substrate 1 and a capillary block 5 having several capillary chan-nels 6. Typical materials for the substrate 1 are insulators such as glass, ceramics and silicon, while the material used for the capillary block 5 can be chosen for its ease of manufacture in regard to the formation of the capillary chan-nels 6. For example, the capillary block 5 is made of moulded glass, etched silicon or etched glass. The substrate 1 and the capillary block 5 are bonded together by epoxy resin. The tances D5 and D6 corresponding to the channel spacings and wi are determined by the desired separation and size of the outlet thus determining the printing resolution. A filling channel 16 supplies ink to the capillary channels 6 from a remote ink reservoir (not shown).

A plurality of resistors 4 is provided on the substrate 1, each resistor consisting of a pad of thin film titanium-tungsten on the bottom of each capillary channel 6. Also provided is a number of electrical connections 17 made of thin film gold for supplying a voltage pulse to the resistors 4. Other typical materials for the connec-tions 17 are chromium or aluminium, whereas the resistor 4 can also consist of platinum or silicon. As indicated by the rupture line in Figs. 5A and 5B, the printing head can be extended so as to include the desired number of outlets.

The name "end-shooter" printing head has been selected for this embodiment because the printing head described above ejects the ink at the ends of the channels.

Figs. 6A and 6B show a second embodiment of the invention, a so-called "side-shooter" printing head. It comprises a substrate 1 which carries two electrical connections 17 and a resistor 4. Two plastics spacers 18 separate the substrate 1 from a cover 19, whereby a channel 6, preferably a capillary channel, is provided for the ink. The cover 19 is composed of silicon and has an etched tapered outlet 8 for the ink droplets. The outlet 8 is located directly opposite the resistor 4. The size of the outlet is typically 0.1 mm x 0.1 mm. In this side-shooter printing head, the ink droplets are ejected not from the end of the channel 6 (as in the end-shooter printing head) but sideways out of the channel.

Fig. 7 shows a third embodiment of the invention, which is side-shooter printing head. A substrate 1 carries two glass spacers 18 for holding ink 13 in a channel 6. A silicon cover 19 is provided having a series of etched tapered outlets as exemplified by outlet 8. Each outlet 8 is recessed in a trough 20 formed in the cover 19 so that a thicker cover can be used to provide better structural stability. As can be seen from Fig. 7, the channel 6 has two portions of different cross-sectional area: the first is a capillary narrow portion 6a underneath the outlet 8 and the second is a portion 6b with a larger cross-sectional area which serves to ensure a reliable ink supply to the portion 6a. A filling tube 16 connects the portion 6b to a remote ink reservoir (not shown).

The printing heads shown in Figs. 6A, 6B and 7 can be extended in the direction of the arrows E shown in Figs. 6A and 7 in order to provide a plurality of outlets. In this way, a one column printing matrix is created. When several of these arrangements are positioned beside one another, a printing head having a matrix with several columns is obtained. For the side-shooter printing heads, it is to be mentioned that the pressure pulse resulting from the expanding vapour bubble serves to eject an ink droplet exclusively from the respective outlet opposite the resistor, since the surrounding ink blocks the pressure pulse in the other directions to the extent that an ejection of ink from any neighbouring outlets in the column is avoided.

Figs. 8 and 9 show fourth and fifth embodiments of the invention which - although slightly more complicated to manufacture - provide a number of additional advantages. In these embodiments, the vapour bubble is not formed directly in the ink as is the case in the embodiments of Figs. 1 to 3 and 5 to 7, but in a separate working fluid.

The side-shooter printing head shown in Fig. 8 includes a having an outlet 8 for ejecting ink. The cover 19 is separate from a flexible membrane 21 by means of spacers 18 so as to provide an ink supply passage in the form of a channel 6. Directly below the flexible membrane 21 there is a cavity 22 for containing a working fluid. The cavity 22 is bounded below by a resistor 4 and on the sides by walls 23, the resistor 4 and the walls 23 being carried by a substrate 1. Also shown are two electrical connections 17 for supplying a voltage pulse to the resistor 4.

As in the embodiments described above, in operation, a voltage pulse is applied to the resistor 4 to cause heating and a sudden vaporization of a portion of the working fluid in the cavity 22, whereby a vapour bubble is formed under the flexible membrane 21. The expansion of the vapour bubble causes the membrane to be deformed, resulting in a local displacement thereof and in the transmission of a pressure pulse to the ink in the channel 6. This pressure pulse then ejects a droplet of ink from the outlet 8. When the voltage pulse is terminated, the vapour bubble will quickly collapse back by recondensation, so that a repeated operation is possible without the necessity of supplying fresh working fluid.

