

[54] INK JET PRINTER

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[51] Int. Cl. G01d 15/18, B41j 3/04, G06k 15/02

[58] Field of Search 346/75, 79, 139 D, 140; 197/133 R, 1 R

[56] References Cited

UNITED STATES PATENTS

1,819,197	8/1931	Ranger.....	346/75 X
2,512,743	6/1950	Hansell	346/75 X

Primary Examiner—Joseph W. Hartary
Attorney, Agent, or Firm—Gerald R. Gugger et al.

[57] ABSTRACT

An ink jet printing system which writes on a record medium by expelling droplets of liquid ink from the cavity of a jet head which is reciprocated repetitively along the printing line. A piezoelectric transducer is used to generate ink droplets on demand under control of suitable storage and character generating equipment. Characters are formed by generating dots in a 5×7 matrix as the head traverses back and forth. The record medium is stationary during printing and is advanced one row space at the completion of each horizontal row of dots and also one line space at the completion of each row of characters.

7 Claims, 9 Drawing Figures

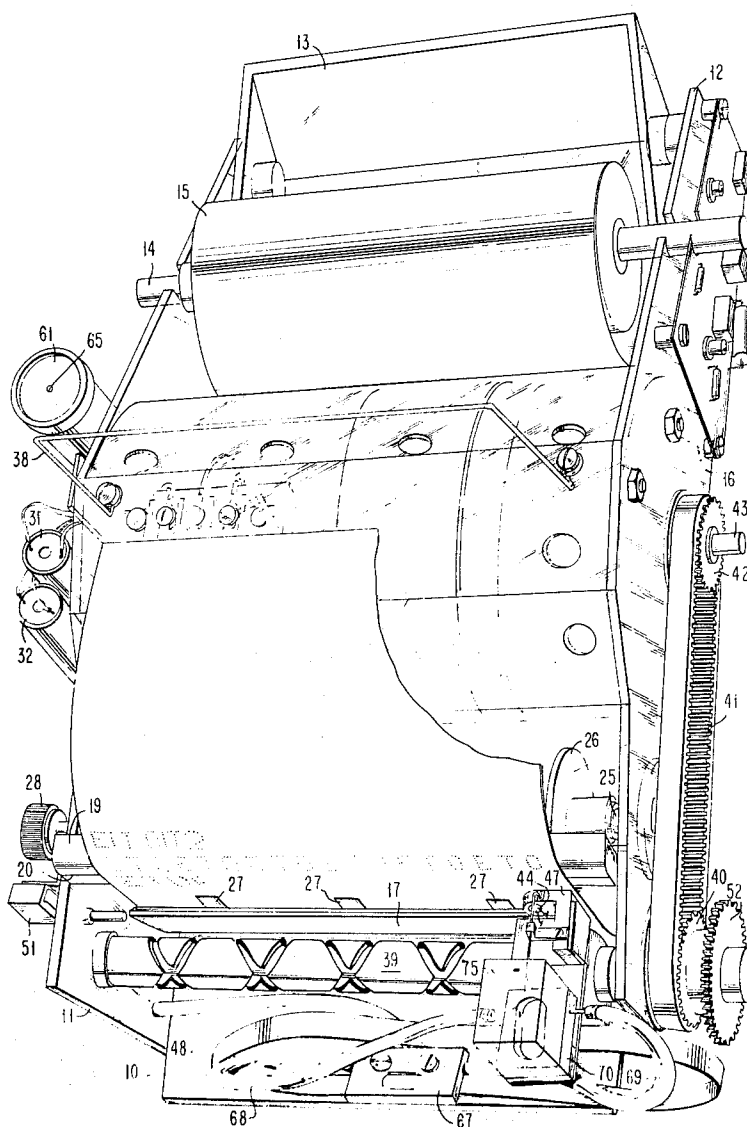
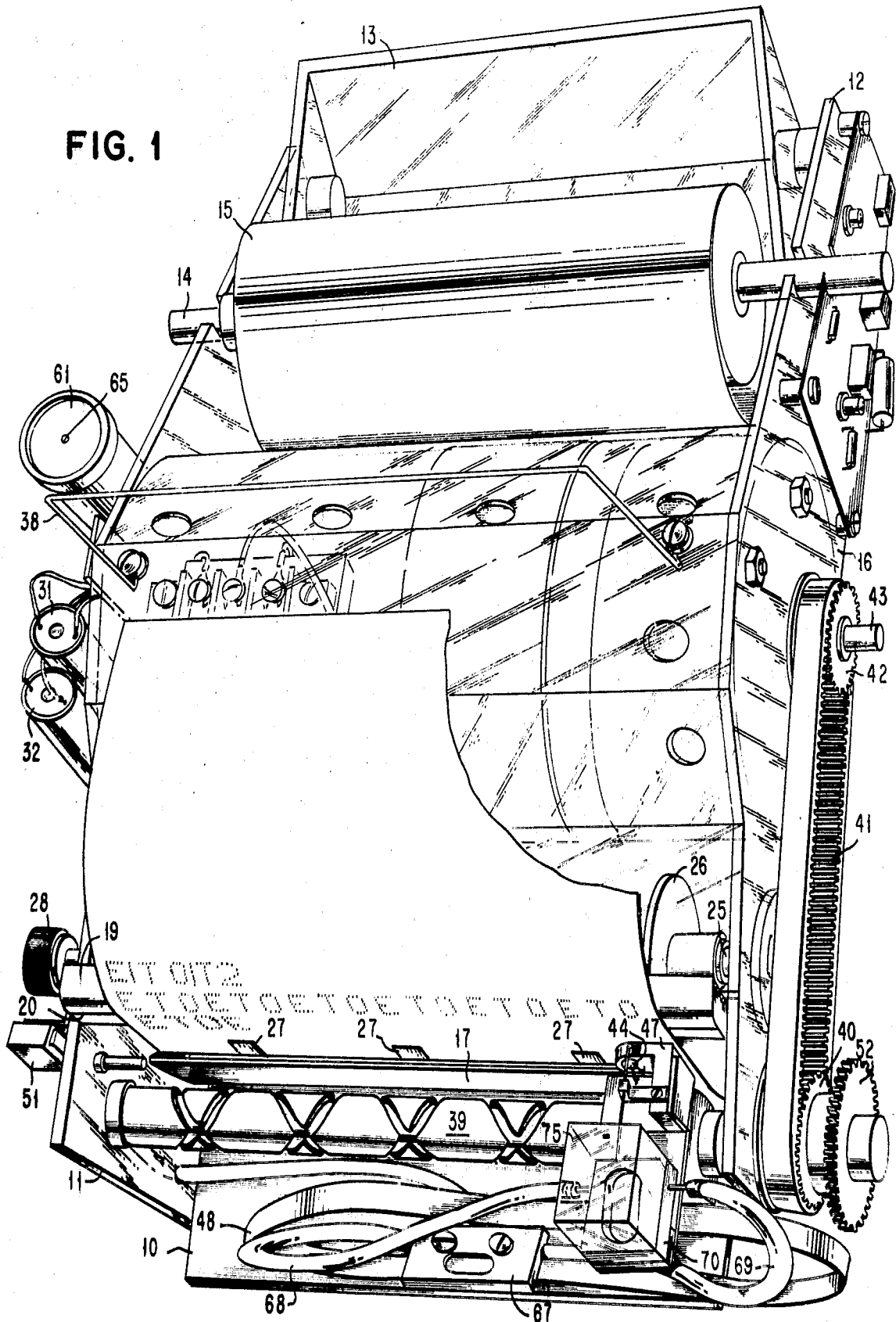


