March 12, 1968 M. AUPHAN 3,373,436

INK JET RECORDER

Filed May 3, 1965 2 Sheets-Sheet 1

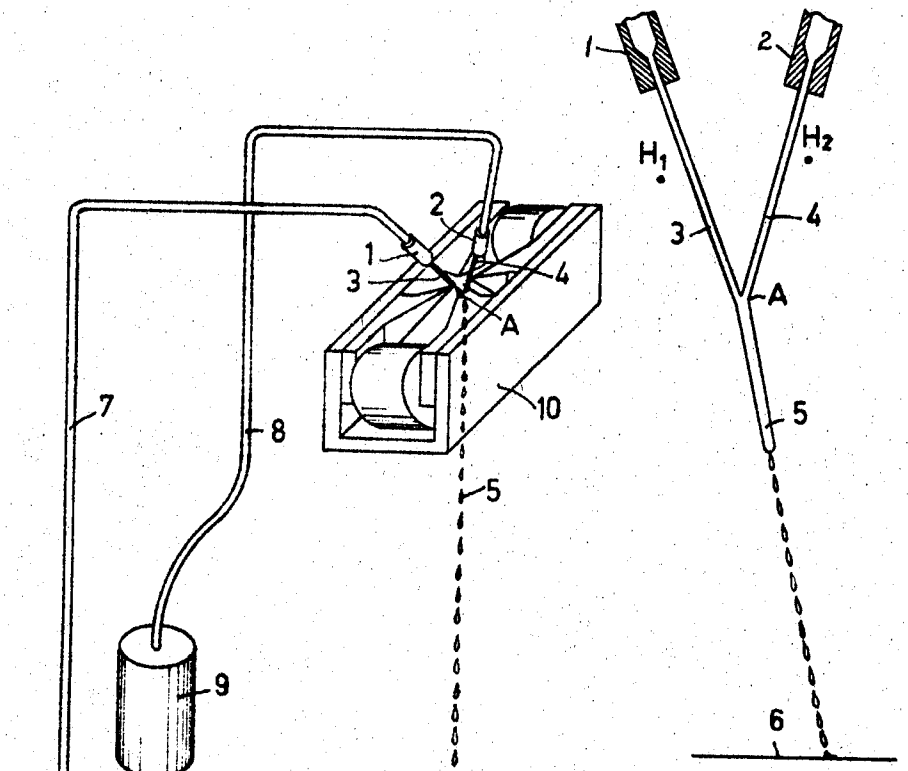


FIG.1

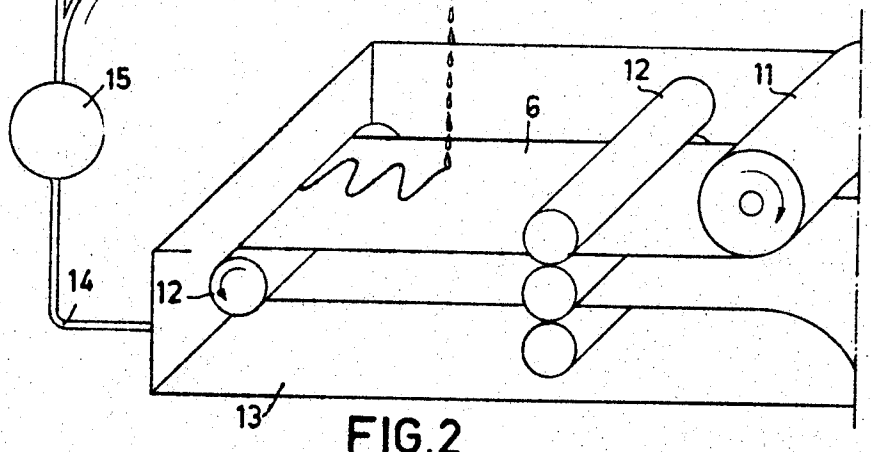


FIG.2

INVENTOR.
MICHEL AUPHAN

BY

Frank R. Trifari

AGENT

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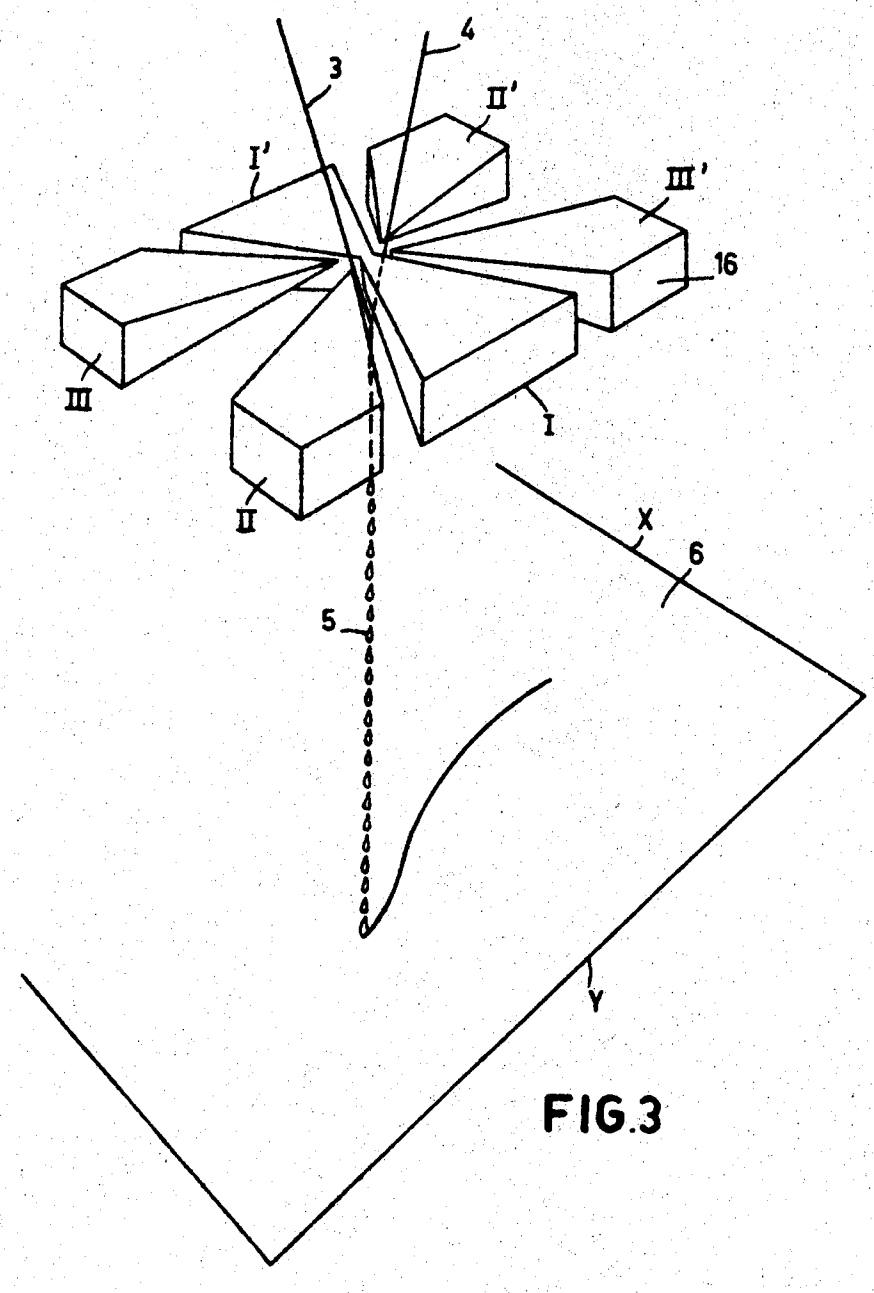


FIG.3

INVENTOR.
MICHEL AUPHAN

BY

Frank R. Trifari
AGENT

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INK JET RECORDER

Michel Auphan, Neuilly-sur-Seine, France, assignor to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

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9 Claims. (Cl. 346—75)

ABSTRACT OF THE DISCLOSURE

A recording apparatus for recording information on a surface employs electrically conductive fluid directed from a pair of nozzles closely arranged to one another and electrically insulated. The nozzles are positioned such that their axes intersect at a point between the nozzles and the recording surface and from this point travel as a single stream towards the recording surface. A potential difference is applied between the two nozzles and a gradient appears along the length of the stream from nozzle to nozzle. Movement of the single stream is controlled by means of a modulating signal applied as an electrostatic field to one of the streams.

The invention relates to apparatus for recording electrical signals and more particularly for visual recording of signals of high frequencies.