The spacers 18 provide only a small separation of the membrane 21 from the outlet 8 to permit adequate energy transfer to the ink and to ensure filling of the channel 6 by capillary action. A typical outlet diameter is 75 µm and the same materials can be used as in the previous embodiments. The flexible membrane 21 consists advantageously of a thin film of silicone rubber, although other materials having the necessary elasticity may be used.

Fig. 9 shows a fifth embodiment of the invention in which only very little working fluid is required to produce a sufficient vapour bubble to cause ejection of an ink droplet. In this embodiment the walls 23 of Fig. 8 are eliminated and a fle membrane 21 is placed directly over a resistor 4. In order to create sufficient space between the resistor 4 and the membrane 21, at least one of these two parts has to have a rough surface so that an adequate volume of working fluid is provided therebetween for a proper vapour bubble formation. This is illustrated in Fig. 9 by showing a vapour bubble 15 creating a local deformation of the membrane 21, whereby an ink droplet (not shown) is ejected from the outlet 8 in the channel 6. Also shown in Fig. 9 are electrical connections 17 for the resistor 4.

As regards the working fluid, water based liquids have proved to give satisfactory results. The working fluid is introduced between the resistor 4 and the membrane 21 during the manufacture of the printing head.

In the fourth and fifth embodiments described with respect to Figs. 8 and 9, it is no longer necessary to take into account the thermal and chemical properties of the ink. It is therefore much easier to produce colour printers using three different inks in one and the same printing head (each colour having its own printing matrix). Another advantage is that a wide selection of working fluids and of materials for the electrical connections and the resistors is permitted without having to worry about wetting characteristics and other problems, in particular chemical problems, associated with the ink composition, such as corrosiveness and the deposition of ink particles on the resistor. Consequently both the ink and the working fluid can be optimised for their individual purposes. A properly selected working fluid ensures a better energy efficiency for the vapour bubble formation than ink compositions.

The embodiments described with respect to Figs. 8 and 9 are side-shooter printing heads. However, the described separate working fluid concept is also applicable to end-shooter printing heads.

List of reference numerals used

substrate	1
metallization layer	2
narrow nonconducting strip	3
resistor	4
capillary block	5
capillary channel	6
channel portions	6a, 6b
inlet	7
outlet	8
wall	9
reservoir	10
electrodes	11, 12
ink	13
surface to be printed	14
vapour bubble	15
filling channel, filling tube	16
electrical connections	17
spacers	18
cover	19
trough	20
membrane	21
cavity	22
walls	23