FIG. 1



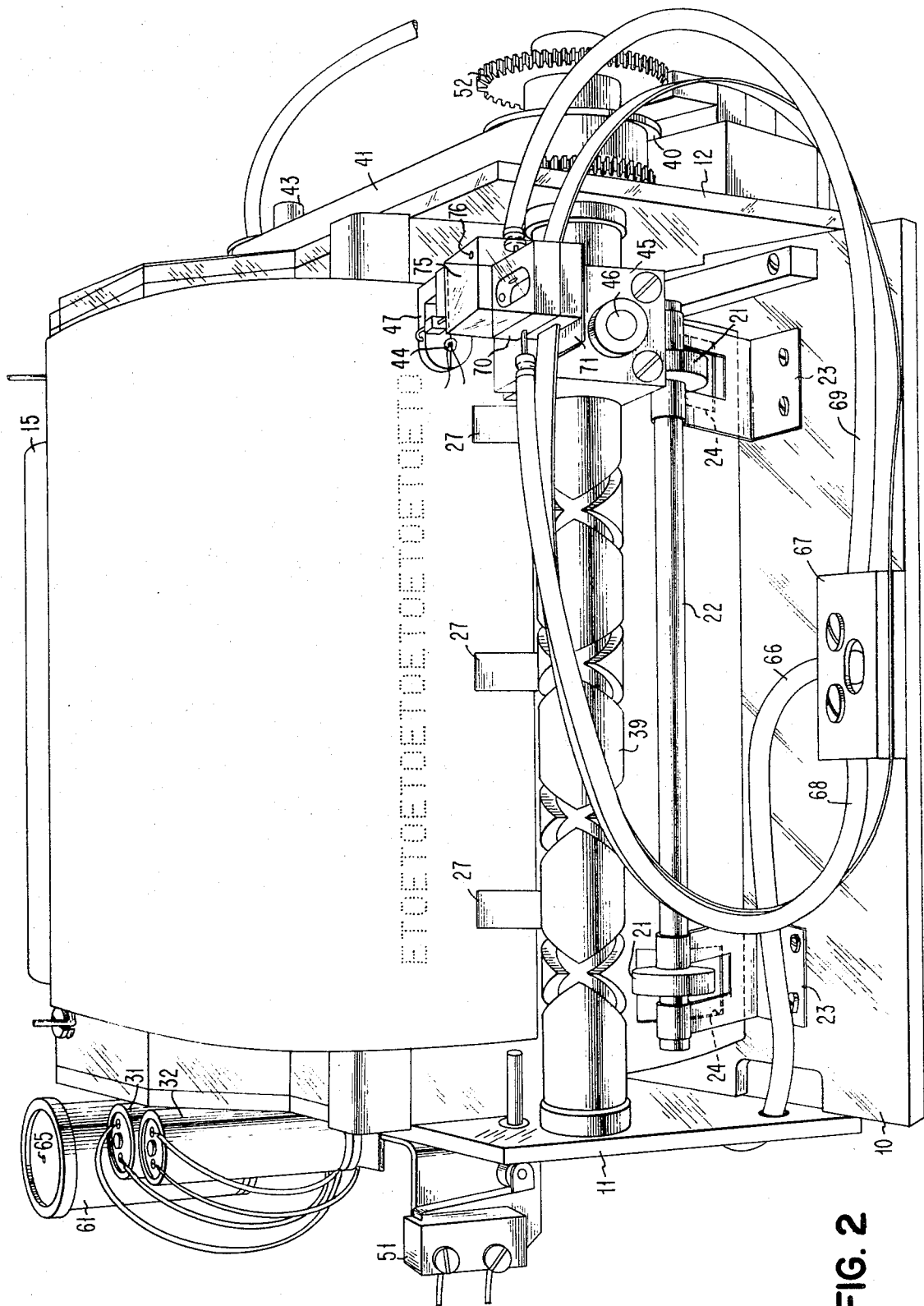


FIG. 2

FIG. 3