The conventional recording method using paper strips may be divided into two categories. The choice of the category depends upon the frequency of the signals to be recorded.

In a known device recording is obtained by applying ink to the paper, for example with the aid of a stylus or a jet of ink from a nozzle. The stylus or nozzle is then mechanically displaced in accordance with the variations of the signal to be recorded. Such mechanically controlled devices have a comparatively great inertia, so that recording is restricted to signals of a maximum frequency of about 100 c./s. with the stylus-controlled devices and a maximum of about 600 c./s. in the devices having a displaceable ink jet nozzle.

For signals of higher frequency, for example more than 1000 c./s. use is made of the second method, wherein signals are recorded on special paper of the photographic type which is rendered sensitive in accordance with the signals recorded. Such devices are expensive in operation owing to the price of the special paper. There are furthermore known devices having a liquid jet, which is formed by electrically charged particles directed towards a record carrier, which is displaced in a plane at right angles to the jet, the particles of the jet being deflected in an electric field in order to produce visual traces on the carrier. Such devices, which allow theoretically the recording of signals of high frequencies, are in practice very vulnerable. The greatest problem is formed by the electric charge of the jet and the use of very high electric voltages required (of the order of a few thousands of volts), so that voluminous output amplifiers are required.

The object of this invention is to obviate the aforesaid disadvantages and to provide a recording apparatus in which a conducting liquid jet is directed towards a recording surface and deflected so that a visual recording of signals of high frequencies is possible, while the record carrier to be employed is not too expensive.

According to the invention a recording apparatus comprises means for producing an electrically good conducting fluid stream or liquid jet directed towards a recording surface. A deflection field deflects the jet in accordance with the electric signals fed thereto. The apparatus comprises at least one pair of nozzles which are closely arranged and electrically insulated from each other, each supplying a liquid jet directed towards the recording surface. The position of the nozzles are such that their axes intersect each other at a point lying between the nozzles and the recording surface, so that the jets emanating from the nozzles meet at a given distance in front of the recording surface and from this meeting point travel as a single jet towards the recording surface. The apparatus further includes means for applying a potential difference between the liquid in one nozzle and that in the other nozzles of said pair, whereby in operation an electric current is caused to flow down one jet and via the meeting point up the other jet. Means are provided for producing at least one deflection field acting upon at least one of the two jets between the nozzle wherefrom it issues and its meeting point with the other jet.

In an advantageous embodiment of the invention there are provided means for producing two deflection fields, each acting upon one of the jets, the deflections of the two jets having the same direction.

In a further embodiment of the invention the potential difference between the two nozzles is variable in accordance with the electric signals to be recorded, while the deflection fields are stationary.

The apparatus according to the invention alternatively may be such that the potential difference between the two nozzles is constant, whereas the deflection field or fields is or are variable in accordance with the electric signals to be recorded.

With the embodiments referred to above, the recording surface is movable in a direction at right angles to the direction of the coinciding jets, so that the signals are recorded as a function of time.

In a further embodiment each jet is subjected to the effect of two orthogonal variable magnetic fields, one in the plane of the two jets and one in a plane at right angles thereto.

In the latter embodiment the jet can be deflected in two orthogonal directions, in which case the two deflections may be a function of time and of a signal to be recorded or both a function of two signals to be recorded each varying with time. In the latter case the recording surface may be stationary, so that the apparatus is operative like an oscillograph, the advantage being that a lasting oscillogram is obtained.

The invention will be described more fully with reference to the accompanying drawing, in which

FIG. 1 shows the basic diagram for explaining the operation of the device according to the invention.

FIG. 2 shows a device according to the invention comprising a movable recording surface.

FIG. 3 shows a second embodiment of the invention having a stationary recording surface.

Two nozzles **1** and **2**, to which a fluid or liquid conveying the electric current is fed, are arranged closely to each other in a mutually oblique position and produce two liquid jets **3** and **4** of small diameter (a few tenths of a mm.) directed towards a recording surface **6**, which is sensitive to said liquid. The two jets **3** and **4** meet at a point A lying at a small distance from the two nozzles in front of the surface **6**. Beyond said point A they form a single jet **5**, which is directed towards the surface **6**. The relative disposition of the nozzles is chosen so that the two jets coincide at a small distance from their point of starting. Beyond a given distance a jet will break up into small drops, so that the jet can no longer convey electric current, the meeting point of the jets **3** and **4** must therefore lie within said distance, where each of the two jets is still continuous.