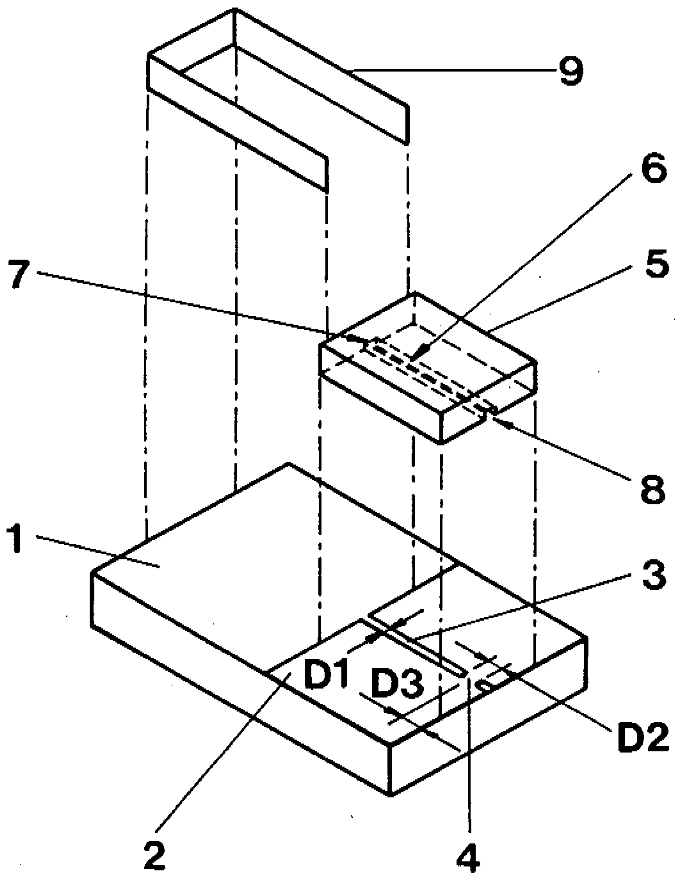

Fig. 1

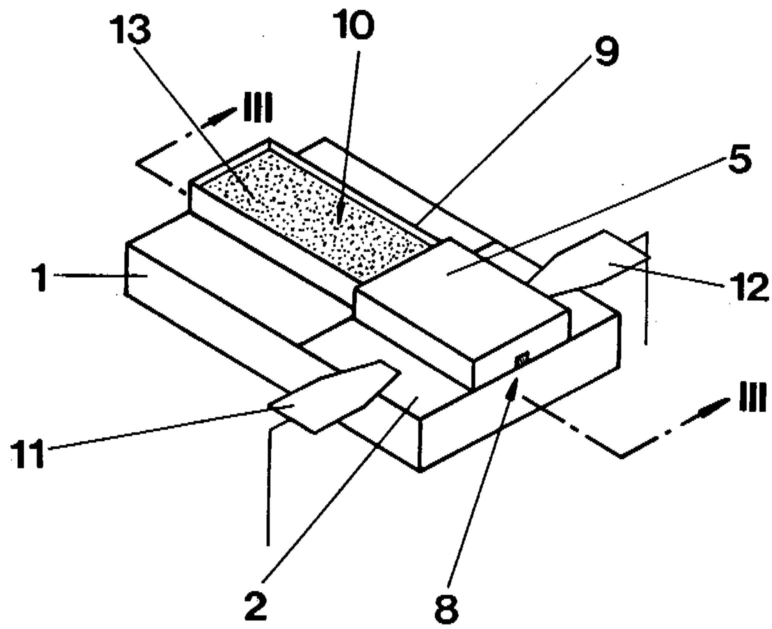

Fig. 2

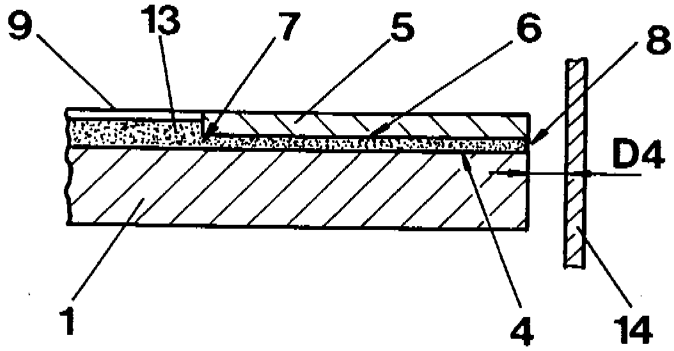

Fig. 3

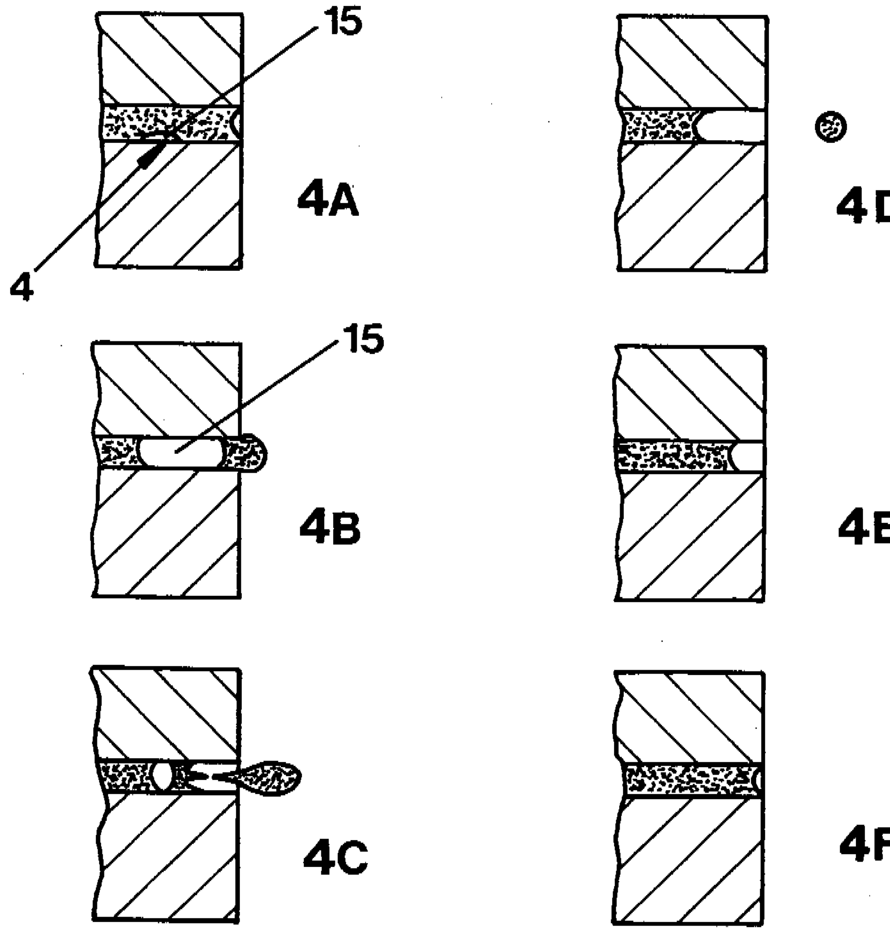

Fig. 4

