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(54) Ink jet printing

(57) An ink jet printing system (50) includes an ink jet nozzle array (54) for ejecting ink droplets during an ink jet printing cycle, and a flat medium (10) positioned to receive ink droplets ejected by the nozzle array during an ink jet printing cycle. A motion apparatus (72, 80, 92) provides relative motion between the nozzle array and the medium such that a spiral locus is defined by the nozzle array relative to the media during an ink jet printing cycle. The spiral maximum diameter may be made equal to the diagonal dimension of a rectangular media, thus allowing drops to be deposited very close to the edge of the media, and so reducing or eliminating the area of unprintable margins on both sides and the top and bottom of the media.

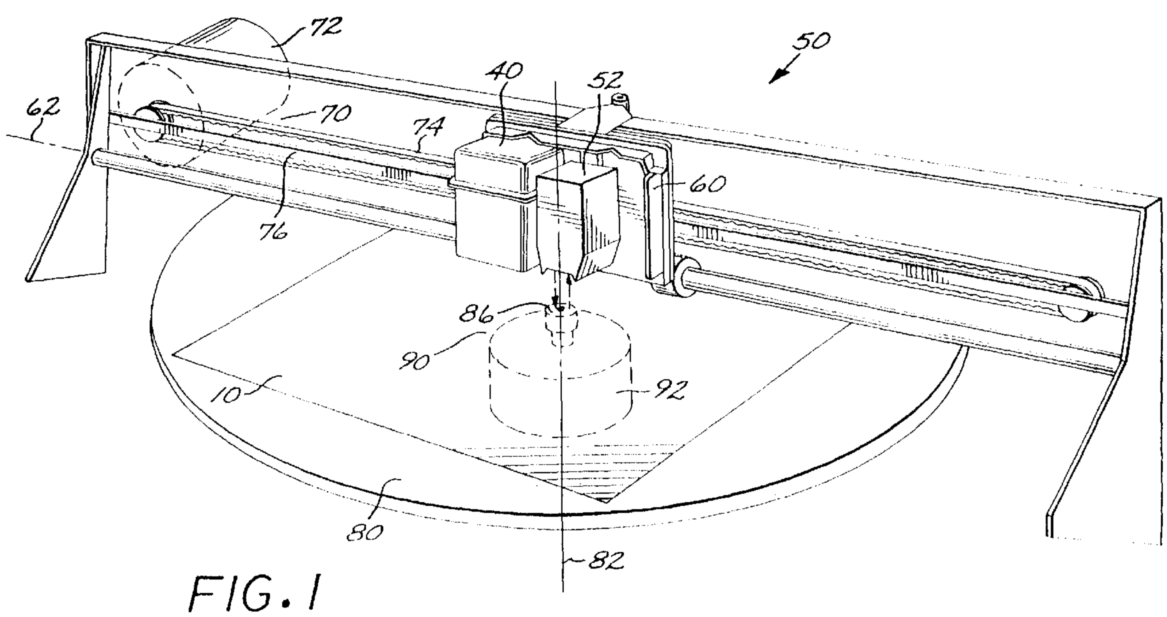


FIG. 1

EP 0 952 003 A1

Description

[0001] The present invention relates to ink-jet printing techniques, and more particularly to a method for media coverage which involves unidirectional ink-jet printing which reduces mechanical hysteresis and reduces the area of unprintable margins to zero by printing along a spiral locus path.

[0002] The present application is related to a co-pending European patent application number entitled "Optical Scanning of Documents" filed on even date and claiming priority from U.S. Patent Application 09/066,622.

[0003] There exists a method for placing drops of ink on media such that an array of nozzles is swept over the surface of a flat, rectangular media in a rectangular "raster" fashion, usually from left to right, and then back from right to left, accompanied by a step-wise motion from top-to-bottom. That method allows the ink-jet nozzle array to essentially "visit" the entire media area one or more times, depending upon the length of the top-to-bottom motion, the length of the left-to-right scan, and the offsets of the sweep start.