In this way there is available a conducting liquid jet

between the nozzle 1, the meeting point A and the nozzle 2, while the jet 5 reaches the surface 6 in the form of droplets. Between the liquid in the nozzles 1 and 2 is applied an electrical potential difference, so that the two jets 3 and 4 are traversed by electric current in opposite directions.

The two jets 3 and 4 are subjected each to a preferably magnetic deflection field H_1 and H_2 respectively, which may be at right angles to the plane going through the jets 3 and 4 and have opposite directions. Each of the jets 3 and 4 is thus subjected to a deflecting force at right angles to the field and jet directions. Since the directions of the two fields H_1 and H_2 are opposite, the jets 3 and 4 are deflected in the same direction and the deflection of the jet 5 is proportional to the sum of the deflections of said jets.

If the forces exerted on the jets 3 and 4 are variable as a function of the signal to be recorded—for example due to the potential difference between the nozzles 1 and 2 or the strengths of the deflection fields H_1 and H_2 being dependent upon the signal to be recorded—the variations of the signal are recorded as a function of time on the record carrier 6, if the latter performs a translatory movement in a plane at right angles to the jets.

FIG. 2 shows an embodiment of an apparatus based on the principle exposed above.

The nozzles 1 and 2 which are accurately identical in order to obtain a satisfactory equality between the jets 3 and 4, receive a liquid under pressure from two supply ducts 7 and 8 respectively, which are electrically insulated from each other. By the interposition of a device 9 interrupting or substantially interrupting the electric current through the liquid in one of the ducts, said ducts are coupled with a common pressurized container 15. The device 9 may be formed for example by a kind of overflow or a narrow capillary tube, in which case it is advantageous to include an identical capillary tube in the other duct.

The liquid may be formed by any conductive substance, preferably a substance which is liquid at room temperature, for example mercury or gallium.

The two jets 3 and 4, which meet at point A, traverse a magnetic yoke 10, which is arranged so that two magnetic fields H_1 and H_2 are produced in opposite directions at right angles to the plane going through the jets.

The velocity of the liquid jets 3 and 4 is subject to a lower limit determined by the length of the regions where the deflection fields H_1 and H_2 act upon said jets. The time required by the liquid particles to traverse the magnetic field must be shorter than the period of the signal to be recorded, since the same particle must not be affected in two opposite directions by two successive signals, which might produce a zero deflection resultant. The single jet 5 is directed towards the recording surface 6, which performs in known manner a translatory movement at right angles to the plane going through the jets 3 and 4.

When mercury is used, this recording surface may be formed by porous paper into which the fine mercury droplets are injected, so that they become visible in the form of a black trace. The paper may be preliminarily treated with a sulphide. In this case the sulphur may be caused to combine with the mercury by a subsequent thermal treatment at the melting temperature of sulphur, so that a black trace of mercury sulphide is produced.

The paper, preferably impregnated with sulphide, travels from a roller 11 through drawing rollers 12 over a trough 13, used for collecting the excess quantity of jet liquid.

The trough 13 communicates through a duct 14 with a pump which may be connected with the pressurized container 15, from where the ducts 7 and 8 are fed, so that the liquid can circulate. In order to ensure that only pure liquid is employed and in order to avoid obturation of the nozzles, which have only very small apertures, the ducts may be provided with filters (not shown) for example near the container 15.

The signal to be recorded may in the form of potential difference varying with time be applied between the two ducts 7 and 8, i.e. between the two jets 3 and 4. In this case the magnetic deflection fields may exhibit a constant magnitude. This provides a deflection of the jet 5 proportional to any variation of the signal, so that the jet 5 draws the waveform of the signal to be recorded on the paper 6. Since the jet 5 reaches the paper in the form of droplets, a signal of high frequency will give a record in the form of a dotted trace, whereas at lower frequencies the dots are so close to one another that the track appears as an uninterrupted line.

In the embodiment described above the signal to be recorded is applied to the jets in the form of a variable potential difference, but it will be obvious that the signal to be recorded may also be applied to energizing coils producing the deflection fields H_1 and H_2, so that these fields H_1 and H_2 vary with the signals to be recorded, whereas the electric current through the coinciding jets 3 and 4 is kept constant.

