

[54] **LIQUID JET PRINTER HAVING A DROPLET DETECTING DEVICE**

3,380,584 4/1968 Fulwyler 346/75 X

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[52] U.S. Cl. **346/75**

[51] Int. Cl. **G01d 15/18**

[58] Field of Search **346/75**

[56] **References Cited**

UNITED STATES PATENTS

3,060,429 10/1962 Winston 346/75 X

[57]

ABSTRACT

An ink jet printer includes a device for generating a pulse in response to a droplet formation or movement, in order to synchronize the operation of a deflection means or a pattern generating means of the ink jet printer with the pulse from the droplet detecting means. The ink droplet detecting means has an electro-conductive plate, which can be used as an accelerating electrode, and a resistor through which the electro-conductive plate is connected to a voltage supply for applying a voltage between the ink to be issued out and the electro-conductive plate.

12 Claims, 7 Drawing Figures

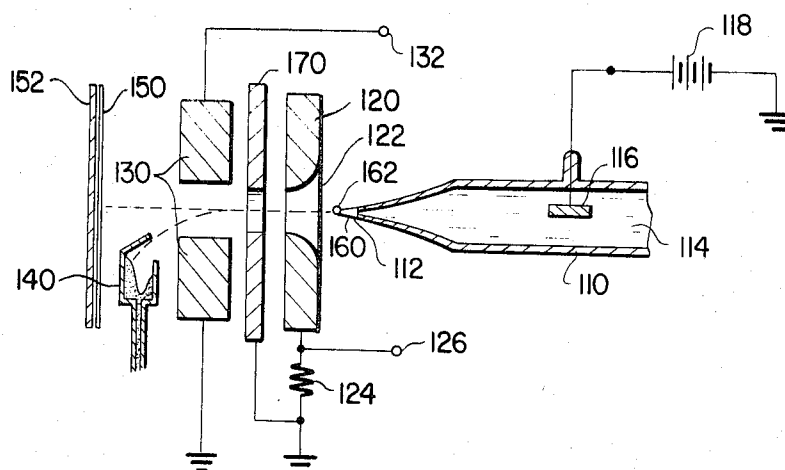


FIG. 1

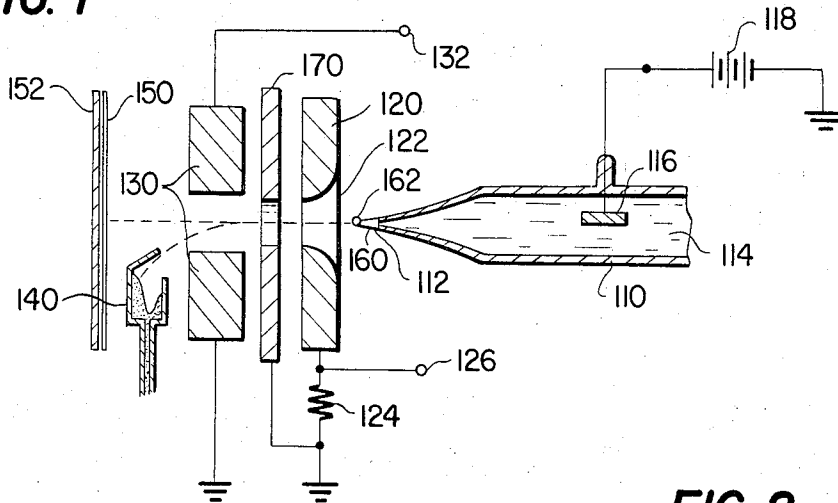


FIG. 2

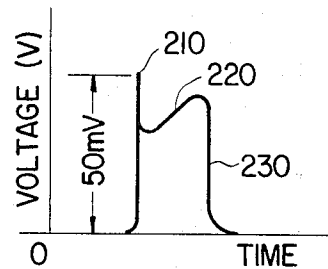


FIG. 3

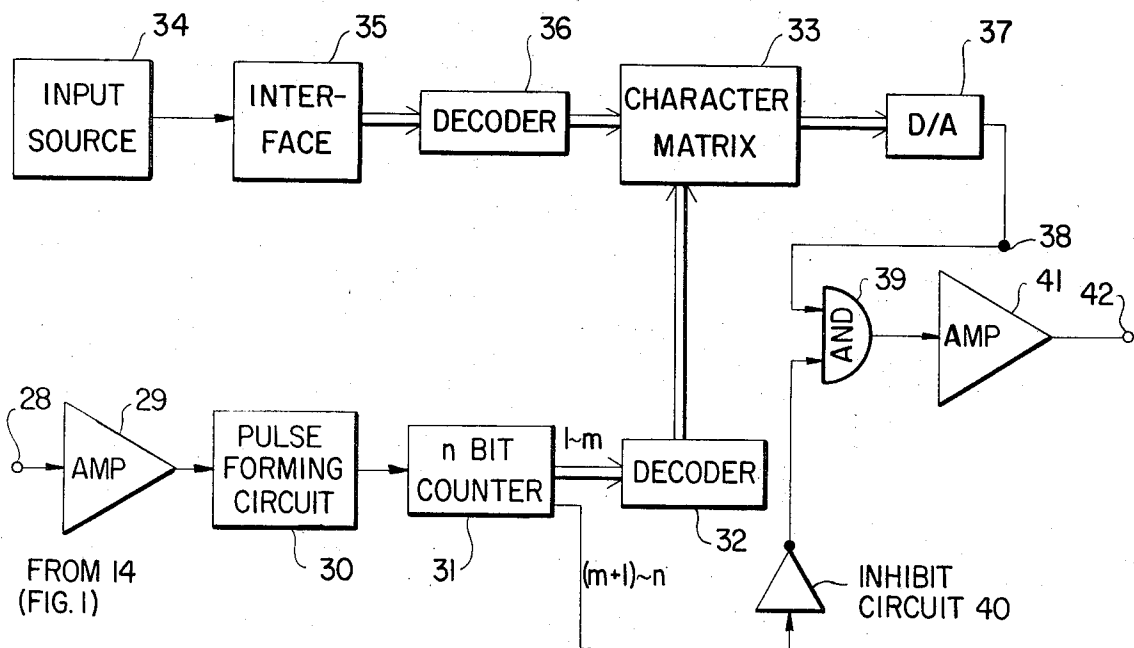


FIG. 4A

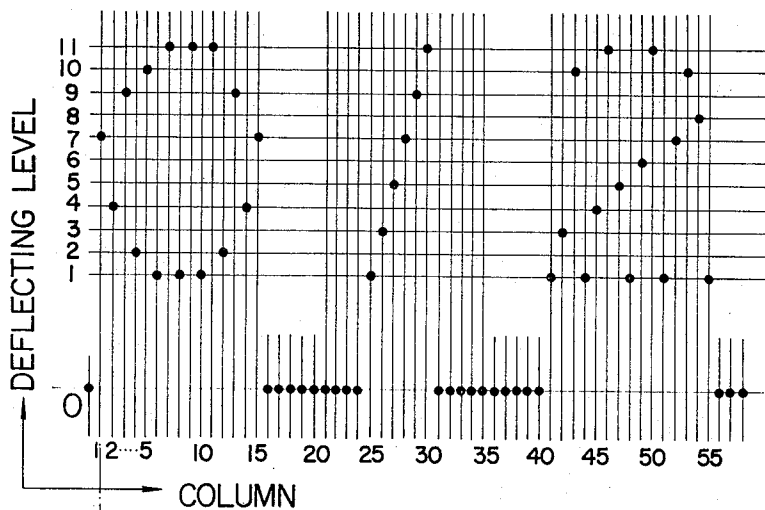


FIG. 4B

FIG. 4C