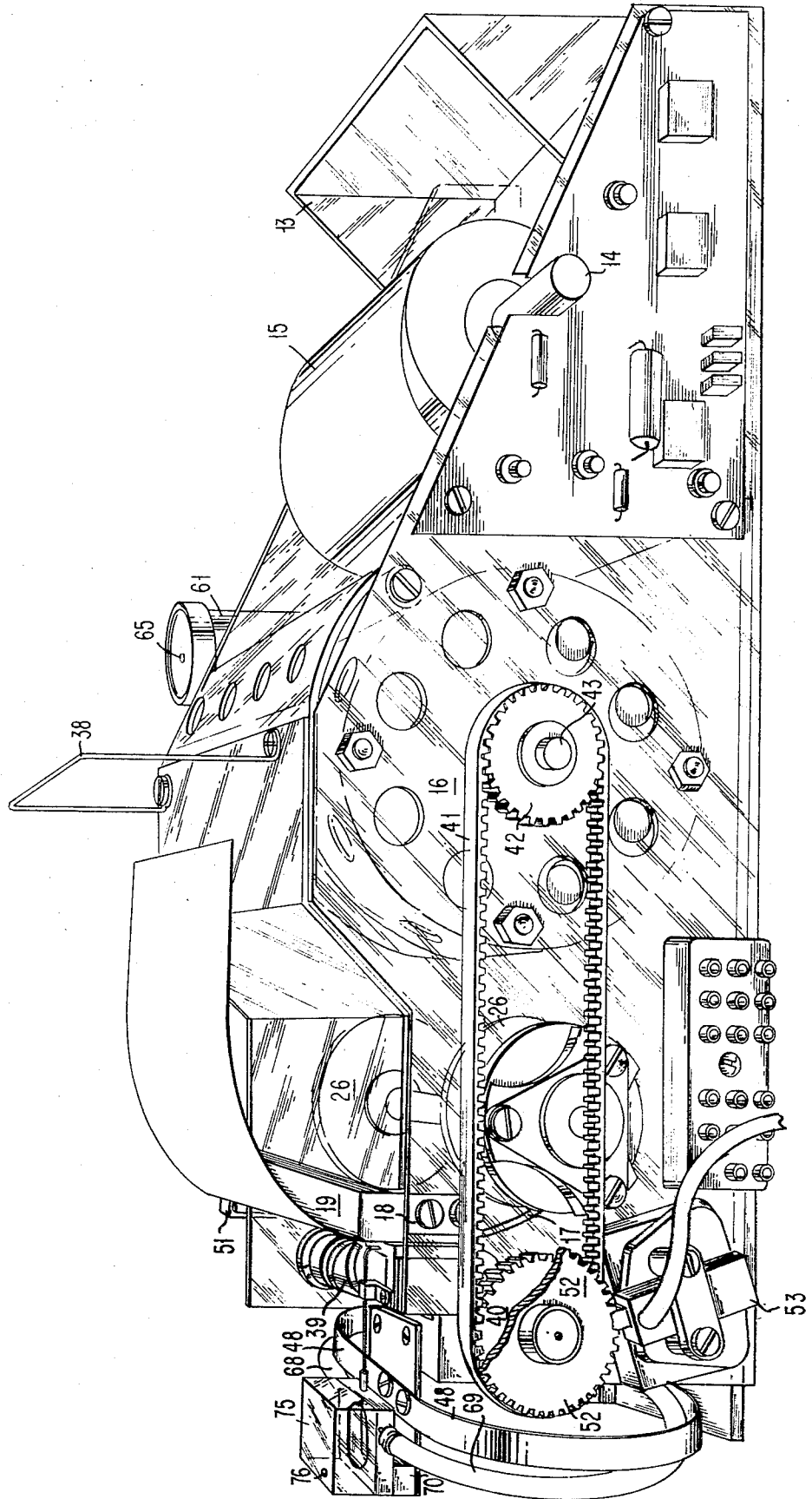
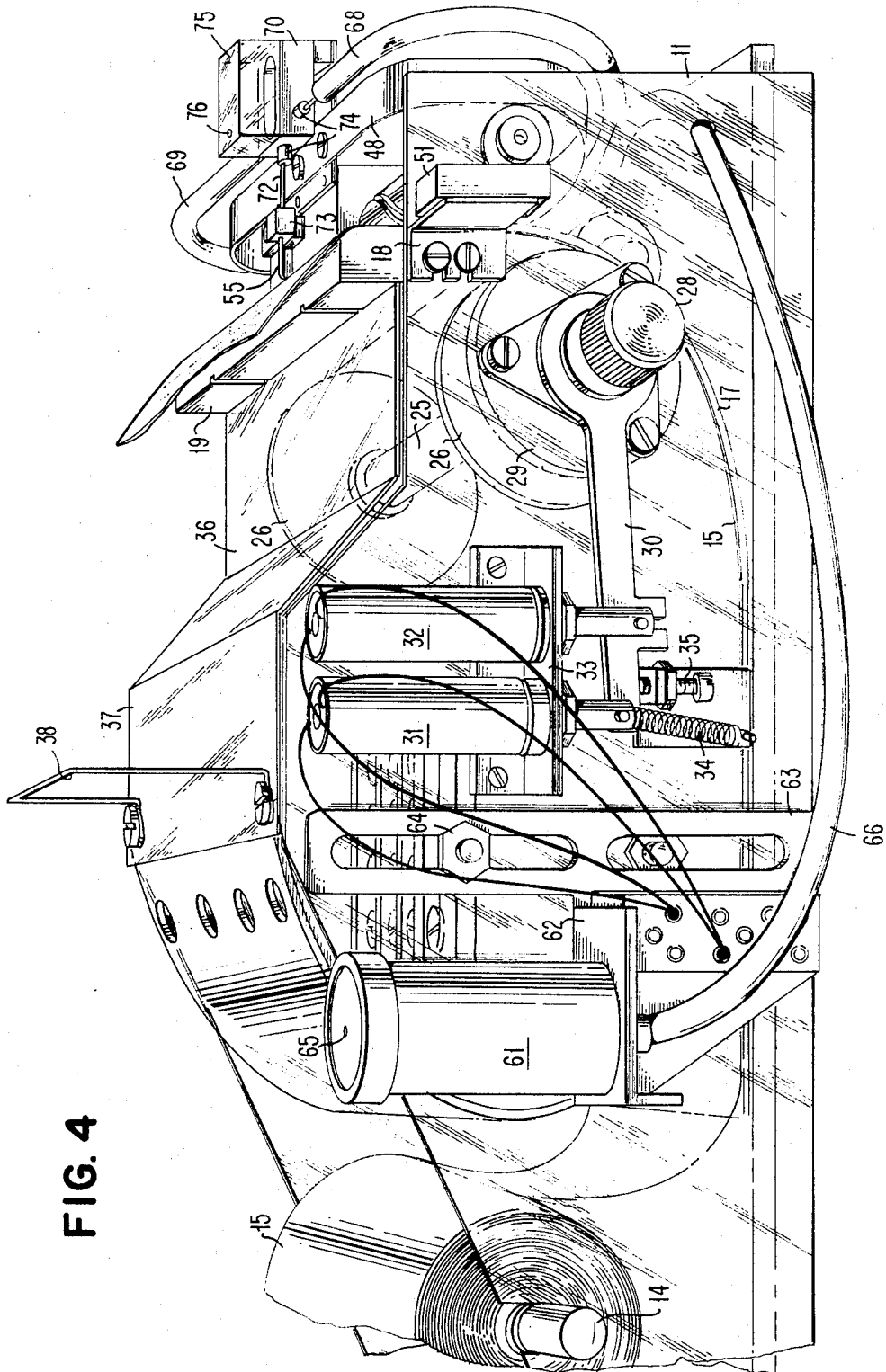