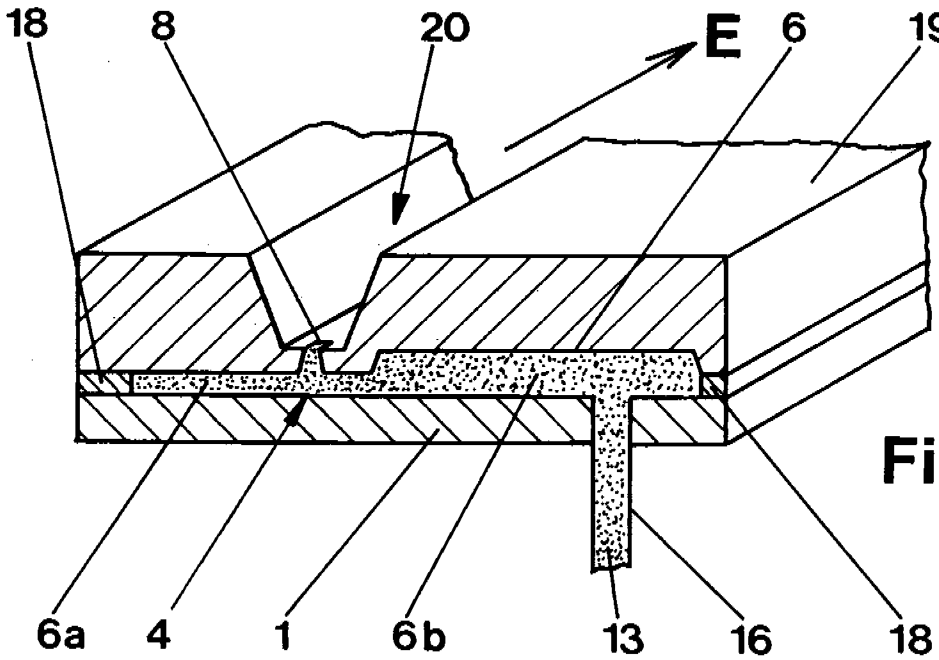

Fig. 7

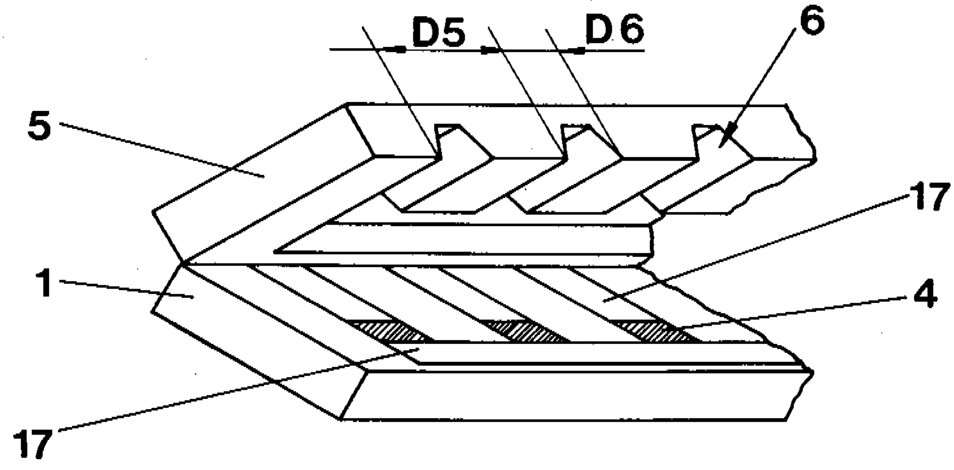

Fig. 5A

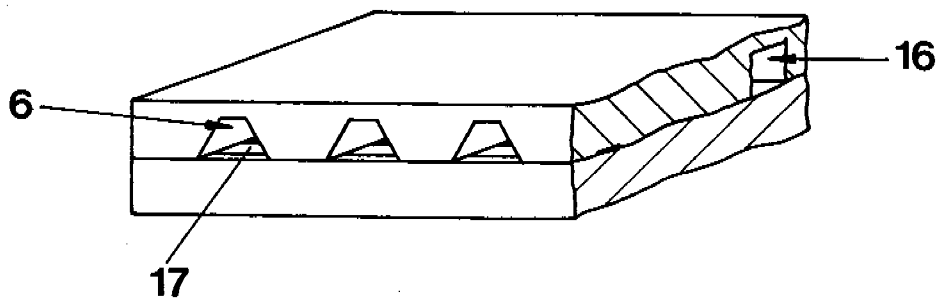

Fig. 5B

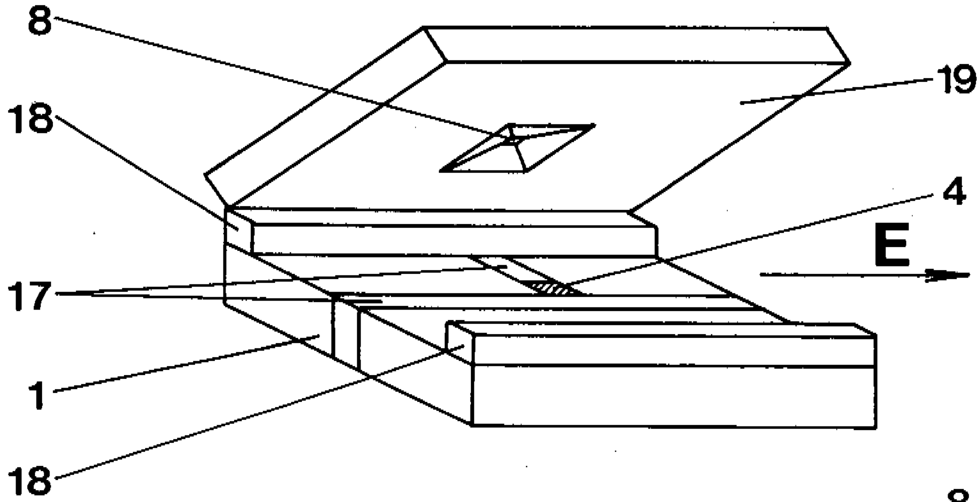

Fig. 6A

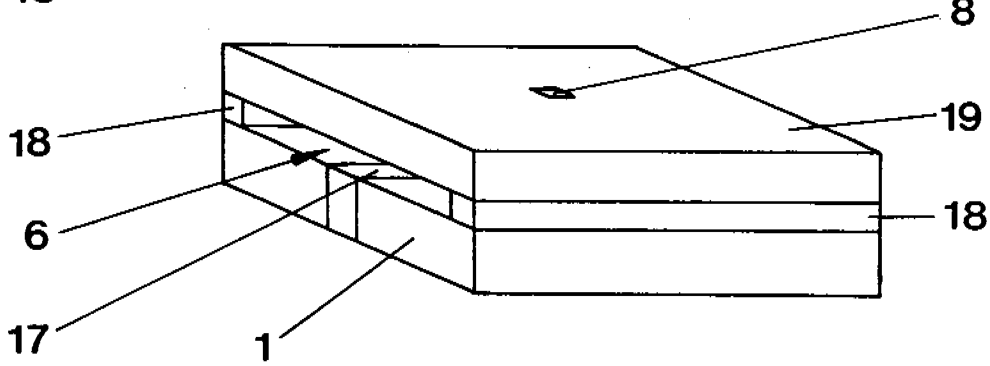