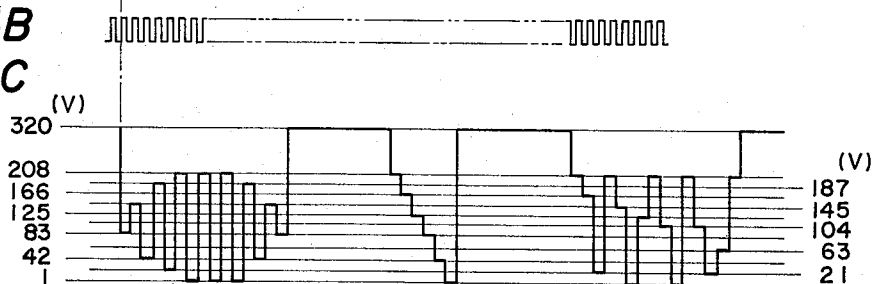
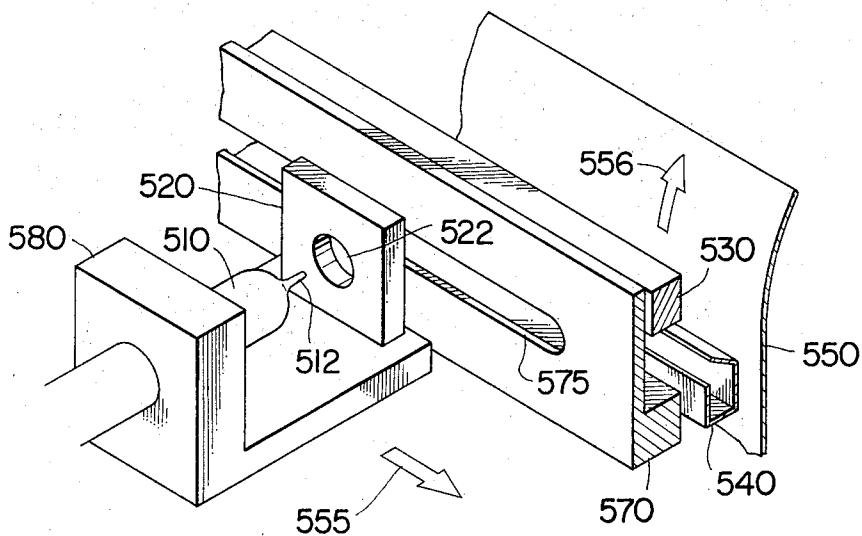


FIG. 5



LIQUID JET PRINTER HAVING A DROPLET DETECTING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a printing apparatus, and more particularly to an ink jet printing apparatus in which ink droplets are generated electrostatically and a signal for controlling the ink jet printing apparatus is generated in synchronization with the ink droplet formation.

2. Description of the Prior Art

In an electrostatic ink jet printer in which a stream of ink is extracted from a nozzle by an electrostatic potential existing between the nozzle and an accelerating plate, droplets are formed from the stream of the ink issuing from the nozzle on account of the surface tension of the ink itself.

The frequency and spacing of the droplets, however, are not constant during its recording, with the result that it is very difficult to accurately determine the timing of the formation of the droplets. Thus, it is impossible to control the deflecting means which must direct the printing in synchronism with the formation of the droplets. In a conventional electrostatic ink jet printer, the frequency of the ink droplet formation generally has no relation to the clock pulse which is used to advance operations of the deflecting means and other circuits used for deflecting the ink droplets which form desired characters on a recording medium. As a result, it is necessary to deflect the droplets producing a desired character on the recording medium in such a way that every character is written by one stroke. This is caused by the fact that the conventional ink jet printer has no detecting means for detecting the droplet formation and the operation for deflecting every droplet is independent of the timing of the droplet formation. Therefore, the control of the conventional deflecting means is very difficult, and consequently, the printed character is not clean and precise.

In addition, it is necessary to keep the printing speed at a low level because each element forming each character is produced by a few droplets, two or three droplets. If the operation speed of the deflecting means is selected at an average speed of the droplet formation, some part or element of the character will not be printed due to lag of the droplet formation. If it is possible that each element of the character is produced by only one ink droplet, the printing speed can reach a very high level.