FIG. 4



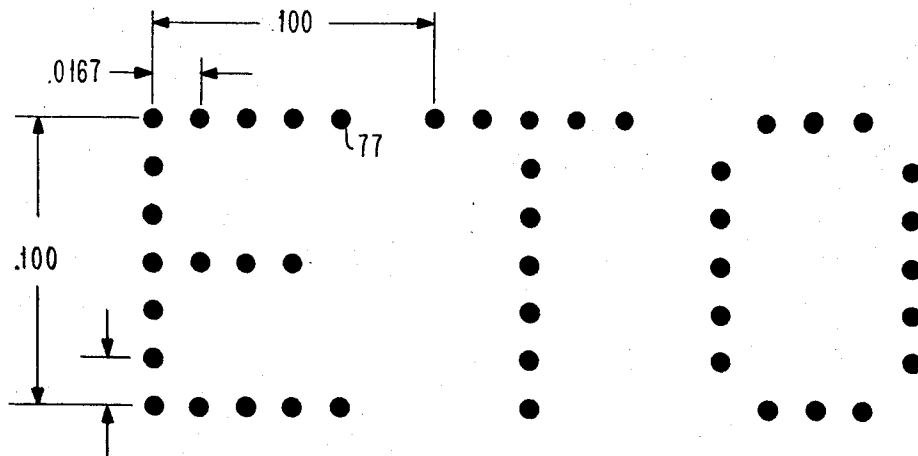
CRT - HARD COPY

1. TV-LIKE CHARACTER GENERATION

"OIL CAN" JET = ELECTRONIC GUN

120 v - 250 μ sec. = UNBLANK PULSE

2. CHARACTER FORMATION IN 5x7 MATRIX



3. MECHANICAL SCAN PROVIDED JET

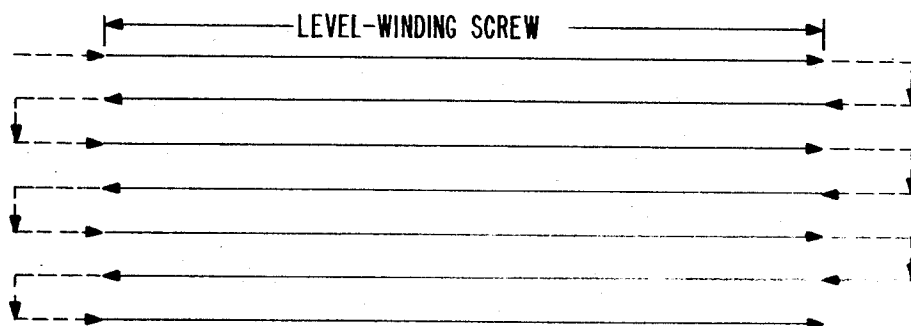


FIG. 5

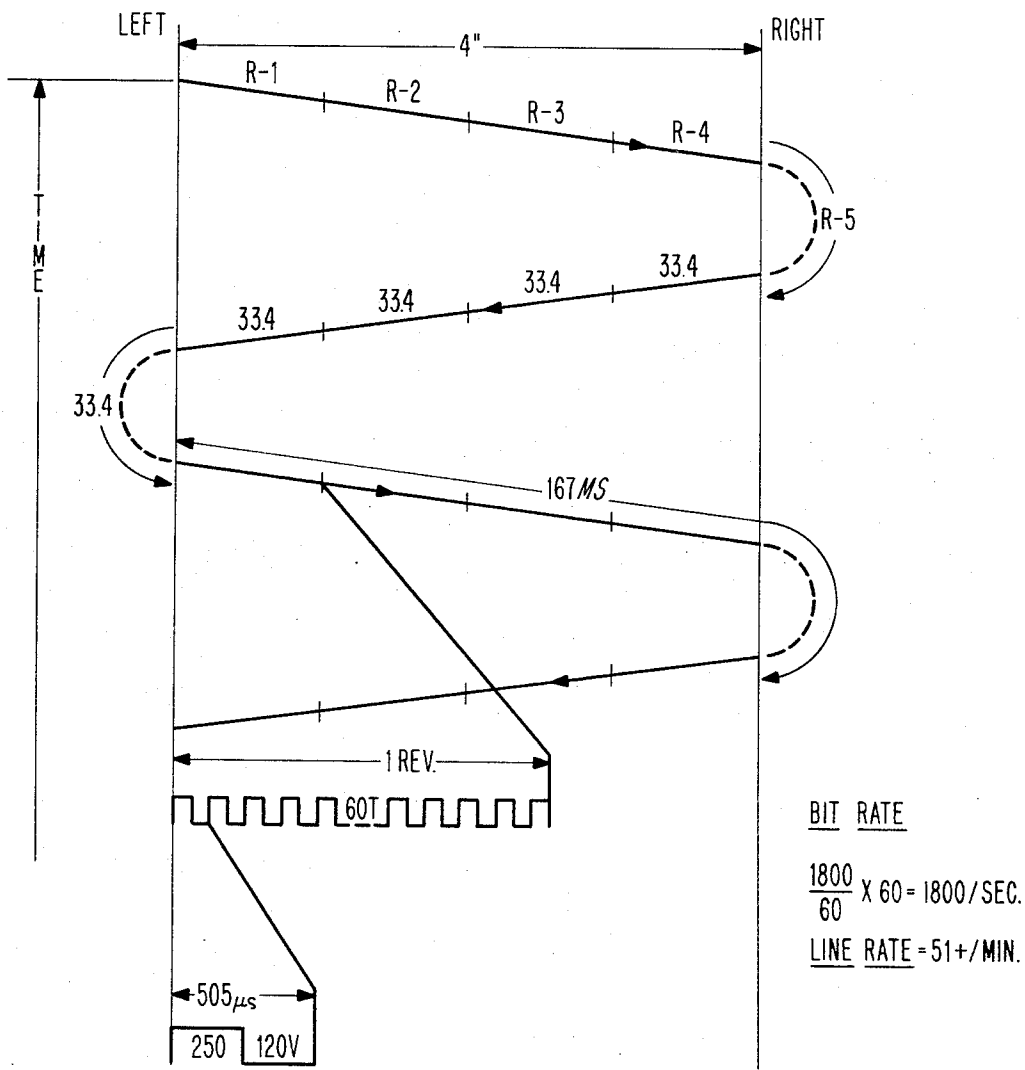


FIG. 6

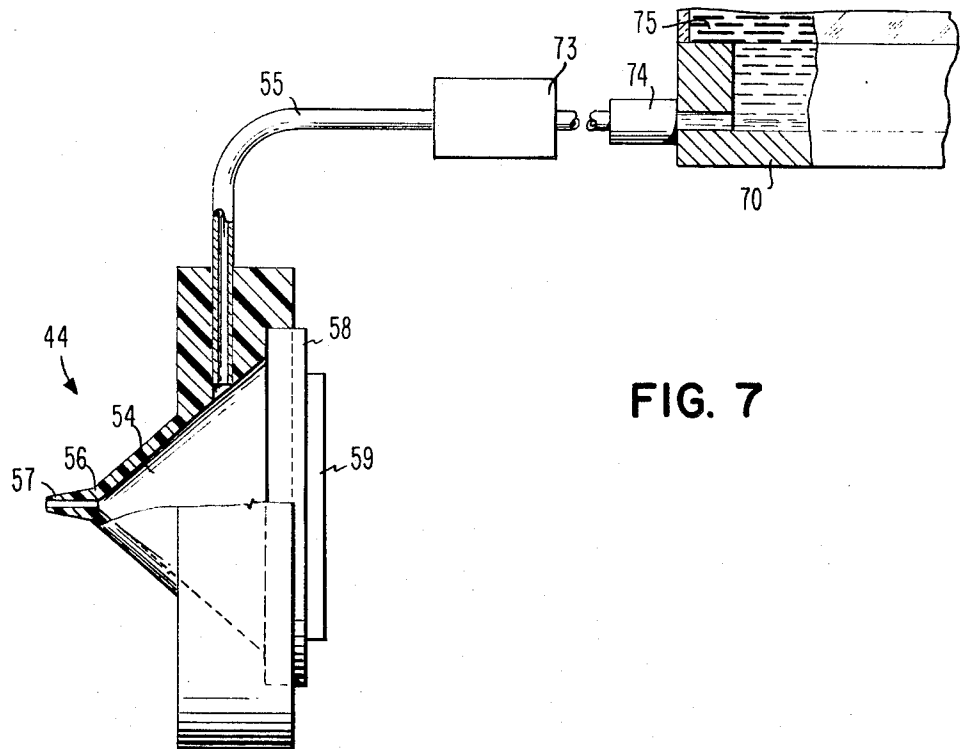


FIG. 7

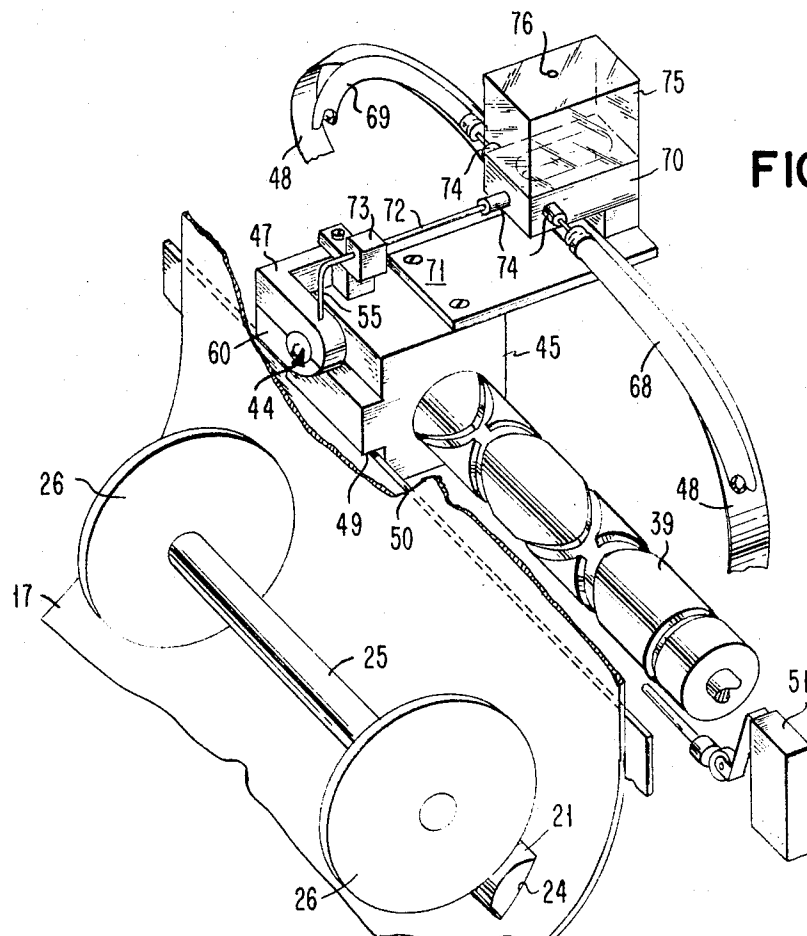


FIG. 9

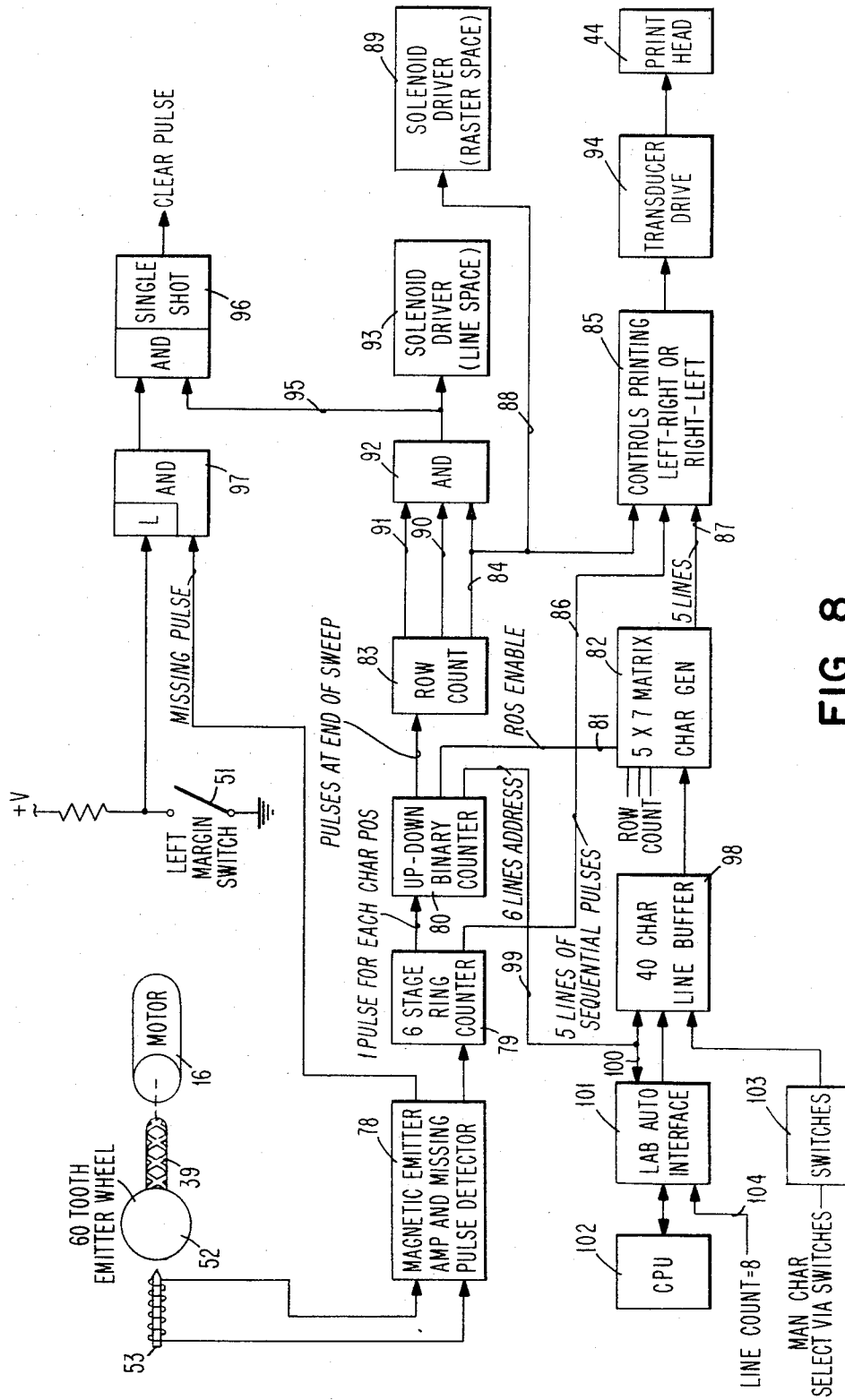


FIG. 8

INK JET PRINTER

BACKGROUND OF THE INVENTION

Fluid droplet printing has been known in the prior art as exemplified by the system shown and described in U. S. Pat. No. 3,596,275 which issued on July 27, 1971. In systems of the type described in this patent, a jet of writing fluid or ink is caused to issue from a nozzle in the form of a succession of tiny individual droplets which are directed toward the surface of a record member. As the individual droplets are formed, they are given an electrostatic charge which is a function of the instantaneous value of an input signal which is to be recorded. The charged droplets are caused to pass between a pair of electrostatic deflection plates. A constant high voltage charge is applied to the deflection plates to produce a constant high voltage electric field between the two plates. As the charged droplets pass through the electric field, they are deflected from their normal path by an amount which is a function of the magnitude of the charge on each of the droplets and in a direction which is a function of the polarity of the charge on the individual droplets. Each droplet of the ink or writing fluid has its own unique charge characteristic for directing it to the desired print position on the record member.

It can be understood that systems of the above patented type are relatively complex, costly, and difficult to implement. And for some applications, this type of printer system is neither desirable nor required. In the present application to be described, it was desired to provide a low cost and simple printer for the production of a hard copy duplicate of a message selected from those displayed on a CRT terminal.