[0004] During the sweep, ink-jet nozzles are activated at different times to "shoot" or eject drops of ink, and these drops land upon the media, thereby making text or images visible upon the media. There are a number of undesirable artifacts which accompany the above described process. These errors are generally due to mechanical alignments within and about the mounting of the ink-jet "head", directionality errors caused by the angles with which the drops are ejected from the nozzles, timing quantization, position sensing, and importantly, mechanical hysterisis.

[0005] Hysteresis is an effect that manifests itself by a non-repeatable position trace while moving from left-toright, and then moving from right-to-left, so that the commanded position has an uncertainty or offset from that of the actual nozzle position. Hysterisis is often the result of friction in a mechanism, accompanied by the normal tolerance of fitted parts, and accentuated by a start-stop motion of the mechanism. Starting friction may be higher than running friction; hence there is a tendency for the heads to move toward one end of their mechanical tolerance at the reversal of the sweep.

[0006] All of these effects cause the drop of ink ejected from the nozzle to land on the media with an error in position, and often there are regular visual effects which then appear as a person views the resulting image or text. Some solutions are found by overlapping the "swaths" of the sweep, or by only firing the nozzles during one of the scan directions, say from left-to-right, or by making multiple passes over the same region of the media, and choosing a drop-firing pattern which averages the mechanical errors. There are also techniques of automatic calibrations which improve the resulting print quality.

[0007] In addition to difficulties of correctly placing ink in position, a usual condition of the mechanism which handles the motion of the media in the vertical direction is that the nozzle array of the ink-jet head cannot move all the way to the edge of the media, thus prohibiting deposits of any ink drops in a margin on both the left and right sides of the media. Additionally, other mechanical constraints prohibit ink drops from being deposited on a top and also a bottom margin of the media.

[0008] This invention improves upon the hysteresis problem, and the margin problem as described above for the case of a rectangular "raster" sweep of an ink-jet nozzle array over a flat media.

[0009] This invention improves upon the hysteresis problem, and the margin problem as described above for the case of a rectangular "raster" sweep of an ink-jet nozzle array; over a flat media. An improvement to the hysteresis problem will be provided if the mechanical system does not start and stop more than once, that is, there is continuous motion of the nozzle array with respect to the media. A printing technique in accordance with an aspect of the invention meets that need by effectively providing relative spiral motion between the media and the nozzle array. Additionally, the spiral maximum diameter may be made equal to the diagonal dimension of a rectangular media, thus allowing drops to be deposited very close to the edge of the media, and so reducing or eliminating the area of unprintable margins on both sides and the top and bottom of the media.

[0010] Thus, a method for media coverage with an ink jet nozzle array in accordance with one aspect of the invention includes the following steps:

providing an ink jet nozzle array;

supporting a flat medium to receive ink droplets ejected by the nozzle array during an ink jet printing cycle;

ejecting ink droplets onto the medium during an ink jet printing cycle;

providing relative motion between the nozzle array and the medium such that a spiral locus is defined by the nozzle array relative to the media during an ink jet printing cycle.

[0011] An ink jet printing system in accordance with another aspect of the invention includes an ink jet nozzle array for ejecting ink droplets during an ink jet printing cycle, and a flat medium positioned to receive ink droplets ejected by the nozzle array during an ink jet printing cycle. An apparatus is provided for providing relative motion between the nozzle array and the medium such that a spiral locus is defined by the nozzle array relative to the media during an ink jet printing cycle.

[0012] These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. 1 is a diagrammatic isometric view of an exemplary embodiment of an ink jet printer embodying the present invention.

FIG. 2 is a graphical illustration of the spiral locus path of the relative motion between the ink jet pen and the flat medium, in accordance with an aspect of the invention.

FIG. 3 illustrates a simplified nozzle array with a plurality of nozzles for the ink jet pen of the printer of FIG. 1, in two positions relative to the surface of the flat medium.

FIG. 4 is a simplified illustration of one exemplary path of the outermost nozzle of the nozzle array of FIG. 3 for a complete rotation (2π radians) of the medium, for the case of a non-overlapped nozzle array spiral.