In U.S. Pat. No. 3,579,245 granted to James M. Berry on May 18, 1971, and U.S. Pat. No. 3,689,936 granted to Robert J. Duulavey on Sept. 5, 1972, a sinusoidal electric potential is applied between the ink in the nozzle and the accelerating electrode in order to produce droplets in synchronization with the sinusoidal frequency, but it is very difficult to control the droplet formation of the ink. In this way, therefore, it is impossible that the element of the character is produced by only one ink droplet.

SUMMARY OF THE INVENTION

Object of the Invention

It is a first object of the present invention to provide a high speed ink jet printer where each droplet pro-

duces one of the elements of the character matrix to be printed on the recording medium.

It is a second object of the present invention to provide a high speed liquid jet printer having a droplet detector so that the operation of the deflecting means is synchronized with the output of the droplet detector.

It is a third object of the present invention to provide a liquid jet printer wherein the operation of the deflecting means is very simple.

Statement of the Invention

The ink jet printer of the present invention has a new droplet detector which generates a signal indicating the condition of the ink droplet formation and/or movement. The operation of the ink jet printer is controlled by receiving a signal from the droplet detector so that each element of the character matrix can be completely indicated by only one droplet. Since the operation of the electric circuits included in the ink jet printer is very much faster than the speed of the droplet formation, the operation of the electric circuit can be completed in the initial duration between the droplet formations and be held until the next formation is effected. When the droplet detecting device detects the formation or movement of the next droplet, the operation of the ink jet printer is advanced to the next stage, in order to deflect the next droplet toward a predetermined point.

The droplet detector has a means for detecting changes of electric field and a voltage generating means. A D.C. potential is applied between the nozzle and the detecting means. When a droplet having an electric charge is issued out from the nozzle and passes near the detecting means, the detector having a current or voltage generating means generates a pulse or signal. The detector can include a plate and a resistor in a simple case. In this case the plate of the droplet detector can be used as an accelerating electrode. In some cases, it can be used as another electrode, such as intermediate electrode.

In the present invention, it is possible to vibrate an ink stream from the nozzle in order to arrange the droplets issuing out from the nozzle.

In contrast to the conventional ink jet printer, the operation of the printer or the deflecting means of the present invention is controlled by a signal from the droplet detector, so as to operate in synchronization with the droplet formation.

In the above explanation, ink is referred to as the liquid for printing or recording characters on the recording medium, but the scope of the present invention is obviously not limited to the use of ink. It is possible to use color paint, chemical solution, etching solution and the like instead of ink. These facts will be easily recognized by those persons ordinarily skilled in the art and the printing apparatus using such liquid is mentioned to simplify the explanation of the present invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic view illustrating a liquid transferring device and a droplet detecting means of the present invention;

FIG. 2 is a voltage signal generated across the resistor 124 of FIG. 1;

FIG. 3 is a schematic block diagram of electric circuits of the liquid jet printer;

FIG. 4 is a diagram of patterns of characters and a deflecting voltage to be applied to the deflecting means of FIG. 1;

FIG. 5 is a perspective view of another embodiment of the liquid transferring device and the droplet detecting means of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a liquid transferring device of an electrostatic liquid jet printer has a nozzle 110 having an orifice 112 for issuing droplets of ink 114 and an accelerating electrode 120 having an opening 122 through which the ink droplets from the orifice 112 pass toward a recording medium 150 on a platen 152. A deflecting means 130 is provided between the accelerating electrode 120 and the recording medium 150 for deflecting the droplets from the orifice 112 in response to a deflecting voltage from a terminal 132. An ink catcher 140 is provided near the recording medium for catching the droplets which do not contribute to completion of characters.