SUMMARY OF THE INVENTION

In the present invention an asynchronous liquid jet printer system is provided which writes on a record medium by expelling droplets of liquid ink from the cavity of a jet head which is reciprocated repetitively along the printing line by way of a carriage nut and level winding screw means. Attached to the drive shaft of the level winding screw is a timing gear from which a magnetic head derives the basic synchronization pulses for the jet head electronic driving circuits. Liquid ink is fed to the cavity by gravity flow and the back of the cavity is closed with a sealed in piezoelectric — metallic diaphragm sandwich. This piezoelectric transducer is of the extensional type in which motion is generated by applying a voltage to the piezoelectric crystal in a radial direction. The application of pulses to the transducer from suitable storage and character generating equipment results in the generation of ink droplets on demand.

Characters are formed by generating dots on a 5 × 7 matrix, 5 horizontally and 7 vertically, as the head traverses back and forth so that printing occurs in both directions. The record medium is stationary during the actual printing of each row of dots and during the turn around time of the jet head at the end of each row, a paper advance solenoid is actuated. At the end of seven of these paper "character-row" advance cycles, all of the selected characters for one line have been printed and during an eighth cycle a line space solenoid is actuated to advance the paper to the desired position for the top row of dots of the next character row.

In the present embodiment, printing occurs 40 characters wide which occupy a space of 4 inches. The circuitry for driving the printer is addressable by switches to print selected characters in each of the 40 character positions. To test character sequences and format, to demonstrate graphics, and to print selected text an IBM 1130 computer system is attachable to the printer electronics. The 1130 in this case controls print-out from punched cards through Fortran using an 1132 write statement.

The present system provides a relatively inexpensive liquid jet printer which is adapted to duplicate character generation borrowed from an associated CRT terminal. It also has advantages over other ink jet systems in that the liquid ink is not pressurized, no drop deflection system is necessary, and no guttering of unused ink is necessary.

It is, then, a primary object of the present invention to provide a novel low cost asynchronous liquid jet printer.

A further object of the present invention is to provide a novel liquid jet printer wherein the liquid ink is not pressurized and no drop deflection system is necessary.

A still further object of the present invention is to provide a low cost liquid jet printer which is adapted for the production of a hard copy duplicate of a message selected from those displayed on a CRT terminal.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing the ink jet printer constructed in accordance with the present invention.

FIG. 2 is a front elevation view of the machine of FIG. 1 and shows the ink jet head and the level winding means.

FIG. 3 is a side elevation view of the right side of the machine of FIG. 1 and shows the drive mechanism.

FIG. 4 is a side elevation view of the left side of the machine of FIG. 1 and shows the paper advancing mechanism.

FIG. 5 is a diagram illustrating the method of character generation.

FIG. 6 is a diagram illustrating the scan data time and the pulse rate.

FIG. 7 is a schematic diagram of the ink jet.

FIG. 8 is a block diagram of the circuitry for controlling the printer.

FIG. 9 is a perspective view showing the ink jet head and carriage assembly.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, the printer apparatus of the present invention comprises a base plate 10 to which is attached the plexiglass side plates 11 and 12. At the back of the machine, there is pivotally mounted a hopper 13 which may be used, if desired, to hold a stack of fanfold forms which may be of paper or card stock. In front of the hopper, there is rotatively mounted in slots cut in the side plates a shaft 14 which carries a supply paper roll 15. In front of the paper roll, a motor 16 is attached to the right side plate so that

there is clearance between the underside of the motor and the machine base plate. Fastened to the baseplate underneath the motor is a paper guide plate 17 which curves upward at the front of the machine, as shown in FIG. 3. The paper guide plate extends across the machine and directly behind the top portion of it is a platen bar 18 which is fastened to the side plates of the machine. Across the top of the platen is a slitting bar 19 which has a groove 20 extending across the front of it so that, if desired, a portion of the paper may be slit from the roll and removed by running a knife, or the like, along the groove.

Referring to FIG. 2, at the front of the machine there is a pair of roller bearings 21 which are rotatable on a shaft 22 fastened on a pair of spring brackets 23. In the paper guide plate, a pair of slots 24 are cut in alignment with the roller bearings and, as shown in FIG. 4, on the other side of the guide plate there is a shaft 25 journaled in the side plates. Fixed on this shaft is a pair of feed rolls 26 which are in alignment with the slots and which coast with the roller bearings to advance the paper. Fastened to the inside of the paper guide plate are three spring fingers 27 which serve to hold the paper against the platen bar 18. To initially feed the paper into printing position, the paper is manually advanced along the inside of the paper guide plate 17 until it reaches the feed rolls 26 which are then operated to advance the paper the rest of the way by manually turning the feed roll shaft counterclockwise by way of the knurled knob 28 fastened on the end of the shaft.

To automatically advance the paper when printing is being carried out, the feed roll shaft 25 is connected to a roller-bearing sprag clutch 29 which operates to rotate the shaft only in the counterclockwise direction. A paper advance arm 30 is connected to the feed roll shaft by way of the clutch and the other end of the arm is connected to a pair of solenoids 31 and 32 mounted on a support bracket 33. Electronic circuitry selectively pulses solenoid 31 during character generation to advance the paper for dot row scanning and solenoid 32 is selectively pulsed for line spacing between character rows. The increment that these solenoids raise the paper advance arm 30 is translated to paper motion by a return spring 34 which returns the arm down against an adjustable stop screw 35 to effect the counterclockwise rotation of the feed roll shaft through the sprag clutch 29. In the present embodiment, solenoid 31 produces a paper advance of 0.0167 inch and solenoid 32 an advance of 0.064 inch.

As shown in FIG. 4, plexiglass cover plates 36 and 37 are provided and fastened on the top of plate 37 is a U-shaped wire member 38 over which the paper is fed so that the paper is kept away from the motor to thereby prevent heating of the motor. It should be understood that it is not necessary to use roll paper and that individually inserted cut sheets can be used. For some applications, the cut sheets may be preferred such as, for example, when duplicating a message selected from a CRT display.

Referring to FIGS. 1, 2 and 9, the reciprocating ink jet head and carriage assembly will now be described. Journaled in the side plates at the front of the machine is a level winding screw 39. The screw is driven by means of a gear 40 thereon which is connected by a belt 41 to a gear 42 on the shaft 43 of the motor. The motor runs at a synchronous speed of 1800 rpm moving the jet head 44 bidirectionally across the face of the

paper by means of a carriage nut 45 riding on the level winding screw. The level winding screw, similar to that found in fisherman's reels, has turn around channels at each end which transfer a pivot follower 46 riding in the helical grooves to the alternate return groove of the screw. The follower 46 is captured in the carriage nut 45 which carries the jet head 44 by means of a bracket 47. The carriage nut is acted upon by friction and torques induced by a flat spring 48 fastened between the nut and the base of the machine and the nut is prevented from turning by engagement of a sliding surface 49 on the nut to a sliding surface 50 on top of the paper guide plate. A microswitch 51 at the left end of the winding screw is actuated by the carriage nut to start a count for printing, as will be later described. As best seen in FIG. 3, attached to the drive shaft of the level winding screw is a 60 tooth timing gear 52 from which a permanent magnetic transducer (variable reluctance) 53 derives the basic synchronization pulses for the jet head electronic driving circuits.