FIG. 5 is a simplified illustration of a first alternate path of the outermost nozzle of the nozzle array of FIG. 3 for a complete rotation (2π radians) of the medium, for the case of a partially-overlapped nozzle array spiral.

FIG. 6 is a simplified illustration of a second alternate path of the outermost nozzle of the nozzle array of FIG. 3 for a complete rotation (2π radians) of the medium, for the case of a partially-underlapped nozzle array spiral.

FIG. 7 is a graph of the angular speed of the flat medium as a function of radial distance to maintain a constant tangential nozzle array velocity for the embodiment of FIG. 2.

FIG. 8 is a simplified schematic block diagram of the control system comprising the printer apparatus of FIG. 1.

[0013] An ink jet printing technique is disclosed, wherein relative motion is provided between a nozzle array and the surface of a flat media, without actually causing the nozzle array or medium to stop and reverse its direction periodically, in one exemplary embodiment. This can be accomplished, in one exemplary embodiment, by mounting the nozzle array on an arm which radiates from a center of coordinates in RHO (ρ), THETA (θ) coordinate space, where RHO is a measure of distance from a center of coordinates, and THETA is a measure of angle, most usually in radians. The nozzle array can then be moved outward from this center, while at the same time the media may be rotated in a circle around the center of coordinates. Alternatively, the nozzle array can be rotated and translated instead of the media to provide a spiral locus for the ink jet nozzles relative to the print medium.

[0014] FIGS. 1-8 illustrate an ink jet printing system 50 which embodies this invention. An ink jet pen 52 including a nozzle plate 54 with an array of ink jet nozzles 56A-56N (FIG. 3) is supported in a carriage 60. The carriage 60 is adapted for movement along a scan axis 62. A carriage drive system 70 is coupled to the carriage to drive the carriage in a path along the axis 62. Carriage drive systems are well known for swath printers, and typically include a drive motor 72, belt drive 74, and encoder strip 76 with encoder sensor 73 (FIG. 3) for providing carriage position data. The drive system for the system of FIG. 1 does not require as high speed carriage velocities as is typically required for linear swath-type printers, and so other drive mechanisms can be employed, such as leadscrew drives.

[0015] The print medium 10 is mounted on a flat turntable platen 80 which is in turn mounted for rotation about a center axis 82, which at the plane of the medium 10 defines the center of coordinates 86. The turntable platen 80 is driven by a rotary turntable drive system 90 which includes a turntable motor 92 and a turntable encoder 94 (FIG. 8) for providing turntable position data.

[0016] In an exemplary embodiment, an apparatus is provided for holding the print medium flat against the turntable. Such apparatus are well known in the art, e. g. a vacuum hold-down system, an electrostatic system, or a mechanical system with a fixture for holding the medium in place. The carriage axis 62 intersects the linear nozzle array axis above the center of coordinates 86 (FIG. 3).

[0017] Also shown in FIG. 1 is a second device 40 being held by the carriage. This device is optional, and can be a black ink jet pen (e.g., pen 40B in FIG. 8), in the case where the pen 52 is a tri-compartment, three colour pen with three nozzle arrays for ejecting ink droplets of three different colours. Motions of the pen carriage and the media turntable may be used to allow both pens to sweep over the same regions on the medium. For example, pen 52 may sweep over a spiral when pen 40 is swept over the same area 2π radians of rotation later. Alternatively, the second device can be an optical scanning head with a light sensor array (eg. array 40A in FIG. 8), for providing an optical scanner function, as more particularly described in the abovementioned co-pending application. An exemplary optical scanning head suitable for the purpose is described in European patent application EP-A-0831639. In other applications, no second device 40 is employed

[0018] FIG. 2 is a chart illustrating the relative motion path, a spiral locus, of the nozzle array in relation to the medium 10 during a printing operation in accordance with an aspect of the invention. LOCUS 1 is a trace of the path taken by the nozzle of pen 52, for example, which is mounted furthest from the centre of coordinates 86, relative to the surface of the print medium 10. REGION 1 is the circular region defined by the relative nozzle sweep which would occur with a stationary nozzle array and the medium in rotation, when the nozzle array is closest to the centre of coordinates 86, such that the inner nozzle is over the center of coordinates 86, and the nozzle located at the position of LOCUS 1 is the furthest from this center. REGION 2 illustrates a typical restangular printing region, W by H. REGION 3 is bounded by a circle indicating the outer limit of coverage for potential ink drops.