Fig. 6B

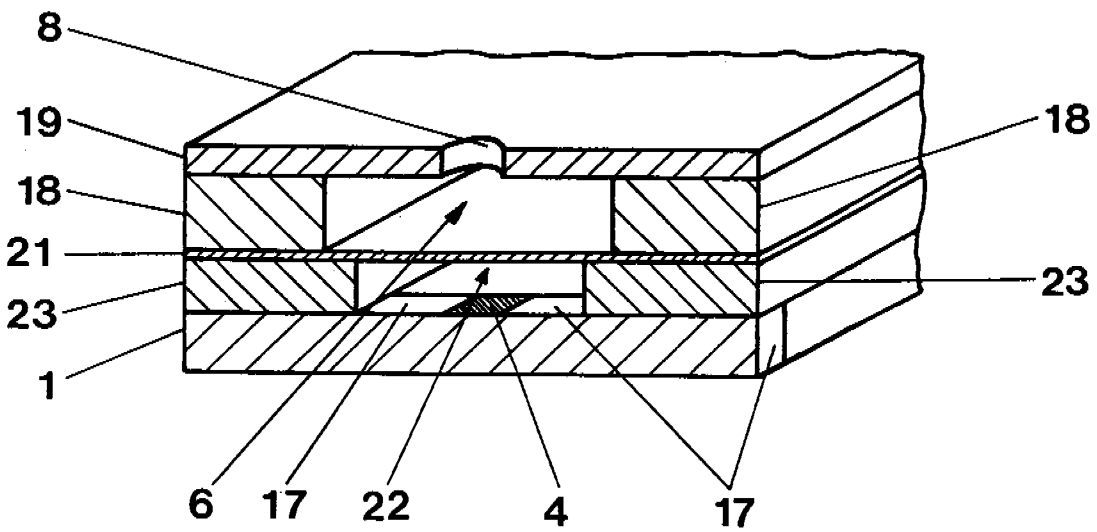

Fig. 8

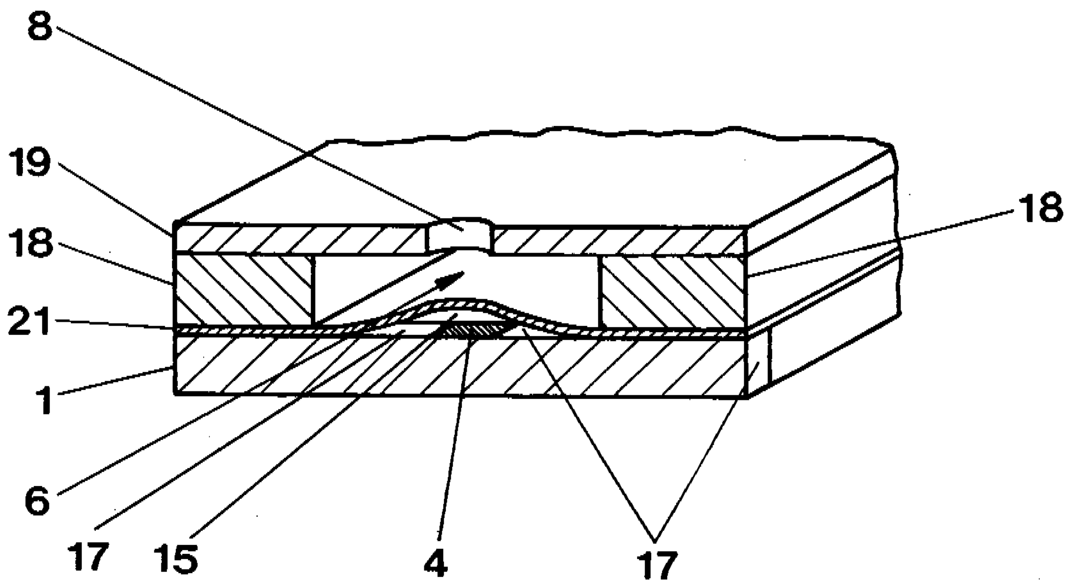

Fig. 9

DOCUMENT I (State of the Art)

The present invention relates to an ink jet printer and in particular to a nozzle head therefor. In the nozzle head to be described herein, the volume of a pump chamber containing ink is abruptly changed in response to an electric signal such that ink droplets are ejected from a nozzle hole.