Referring now to FIG. 7, there is shown the details of the jet head 44. Liquid ink is fed to the cavity 54 by gravity flow and is introduced to the cavity by 2 curved pipe 55 at the top and the drops are generated for printing on demand. The body 56 and nozzle portion 57 are preferably of teflon due to the fact that teflon resists wetting and thereby resists free bleeding of the jet. The nozzle diameter would typically be in the order of 0.004 inch in diameter.

The back of the cavity is closed with a sealed in piezoelectric - metallic diaphragm sandwich. The disc 58 of this sandwich is typically 3/16 inch in diameter and 0.008 inch in thickness. Fastened central to this disc, by epoxy, is a piezoelectric ceramic wafer 59 which is 5/8 inch in diameter and 0.008 inch in thickness. This piezoelectric transducer is of the extensional type in which motion in a radial direction is generated by applying a voltage to the piezoelectric crystal. Application of a positive pulse produces inward radial motion of the crystal which buckles the metallic diaphragm inward, in the manner of an oil can diaphragm being pushed inward, and liquid is expelled from the cavity. The application of one pulse produces one droplet of liquid or ink. The application of two pulses produces two droplets, etc. As shown in FIG. 9, a metal slide plate 60 is provided on the end of the bracket 47. This plate slides across the paper and prevents the end or tip of the jet nozzle from contacting the paper.

Referring now to FIGS. 2 and 4, a supply of liquid ink is placed in a container 61 mounted on a platform 62 which is vertically adjustable by way of a slide plate 63 and screw 64 so that the height of the container can be adjusted to control the gravity flow of the ink. An air vent hole 65 in the cap of the container prevents an air lock and assists the gravity flow. The ink flows out of the container through a liquid line 66 and is directed to a T-connector block 67 fastened at the front of the base plate. The loop of flat spring 48 is actually split and the two ends are overlapped and fastened between the block and the base to provide, in effect, a pair of twin oscillating springs. From the connector block 67, the ink is directed by way of two balanced liquid lines 68 and 69 upward to another T-connector block 70 which is supported on a mounting plate 71 fastened to the carriage nut 45. The oscillating springs 48 also serve to support these liquid lines, as well as the electrical lines to the jet. From the connector block 70, the ink is di-

rected through a liquid line 72 supported in a bracket 73 mounted on the carriage nut and the ink is then directed from line 72 through the curved pipe 55 and into the cavity 54 in the jet head 44. The liquid lines 68, 69 and 72 are actually connected to the connector block 70 by way of metering restrictor connectors 74 which comprise little needle inserts. During printing when the jet head assembly is reciprocating, the liquid lines 68 and 69 are also reciprocated and as the head direction reverses, these lines will bend and act as pumps to cause liquid surges. The purpose of the restrictor connectors is to iron out these surges so that there will be no bleeding of liquid from the jet onto the paper. Connected to the top of the T-connector block 70 is a bubble chamber 75 having an air vent hole 76 on top. This chamber functions to prevent the build-up of pressure in the connector block 70 and thus prevent liquid surges. The chamber and restrictor connectors serve as a simple pressure filter system.

The method of character generation is outlined in FIG. 5 with the relative jet head and paper motions shown at the bottom of the chart. Print dots 77 are generated starting at the left side of the paper and as the head traverses to the right. All of the top dots of selected characters are printed in this "character row" motion. During the turn around time, the paper advance solenoid 31 is actuated and the spring 34 completes the paper advance for a scan-to-left jet dot generation cycle. All of the second row dots of the selected characters are printed during this right to left head motion. A similar turn around cycle set-up and paper advance now takes place. At the end of seven of these paper "character row" advance cycles, all of the selected characters for one line have been printed. During an eighth cycle, the line space solenoid 32 is actuated and the spring advances the paper one line space. The first scan of the next line of selected characters starts when the head begins advancing to the right. In each case, the paper advance is at rest during the character jet printing function and printing thus occurs in both directions. Typical dimensions of the characters and dot spacing are shown in FIG. 5. In the present embodiment, printing occurs 40 characters and the 40 characters occupy a space of 4 inches on a paper width of 5 inches. Of course, other dimensional formats could be used.

The 5×7 character matrix is used to produce a message 40 characters in line width and 6 lines in length with line density being 6 lines per inch. Character width and spacing are such as to give a character density of 10 characters to the inch. The level winding screw 39 which actuates the jet head is designed with a lead of one turn per revolution and, as has been described, directly attached to the screw is the 60 tooth emitter or magnetic impulse wheel 52 from which impulses are sensed by the magnetic reluctance pick-up head 53. These impulses are basic to the control of all of the electronics of the machine, as will be described.

Since there is a character density of 10 characters to the inch and since the winding screw moves the jet head laterally one inch during 60 impulses, it is seen that with the 5×7 dot matrix a character space of one dot exists between characters in horizontal or line direction spacing. The character and character space increments are 0.1 inches. The vertical dot spacing is made approximately 0.016 inches resulting in a between line spacing of approximately 0.067 inches for a

line spacing of 6 lines to the inch. This is shown graphically in FIG. 5 where the characters "ETO" are sketched by dot position. At the bottom of FIG. 5 there is shown how 7 horizontal "raster" mechanical scans of a controlled dot position ink emitter generate these characters. It will be noted that the first scan is from left to right, the next scan from right to left, etc. A scan data time and pulse rate for a 4 inch write to the right, turn around, and write to the left cycle is shown in FIG. 6. During R-1, R-2, R-3 and R-4, the top line of 10 characters are written as the head moves horizontally one inch per turn.

Referring now to the block circuit diagram shown in FIG. 8, the motor 16, operating at 1800 rpm, drives the level winding screw 39 and the timing emitter gear 52 which is a 60 tooth wheel with one tooth removed at the "home" position. This wheel is adjusted at assembly to have an axial position on the level winding screw such that the missing emitter tooth is registered with the magnetic reluctance pick up head 53 at the first level winding screw crossover after left turn around. The jet head is also aligned at assembly to have a common perpendicular axis to this first level winding screw crossover after left turn around. The magnetic impulses are sensed by the head 53 and the impulses are fed to a magnetic emitter — amplifier — shaper 78. The missing pulse from the missing home tooth on the emitter wheel is reinserted and identified as a home pulse in this amplifier. The output from amplifier 78 feeds a six stage ring counter 79 and this counter, because of the 5 character dot positions plus the single dot character - space, as shown in FIG. 5, gives one character pulse output for each six emitter pulses received. The character pulses from counter 79 feed an up-down binary counter 80 and the purpose of this counter is to count the chosen number of characters per page width, which in the present embodiment is 40. By means to be described, the first dot of the first character will be printed at the first scan left level winding screw crossover after left turn around. The up-down counter 80, therefore, counts 40 character positions as the first print scan to the right proceeds to completion. At the 40 character count, one output of the up-down counter goes down in voltage level along a line 81 which signals the read only storage (ROS) enable line in a 5×7 matrix character generator 82 resulting in stopping further scan one character generation signals. The jet head is now carried into mechanical turn around on the right turn around section of the level winding screw. The signal on line 81 to the character generator ROS stays down during the entire turn around time. Meantime, the up-down counter 80 is counting the ten more words generated by the 60 tooth emitter wheel in this one revolution turn around. At the end of this additional ten character turn around time, the signal on line 81 from the up-down counter 80 is brought back up in signal level allowing the character generator 82 to again operate, this time as scan 2 proceeds to the left.