[0019] FIG. 3 illustrates a simplified nozzle array 54 with a plurality of nozzles 56A-56N. Position 1 shows the nozzle array in a start position relative to the surface of the medium 10, with the nozzle 56A at the platen center of coordinates 86. Position 2 shows a relative rotation (by some angle θ) between the nozzle array 54 and the medium 10. In this exemplary embodiment, the carriage is stationary during the first complete rotation of the platen 80, to provide complete coverage, i.e. to sweep cut, REGION 1. This first complete relative rotation is circular, and the nozzle 56A remains at the center of coordinates 36, which is illustrated in FIG. 3. On the second rotation, the carriage is put in motion, to provide a spiral relative path as shown in FIG. 4.

[0020] FIG. 4 is a simplified illustration of the path of the outermost nozzle 56N for a second complete rotation (2π radians) of the medium 10, i.e. for the case of a given motion of the carriage along the carriage axis 62 as the platen 80 rotates. The path starts at position A of the nozzle 56N, at $\theta = 0$, radius $\rho = 1$ unit (equal to the width of the nozzle array), and ends at position E of the nozzle 56N, at $\theta = 2\pi$, $\rho = 2$ units. The nozzle 56N follows through the path illustrated relative to the medium, with position B occurring at $\theta = \pi/2$, $\rho = 1.25$ unit, position C occurring at $\theta = \pi$, $\rho = 1.5$ unit, and position D occurring at $0 = 3\pi/2$, $\rho = 1.75$ units. During this second complete rotation, i.e. the first rotation after the carriage is put into motion, there will be overlapped coverage of print nozzles with respect to the initial rotation. Preferably, the printer controller is programmed to suppress firing the nozzles, for this second rotation, over the overlapped area to prevent duplicate dot coverage. Also, the drops or dots of ink are preferably spaced evenly along the spiral path in accordance with standard design practices.

[0021] FIGS. 2 and 4 also illustrates the condition that, for this exemplary embodiment, the radial motion of the nozzle array is constrained to move one nozzle array width in the radial direction for each 2π radians (360 degrees) rotation of the medium 10 on platen 80. Thus, in FIG. 2, the spiral path does not overlap or underlap onto itself. For the third and all subsequent rotations of the platen 80, there will be no overlapped coverage of the nozzle array relative to earlier rotations/passes of the nozzle array.

[0022] In many applications it is desirable to overlap the path to prevent spiral banding, just as is presently done to prevent swath banding in known rectangular coordinate printers. In this case, then, the nozzle array will be moved less than a full nozzle array width (1 unit) for each 2π radians rotation of the medium 10. FIG. 5 illutrates an exemplary spiral locus for such an overlapped case. In this example, the carriage moves outwardly at a rate of .5 unit (nozzle array width) per couplete rotation of the nozzle array. Alternatively, the nozzle array can be moved more than a full nozzle array width for each 2π radian rotation of the medium 10, providing gaps in the print coverage as the nozzle array moves outwardly. These gaps can be filled in on a reverse spiral scan, moving the nozzle array from an outside position back to the start position shown in FIG. 3. FIG. 6 illustrates an exemplary spiral locus for such an underlapped case. In this example, the carriage moves outwardly at a rate of 2 units (nozzle array widths) per complete rotation of the nozzle array.

[0023] In order to completely cover REGION 1 with potentiel ink drops, when the nozzle array is located over REGION 1, it needs to maintain this position during the first full revolution of the medium 10 on the platen 80. Subsequently, in the second and subsequent revolutions of the platen 80, as the nozzle array moves outward, all the remaining area of REGION 3 becomes the potential target of ink drops. REGION 3 is circular, but most of the media upon which it is desired to print will typically be rectangular, as illustrated by the rectangular printing REGION 2. In order to completely cover this region, the innermost nozzle of the nozzle array needs to travel array from the center of coordinates outward, and the outermost nozzle must be able to just reach the furthest corners of the media.