A D.C. voltage supply 118 is connected between an electrode 116 submersed in the ink 114 and the accelerating electrode 120 through a resistor 124 and applies about 2K(V) ~ 5K(V) between them. The ink 114 is attracted toward the electrode 120 in the form of successive drops by the electric potential between the ink and the accelerating electrode 120 and the successive drops form a charged stream of the ink 114. The droplet 162 having a charge is separated from the charged ink 160 and passes through the opening 122 of electrode 120. During this time, the inductive voltage or inductive current generated by a changing of the electric field or electric flux created by the passage of the charged particles causes a small current to flow through the resistor 124.

The induced current is considered to be caused for the following two reasons.

1. When the ink droplet 162 separates from the stream of ink 160 it causes some change in the electric flux which extends from the accelerating plate 120 to the ink stream 160. It also causes a change of electric current, which is a so-called displacement current denoted by I_{ld}

$$I_{ld} = \partial D / \partial t$$

where D is the electric displacement.

2. A particle with some charge travelling with the velocity V toward the accelerating plate 120 induces current I_{ind} in the accelerating plate 120, that is

$$I_{ind} = kQV$$

where k is constant and Q is the charge on the particles. The total current I which we can observe is the sum of the foregoing two independent current components, i.e.,

$$I = I_{ld} + I_{ind}.$$

The waveform of the current is as shown in FIG. 2.

A voltage pulse resulting from the flow of this small current through the resistor is shown in FIG. 2. A peak 210 is caused by separation of the droplet 162 from the charged stream 160, and after the droplet has passed through the opening 122, the induction voltage falls, as shown by the curve at 230. When the supply voltage between the ink 114 and the acceleration electrode

120 is 2.7 KV and the resistor 124 is a non-inductive resistor having a value of 100 K ohms, a voltage wave having 50 mV peak-to-peak is generated across the resistor 124.

A shield plate 170 is provided between the electrode 120 and the deflecting means 130, in order to isolate the accelerating electrode from the affects of the deflection voltage. The deflecting voltage pulse is applied to the deflecting means 130 for deflecting the charge droplets. The change of this pulse voltage changes the electric field near the electrode 120 and causes noise voltages across the resistor 124.

The deflecting means 130 has a pair of electrodes for deflecting the droplets in only the vertical direction. The horizontal deflection may be caused by horizontal movement of the ink transferring device. It is also possible to deflect the droplets in two dimensions, i.e., in the horizontal and vertical directions, by two pairs of electrodes.

The electrode 120 is operated both as a droplet detecting means and an accelerating electrode, but it is possible to separate the electrode of the droplet detecting means from that of the accelerating electrode by provision of an accelerating electrode between the nozzle 110 and the droplet detecting means. The opening 122 of the electrode 120 follows a curved line along the droplet path in order to prevent the affects of divergence of electric flux.

Referring now to FIG. 3, which shows one embodiment of a character generating circuit, a pulse input terminal 28 is connected to the output terminal 126 of the droplet detecting means (FIG. 1) and receives the signal or pulse shown in FIG. 2. The pulse is amplified by an amplifier 29 and is applied to a pulse forming circuit 30 for forming the input from the amplifier 29 in rectangular waveform, which is required by the following circuit.

Since the output of the pulse forming circuit 30 has the same timing as the droplet formation and represents the condition of the droplet, a counter 31 is advanced by the output of the pulse forming circuit 30 in synchronization with the droplet formation to one count, whereupon it is reset. The n -bit counter 31 has two outputs, one output being connected to a decoder 32, the other being connected to an inhibit circuit 44. The output signal is applied to the decoder when the count value of the counter 31 is positioned from one to m , and when the count value is positioned from $(m + 1)$ to n , the output is applied to the inhibit circuit 40. In description of FIG. 4, the value of m is 15, and the value of n is 20, but these values may be changed with design of the characters. Namely, m is the number of columns or droplets which are needed for forming each character, and the value $(n - m)$ is the number of blank spaces between characters. The decoder decodes the output of the counter in synchronism with the timing of the ink droplet formation and applies its output in parallel to a character matrix circuit 33. The character matrix circuit 33 may take various forms, for example, a read only memory, a diode matrix, a wire memory, etc. Every type of such known memory is available for use with the present invention.