In the foregoing a deflection of the jet in only one direction is considered. FIG. 3 shows an embodiment of a deflection method in which the jets are deflected in two orthogonal directions O_x and O_y by two signals, one of the signals being for example a time-base signal. The two signals are preferably dependent upon time, so that the apparatus operates like an oscillograph. Then a visible and lasting track in the form of an oscillogram is obtained. In this case the potential difference between the two jets 3 and 4 and hence the electric current through said jets are preferably kept constant. On the other hand, it is well possible to have both the deflection fields vary sinusoidally with time, while the signal to be recorded is caused to modulate the electric current through the two jets 3 and 4. In that case the signal is recorded in the form of a deviation from the track, which would be recorded by the jet 5 when a constant electric current is sent through the jets. The magnetic fields operate together as time base, and one may, for example give a circular track.

The magnetic deflection fields are generated by an electromagnet 16 of a special type, since it has six poles. For the sake of clarity in FIG. 3 only the magnet poles are shown. The poles I and I' of this circuit are interconnected at the center of the system, whereas the poles II, III, II' and III' are separated from each other. The jet 3 passes in between the poles II, III and I–I' and the jet 5 passes in between the poles II', III' and I–I'. A magnetic energization of the pole II relative to pole III and of the pole II' relative to III produces a deflection in the direction Y, whereas a magnetic energization of the pole I–I' relative to II+III and II'+III' produces a deflection in the direction X. To this end the pole pieces are connected on the outer side by a system of magnetic cores with at least two separate coils, which are traversed by suitable currents in order to obtain the desired effect.

The two jets 3 and 4, which carry a constant current, are subjected to variable magnetic fields due to the variable voltages to be recorded.

Numerous variants of the embodiments described above are possible within the scope of the invention. Use may be made of a magnetic circuit producing two deflection fields in the plane going through the jets. Thus a deflection is produced in a perpendicular plane, whilst the translatory movement of the recording surface is then performed in the plane going through the jets. It is also possible to reduce the quantity of liquid supplied by the nozzles so that the liquid is absorbed by the paper, in which case the liquid circulating device may be omitted.

What is claimed is:

1. A recording device comprising means for directing a jet of electrically conductive fluid towards a recording surface, said means including at least one pair of elec-

trically separated and adjacently arranged nozzles each adapted to have issued therefrom a fluid jet generally directed towards said recording surface, the nozzles of said pair being mutually positioned such that their respective axes intersect at a point in the space between said nozzles and said recording surface, said jets issuing from said nozzles meeting at a point in front of said recording surface to form a single jet and from said meeting point traveling towards said recording surface, means for applying an electrical potential between each of said pair of nozzles, and means for generating a magnetic deflection field so as to deflect at least one of said jets, thereby giving said jet a movement controllable in accordance with the relative strength variation between said field and said electric potential.

2. A recording device as claimed in claim 1 wherein said means for generating a magnetic deflection field includes means for generating a magnetic deflection field for each of the intersecting jets issuing from said pair of nozzles, said deflection fields being adapted to deflect both jets simultaneously in the same direction.

3. A recording device as claimed in claim 1 wherein said deflection field is perpendicular to and crosses said jet.

4. A recording device as claimed in claim 1 wherein said means for generating a magnetic detection field includes means for generating a deflection field for each of the intersecting jets issuing from said pair of nozzles, said deflection fields being adapted to deflect each of said jets in opposite directions along parallel planes.

5. Recording device as claimed in claim 1 wherein the said jet fluid is mercury and the said recording surface is a porous foil material impregnated with a sulphite.

6. Recording device as claimed in claim 1 wherein the electric voltage applied between the jet liquids in the pair of nozzles is varied in accordance with electrical signals to be recorded.

7. Recording device as claimed in claim 1 wherein the deflection field acting upon said jets issuing from said pair of nozzles is varied in accordance with electric signals to be recorded.

8. Recording device as claimed in claim 1 wherein said deflection field comprises two perpendicular variable magnetic fields, one in the plane of the jets and one perpendicular thereto, the parallel extending fields cooperating each with a different one of the said jets being oppositely sensed.

9. Recording device as claimed in claim 1 further including means for moving the recording surface in a direction perpendicular to the plane of the intersecting jets.

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RICHARD B. WILKINSON, *Primary Examiner.*

J. W. HARTARY, *Assistant Examiner.*