[0024] In most cases, in order to minimize the total printing time for a print job, the ink-jet nozzles fire their drops out at a constant rate, although this is not required by this invention. However, if this is a desired operation, then since the velocity of a given nozzle along the spiral would increase with radius RHO (ρ) for a constant rotation-al speed (dθ/dt), the circular rotational velocity of platen 80 is adjusted such that if S is a tangential distance along LOCUS 1, and [1] dS = RHO*dTHETA using 'd' to indicate "differential" as in calculus notation, then if t stands for time, [2] dS/dt = RHO∗dTHETA/dt = V, where V is the desired constant velocity along LOCUS 1. Solving [3] dTHETA/dt = V/RHO, where RHO starts out as 1 nozzle unit width, and reaches $(W^2+H^2)^{½}/2$ at the point where full coverage of the media has occurred. Because RHO is a variable which occurs in the denominator position, this means the rotational velocity is a nonlinear function of the position of the ink-jet head, if one desires a constant tangential velocity of the head. FIG. 7 is a graph plotting an exemplary angular speed of the head as a function of the radial distance from the center of coordinates.

[0025] Expressed another way, the maximum rotational rate of the media will be V radians per second, when the innermost nozzle is located over the center of rotation, and the minimum rotational velocity will be $2V/(W^2+H^2)^{½}$ radians per second for a nozzle array of 1 unit length.

[0026] By way of illustrative example, assume that it is desired to print edge-to-edge on an 3.5 x 11 inch media using an ink-jet array which consists of 300 nozzles each of which is spaced equally from its neighbors by 1/300th of an inch. This array then is 1.0 inches long. Ink jet pens are typically designed for a maximum firing rate. Hence, the equally spaced drops dictate the distance the pen (head) moves in 1/f seconds, where f is the firing rate (frequency). This sets the maximum velocity of the pen (head). Suppose further that the maximum tangential velocity that this nozzle array supports, while firing dots at its maximum rate, is 10.0 inches per second. Thus, 10*300 = 3000 dots are fired per second while the head moves over the media at this speed, and the "swath-width" is 1.0 inch wide.

[0027] The maximum position the nozzle furthest from the center of rotation needs to be away from this center, for this example, is $(W^2+H^2)^{½}/2 = (8.5^2+11^2)^{½}/2 = 6.95$ inches, and when it reaches this outer limit of RHO its rotational velocity will be dTHETA/dt = V/RHO = 10.0 inches-per-second/6,95 inches = 1.44 radians per second, or about 13.75 RPM (rotations per minute) as in FIG. 7. The tangential velocity is the rotational velocity times the radius, which is 1.44 * 6.95 = 10 inches per second, as expected.

[0028] Now when the nozzle furthest from the center of rotation is at RHO = 1.0 inch, the rotational velocity is 10.0 inches-per-second /1.0 inches = 10.0 radianspersecond, or about 95.5 RPM, as in FIG. 7.

[0029] The total print time can be approximated as the time it takes to sweep out the total circular area of REGION 3 at the constant rate of 10 square inches per second (the area swept out be the head in one second is the length of the nozzle array times the distance traveled in one second). The total "swept out" circular area is $\pi*(RADIUS^2) = 3.14159*(6.95^2) = 151.75$ square inches, where RADIUS is one half the diagonal dimension of REGION 2. At 10 square inches per second, this is about 15.2 seconds.

[0030] In the case wherein an image is rendered which is typically organized, in a conventional fashion, in rows and columns of data pixels, or picture elements, there are some regions of the media where the drops may not land exactly upon the desired "cartesian" coordinate due to quantization-type effects which exist between the cartesian coordi-nate system of rows and columns, and the RHO-THETA coordinate system illustrated in FIG. 2. The maximum error in the above schemata will occur at a rotation angle of 180 degrees, or π radians, with π representing the ratio of the circumference to the diameter of a perfect circle. By re-sampling the raster Cartesian data into RHEO-THETA coordinates, using known digital techniques (e.g. convolution), printing artifacts will be minimal. The above-mentioned copending application describes a technique to eliminate the need for such coordinate coversions altogther.