On the other hand, a conventional input/output interface 35 may have a storage means or buffer register for digital code representations of desired characters to be recorded and may interface with an input source 34, which is available in various conventional forms, such

as a conventional keyboard, punch tape reader, telephone line, computer calculator output or similar digital signal source.

The output of the interface 35 provides a parallel input to a conventional decoder circuit 36, which decodes and generates character signals as series parallel outputs, which indicates, in code signal, a character received by the input/output interface 35. The buffer register of the interface 35 transfers the output into the character matrix circuit 33 in synchronization with the output of the pulse forming circuit 30.

The character matrix circuit 33 receives the decoded signals both from the decoder 36 and the decoder 32, and determines the kind of characters and the number of the dot or element of the character matrix comprising the desired character.

According to these decoded inputs, the character matrix circuit 33 generates parallel coded outputs, which represent a deflecting voltage of each dot or element of the character matrix for recording the character. These parallel outputs of the character matrix circuit are applied to the conventional D-A converter in order to be converted to an analog signal representing the deflecting voltage.

The signal from the output terminal 38 of the converter 37 provides one of the inputs of the AND gate 39, the other input of which is made up of pulses from the $(m + 1)$ th (i.e., 16th) to n th (i.e., 20th) applied through inhibit circuit 40.

The combination of the AND gate 39 and the inhibit circuit 40 operates so as to pass any signals which are provided to the terminal 38 only when no signal exists on the input of the inhibit circuit 40, and when a signal exists on the input of the inhibit circuit 40, no signal passes through the AND gate 39.

The output of the AND gate 39 is connected to provide to the video amplifier 41 the analog value of the character element, and the output of the amplifier 41 is applied to the terminal 42, which is connected to the deflecting plate 130 of FIG. 1.

Reference will now be made to FIG. 4A, showing some of the recording forms of the alphanumeric characters, and to FIGS. 4B and 4C, showing a dot pulse train detected by said droplet detector and the waveform of the voltage applied to the deflecting electrode, respectively. The explanation will hereinafter refer to the example wherein a character "O" is selected as the character to be printed. Signals corresponding to character O are sent to the character matrix through the usual decoder from a selected input data processing device, such as a calculator or the like.

On the other hand, a series of dod pulses, as shown in FIG. 4B (detected by the droplet detector), are sent to the n -bit counter (having 20 bits in this example) to be counted therein. When the first dod pulse is counted by the n -bit counter, signals corresponding to this first dod pulse are also applied to the character matrix through the usual decoder.

As well known, in the character matrix these two kinds of input signals are selectively combined to produce a digit signal representing a deflection level corresponding to the first dod pulse. In this case the level is equal to 7 as shown in FIG. 4A. The digit signal representing the level 7 is converted to an analog voltage by the well known D-A converter, and the analog voltage is amplified by a given amplifier up to the value of 83

volts, as shown in FIG. 4C. The amplified voltage is supplied to the deflecting means, so that since the droplet of the ink has considerable charge, the droplet is deflected upon passing through the deflecting means by the predetermined displacement from the straight line.

The displacement at the recording medium (that is, when the droplet reaches it) must be equal to the level 7. The voltage of value of 83 volts is held till the next following dod pulse is counted by the n -bit counter.

When the second dod pulse from the droplet detector is counted, signals corresponding to the second dod pulse are applied to the character matrix again. The character matrix produces the digit signal corresponding to the second dod signal. The digit signal at this time has a deflection level 4, as is apparent from FIG. 4A, which corresponds to the analog voltage of 145 volts.

The low deflecting level number has a high voltage at the electrode 130, as indicated in the correspondence of the voltage to the level shown in FIG. 4C. For example, the deflecting level number "o" has a voltage of 320(V) at the electrode in order that the ink droplets are caught by the ink catcher 140.