During the operation just described, the up-down counter 80 was also sending character pulses to a row counter 83. The output of the row counter, in the scan from left to right, identified row 1 along an output line 84. The output on line 84 goes to a logic block 85 which controls whether the identified scan will print dots from the character generator 82 in a left to right going progression or in a right to left going progression in conjunction with the 5 signal lines, identified as line

86, which leave the ring counter 79 and also enter the logic block 85 to identify the five dot times and to selectively gate the stored character out of the character generator 82 along 5 lines, identified as line 87, in the selected left or right progression. As shown in FIG. 5, scan 1 is to be a left to right progression as are scans 3, 5 and 7. Similarly, upon right turn around the count in row counter 83 becomes even and the dot output from the character matrix is in a right to left progression during scans 2, 4 and 6. The three output lines from the row counter 83 are also shown as inputs to the 5×7 character matrix generator 82. Also, a branch line 88 from the row counter output line 84 feeds a solenoid driver block 89 for raster or inter-character output spacing at each turn around. The row counter output lines 84, 90 and 91 feed an AND block 92 and upon the count of eight rows, one output from the AND block signals a solenoid driver block 93 to effect a line space. Because of the mechanical structure of the solenoids 31 and 32, both solenoid drivers 89 and 93 are activated at 8 row count with the raster solenoid 31 aiding the line space solenoid 32 in initiating the large line spacing.

The output from controls printing logic block 85 is taken to a transducer driver block 94 to pulse the ink jet print head 44. A branch output line 95 from the AND block 92 is taken to the AND section of a single shot 96 whose purpose is to clear the counters. The clearance of counters occurs at the end of row count 8 and the coincidence of a new print cycle, as follows:

The microswitch or left margin switch 51, located at the left end of the winding screw and actuated by the jet head carriage nut, is connected to the latch section of logic AND block 97 and is held after make until the missing tooth "home-pulse-signal" is received at the first level winding screw crossover after left turn around. At this time, the output of logic block 97 enters the AND section of single shot 96 in conjunction with the row 8 count signal, described above, and all of the counters are reset to zero and a new count cycle is initiated.

The foregoing has described how information is read from the character generator 82 by the machine operation and associated electronics controlled by the level winding screw pulse emitter wheel.

To select the character positions of a 40 character line buffer 98 that will either load that position or deliver that position to the 5×7 character matrix 82, six lines of address, identified by the line 99, are delivered from the up-down binary counter 80 to common lines, identified as line 100, which connect the 40 character line buffer 98 with a laboratory automatic interface unit 101. The line buffer comprises six 4×4 , 64 bit, read-write random access memories for the 40 characters. The interface unit is essentially a digital multiplexer for channeling out of a suitable computer 102 such as, for example, an IBM 1130. The common lines between the line buffer and the interface unit may be disconnected if manual switch loading of the 40 character line buffer is desired. In this case, the same character will be read out of its respective buffer position to the character matrix 82 as each buffer address is received along line 99 to the buffer. In this way, line after line of the same characters stored in the buffer may be printed. Also, by manually changing switches represented by the block 103 feeding the buffer, new characters may be manually entered into the buffer.

Loading of the 40 character line buffer by the computer occurs under control of the interface unit 101. A line, not shown, leaves the row counter 83 bringing a line count of eight along the line 104 into the interface unit. During the "8" time, the line buffer may be loaded from the computer. Under this control, a new set of 40 characters may be loaded at each "8" time or, in other words, on a line by line dynamic basis as long as data is being received from the computer in 40 character line widths.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An ink jet printing system for writing on a record member by expelling droplets of liquid ink which comprises:

an ink jet head comprising a body member having a cavity with a nozzle portion at one end and a piezoelectric - metallic diaphragm sealed at the opposite end;

means for supplying liquid ink to said cavity;

means for reciprocating said jet head back and forth across the front of the writing surface of said record member;

storage and character generating circuit means responsive to input data to be printed for pulsing said piezoelectric diaphragm whereby droplets of ink are expelled from said nozzle to produce rows of dots on the record member as the head reciprocates back and forth;

counter circuit means for controlling the drive of said storage and character generating circuit means;

transducer means controlled by the mechanical motion of the jet head for producing synchronization pulses for controlling the drive of said counter circuit means;

drive means for spacing said record member;

first means responsive to said counter circuit means for actuating said drive means to space the record member at the completion of each row of dots whereby characters are formed in a dot matrix; and second means responsive to said counter circuit means for actuating said drive means to space the record member at the completion of each row of characters.

2. An ink jet printing system as in claim 1 wherein said liquid ink is supplied to the jet head by gravity flow.

3. An ink jet printing system as in claim 1 wherein said record member may take the form of a roll strip or individual cut sheets.

4. An ink jet printing system for writing on a record member by expelling droplets of liquid ink which comprises:

a rotatable helically grooved level winding screw having turn around channels at each end, said winding screw extending across the writing surface of the record member and in close proximity thereto;

a carriage nut mounted on said winding screw and having a follower riding in the helical grooves;

an ink jet head mounted on said carriage nut, said head comprising a body member having a cavity

with a nozzle portion at one end and a piezoelectric
- metallic diaphragm sealed at the opposite end;
means for supplying liquid ink to said cavity;
means for rotating said winding screw whereby said
jet head traverses back and forth across the front 5
of the writing surface of said record member;
storage and character generating circuit means re-
sponsive to input data to be printed for pulsing said
piezoelectric diaphragm whereby droplets of ink are
expelled from said nozzle to produce rows of data 10
on the record member as the head traverses back
and forth;
counter circuit means for controlling the drive of said
storage and character generating circuit means;
transducer means controlled by the mechanical mo- 15
tion of the jet head for producing synchronization
pulses for controlling the drive of said counter cir-
cuit means;
drive means for spacing said record member;
first means responsive to said counter circuit means 20

for actuating said drive means to space the record
member at the completion of each row of dots
whereby characters are formed in a dot matrix; and
second means responsive to said counter circuit
means for actuating said drive means to space the
record member at the completion of each row of
characters.

5. An ink jet printing system as in claim 4 wherein
said transducer means comprises a toothed wheel rotat-
able with said winding screw and a magnetic head for
sensing the teeth on said wheel.

6. An ink jet printing system as in claim 4 wherein
said drive means comprises a one-way clutch and feed
roll means adapted to space either a roll strip or indi-
vidual cut sheets.

7. An ink jet printing system as in claim 4 wherein
said liquid ink supply means comprises a vertically ad-
justable ink container and supply lines for feeding the
liquid ink to the jet head by gravity flow.

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