[0031] FIG. 8 is a simplified schematic block diagram of the control system for the printer system illustrated in FIG. 1. A controller 100 is coupled to a memory 102 for retrieval of data defining a print job. The controller generates the drive commands to the pen scanning motor 72, which comprises the carriage drive, and receives position signals indicative of the carriage/pen position from pen scanning encoder 78. The controller also generates turntable motor drive commands to control the turntable motor 92 which rotates the turntable platen, and receives encoder signals from the turntable encoder 94 to determine the position and angular velocity of the turntable platen. The controller thus can control the carriage drive to achieve a non-overlapping spiral locus of the pen nozzle array with respect to the medium, or an overlapped spiral locus to prevent banding or other artifacts, or an underlapped locus to provide for other special printing modes. Other exemplary print modes include skipping printing on alternate rotations forming the spiral, and to reverse the direction of the carriage at the end, filling in the omitted dots in the alternate rotations.

[0032] The controller also provides firing pulses to the pen printhead nozzles 54, in dependence on the image to be generated and the position of the pen in relation to the center of coordinates. The image data can be stored in the memory 102, or received from a host computer 120. The controller can also set the firing rate for the pen nozzles. While in many cases it is desirable to use a constant (maximum) firing rate, for other jobs or applications, the controller can control the firing rate to be non-constant over a particular print job, or to use a slower constant firing rate. Faster or slower firing rates can be used to achieve higher or lower densities of dots in particular regions on the medium 10.

[0033] Each nozzle in the nozzle array 54 is at a different radial distance from the center of coordinates 86 than any other nozzle. The result of this is that firing all nozzles at a constant rate produces dot spacing differences which will be readily apparent at small values of RHO, especially in REGION 1 of FIG. 2. For example, in REGION 1 during the initial rotation of the media (which is not accompanied by a radial motion of the carriage), and for a $1/300^{th}$ inch nozzle spacing, the nozzle 56N (FIG. 3) at RHO furthest from the center of rotation must fire 300 times for every inch along the circumference. For a one inch nozzle array, the circumference is 2π inches. Hence there will be 1,885 dots printed at a spacing of $1/300^{th}$ of an inch along this circumference. At the second nozzle 56B out from the center of coordinates, the circumference is only $2\pi/300$ inches, or .0209 inch, and firing 1,885 dots of ink along this circular path is incorrect because it will produce too much ink along that circular path. At the nozzle next to the outermost nozzle, i.e. 1/300 inch closer to the center of rotation, the number of dots fired to maintain 300 dots per inch should be $2\pi(1.0-1/300)(300)$, which is 1,879. Instead, however, 1,885 dots would actually be fired if the firing rate were to be the same as the outermost nozzle, and the dots thus produced would be closer together than those produced by the outermost nozzle. During the sweep of REGION 1, or at any other region of the medium, pixels which have been printed should not be reprinted, and logic in the controller can easily determine which pixel is to be printed by each nozzle, and nozzles closer to the center of rotation can be fired less frequently.

[0034] As a further example, when the nozzle array has reached a RHO value of 2.0, after the second complete rotation of the medium, the nozzle 56A. (closest to the center of rotation) is at a RHO value of 1.0, and will need to be fired at one-half the rate of the outermost nozzle to maintain the same dot spacing. Again, logic in the controller will adjust the firing rate to not put ink on a pixel which has already been printed once. However, it is desired to minimize total print time by making the nozzle 56N, i.e. the outermost nozzle, fire at the maximum (constant) rate possible. FIG. 7 shows the relationship between the constant (maximum) rate of this outermost nozzle, while all other nozzles will actually fire when the pixel over which they are to print is at least 1/300th of an inch away from any adjacent pixel, and this will always be at a lower rate of firing than the maximum possible. These differences in rate rapidly diminish with distance from the center of rotation.