Droplets corresponding to the columns 1 to 15 are used for composing a character to be printed and droplets corresponding to the column 16 to 20 are used as a space between the characters.

In the foregoing printer the printing medium such as a paper or the ink jet nozzle is moved in the horizontal direction and the space of each column is determined by that moving speed.

FIG. 5 is another embodiment of an ink transfer device in accordance with this invention. A nozzle 510 having an orifice 512 is provided on a scanning base 580 which can be moved by any conventional means, such as a motor (not shown), in a direction shown by arrow 555. An electrode 520 of a droplet detector is fixed on the insulating scanning base and connected to the ground through a resistor (not shown). A high D.C. voltage is applied between the electrode 520, having an opening 522, and the ink provided in nozzle 510 made of glass. A shield member 570 being grounded has a long opening 575 through which the droplets of ink are passed and a low side thereof is bent into an L shape and facing a deflecting electrode 530 to which the character signal, as shown in FIG. 4(C), is applied. An ink catcher 540 is provided in front of a recording medium 550.

The scanning base 580 having the nozzle 510 and the electrode 520 is mounted for scanning and is returned to the home position. All droplets from the orifice 512 are caught by the catcher 540 during the return stage and the recording medium or paper 550 is advanced by one line.

While we have shown and described two embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

What is claimed is:

1. In a liquid jet printer including a nozzle filled with a liquid for printing characters;

an accelerating electrode disposed adjacent said nozzle for producing droplets from the liquid in the nozzle and accelerating said droplets along a path;

memory means for storing information relating to the pattern of each of the characters to be printed; deflecting means for deflecting the droplets passing along said path in accordance with the information derived from said memory means; and a recording medium disposed opposite said nozzle for receiving the droplets deflected by said deflecting means; the improvement comprising droplet detecting means for generating signal pulses representing a condition of generation and movement of the droplet, said detecting means being arranged so that the generation and the movement of the droplet are detected before the droplet arrives at said deflecting means and means for applying the signal pulses of said detecting means to trigger said memory means to read out the information of the desired characters to be printed on said recording medium.

2. A liquid jet printer according to claim 1 wherein said droplet detecting means is provided between said nozzle and said deflecting means.

3. A liquid jet printer according to claim 2 wherein said droplet detecting means has an electrode provided along said path of the droplets which also forms said accelerating electrode, and a resistor connected with said electrode and to a D.C. supply for applying an accelerating voltage between said electrode and said liquid in the nozzle.

4. A liquid jet printer according to claim 3, further including shield means for shielding the electrode of the droplet detecting means from the electric field of said deflecting means.

5. A liquid jet printer according to claim 4 wherein the electrode of the liquid droplet detector has an

opening through which droplets from the nozzle pass toward said printing medium.

6. A liquid jet printer according to claim 3 wherein said resistor is a noninductive resistor.

7. A liquid jet printer according to claim 3, further including counter means for controlling said memory means in accordance with the signal pulses from the droplet detecting means.

8. A liquid jet printer in accordance with claim 5 wherein said accelerating electrode has an opening therein through which said droplets pass on said path to said recording medium, said opening in said electrode having a radially increasing diameter in the direction of said nozzle.

9. A liquid jet printer according to claim 3, further including delay circuit means for delaying said pulses from said droplet detecting means wherein said memory means is triggered by the delayed pulses.

10. A liquid jet printer according to claim 3 wherein said memory means includes a character matrix providing outputs relating to the pattern of each of the characters to be printed, input means connected to said character matrix for selecting a particular character, and timing means responsive to the signal pulses from said detector for triggering said character matrix to sequentially read out signals defining respective portions of the selected character.

11. A liquid jet printer according to claim 10 wherein said timing means includes a counter receiving said signal pulses from said detector and a decoder connected between said counter and said character matrix.

12. A liquid jet printer according to claim 11, further including inhibit means connected to the output of said counter for inhibiting the output of said character matrix during a selected portion of the count of said counter.

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