The invention will be more closely described with respect to the appended drawings, in which:

Fig. 1 is a side view, partially in cross-section, of the nozzle head according to the invention,

Fig. 2 is a front view of the nozzle head according to the invention and

Fig. 3 is a schematic representation of an ink channel in cross-section along the line III-III of Fig. 1.

The nozzle head 1 consists of a base plate 2 and a flexible covering plate 3. In the base plate 2 there is formed an ink supply path 6 for supplying ink from a slightly pressurised ink tank (not shown) to an ink reservoir 5 through a supply pipe 4. From the ink reservoir 5 the ink reaches pump chambers 7 through flow paths 11 including fluid diodes 10. The fluid diodes 10 permit an ink flow towards the pump chambers 7 and prevent an ink flow from the pump chambers back to the reservoir. The pump chambers 7 are connected to nozzle holes 9 by means of flow paths 11a. The flexible covering plate 3 is joined onto the base plate 2 and electrorestrictive elements 12 such as piezoelectric crystals are mounted on the outer surface of the plate 3 at positions corresponding to the pump chambers 7.

When - under the control of the printer electronics - a voltage pulse +U as shown schematically in Fig. 3 is applied to one of the electrorestrictive elements 12, the element undergoes a deformation (which is indicated in Fig. 3 in chain-dotted lines). This deformation is transmitted to a portion of the flexible covering plate 3, whereby a pressure pulse is applied to the ink in the corresponding pump chamber 7. In this way, a progressive wave is generated in the ink in the pump chamber 7, one half of which heads towards the ink reservoir 5 but is blocked by the fluid diode 10, whilst the other half heads towards the nozzle hole 9 and ejects the ink in the form of a droplet 8 through the nozzle hole 9.

Each fluid diode 10 provided between the ink reservoir 5 and the respective pump chamber 7 consists of a heart-shaped barrier 13 which creates an impedance to flow towards the ink reservoir 5 which is considerably higher than that towards the nozzle hole 9. In this way, an efficient ejection of ink droplets out of the nozzle holes 9 is guaranteed.

It should be noted that two or more of the "one column matrix" nozzle heads of the type shown in Figs. 1 to 3 can be joined together in order to create a printing matrix with a higher number of nozzle holes.

DRAWINGS OF DOCUMENT I (State of the Art)

FIG. 1

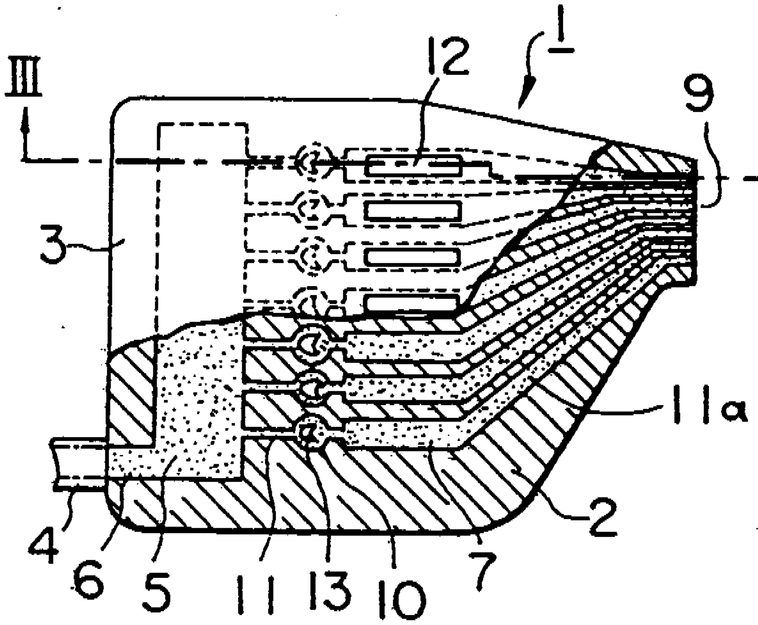

FIG. 2

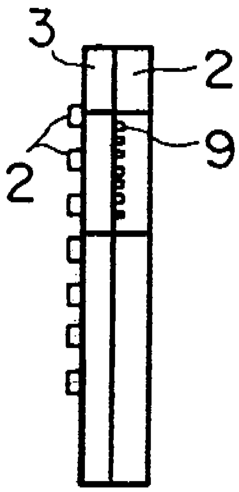

FIG. 3