[0035] It is understood that the above-described embodiments are merely illustrative of the possible specific embodiments which may represent principles of the present invention. For example, other arrangements can be enployed to provide the desired relative motion between the pen and the print medium to provide a spiral path. For example, the pen can located on an arm mechanism which moves in a spiral path, with the print medium located on a stationary platen. Or conversely, the pen can be located in a stationary position, and the print medium located on a platen which provides the desired spiral movement locus. Also, while the motion of the pen has been described as commencing from a position at the center of coordinates and moving radially outwardly, the pen could alternatively be started at any other position, e.g., at the outermost position and spiraled inwardly to end at the center of coordinates. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope of the invention.

Claims

1. A method for media coverage with an ink jet nozzle array, comprising a sequence of the following steps;

providing an ink jet nozzle array (54);
supporting a flat medium (10) to receive ink droplets ejected by the nozzle array during an ink jet printing cycle;
ejecting ink droplets onto the medium during an ink jet printing cycle;
providing relative motion between the nozzle array and the medium such that a spiral locus is defined by the nozzle array relative to the media during an ink jet printing cycle.

2. A method according to Claim 1, further characterized in that said step of providing relative motion is accomplished without causing the nozzle array (54) to stop and reverse its direction periodically during the printing cycle.

3. A method according to Claim 1 or Claim 2, further characterized in that said nozzle array (54) is mounted on an arm which radiates from a center of coordinates, and wherein said step of providing relative motion includes moving the nozzle array outwardly on the arm from the center of coordinates while rotating the medium (10) about the center of coordinates.

4. A method according to Claim 3, further characterized in that the nozzle array (54) spans a first distance in a direction extending radially from the center of coordinates, and said step of providing relative motion includes moving the nozzle array radially at a rate such that the nozzle array is moved radially by a distance equal to the first distance for each complete rotation of the medium (10) about the center of coordinates.

5. A method according to Claim 3, further characterized in that the nozzle array (54) spans a first distance in a direction extending radially from the center of coordinates, and said step of providing relative motion includes moving the nozzle array radially at a rate such that the nozzle array is moved radially by a distance which is less than the first distance for each complete rotation of the medium about the center of coordinates.

6. A method according to any of claims 3-5, further characterized in that the nozzle array (54) includes a plurality of nozzles (56A-56N) including an outermost nozzle (56N) relative to the center of coordinates, and the step of ejecting ink droplets during an ink jet printing cycle includes ejecting the ink droplets from the outermost nozzle at a constant rate, and the step of providing relative motion includes varying the relative rotation rate of the medium (10) to achieve a substantially constant tangential velocity of the outermost nozzle of the ink jet nozzle array.

7. A method according to any of Claims 1-3, further characterized in that said step of providing relative motion between the nozzle array (54) and the medium (10) includes moving the nozzle array radially at a rate selected to provide a partial overlap of the nozzle array relative to the medium during the printing cycle.

8. A method according to any of Claims 1-3, further characterized in that said step of providing relative motion between the nozzle array (54) and the medium (10) includes moving the nozzle array radially at a rate selected to provide a partial underlap of the nozzle array relative to the medium.

9. A method according to any preceding claim, further characterized in that the step of providing relative movement includes moving the nozzle array (54) radially by a distance which is large enough to provide swept coverage of the nozzle array over the entire area of the medium (10).

10. An ink jet printing system (50), comprising:

an ink jet nozzle array (54) for ejecting ink droplets during an ink jet printing cycle;
a flat medium (10) positioned to receive ink droplets ejected by the nozzle array during an ink jet printing cycle;
apparatus (60, 72, 80, 92) for providing relative motion between the nozzle array and the medium such that a spiral locus is defined by the nozzle array relative to the media during an ink jet printing cycle.

11. A printing system according to Claim 10, further characterized in that said apparatus (60, 72, 80, 92) for providing relative motion between the nozzle array (54) and the medium (10) is adapted to move the nozzle array radially at a rate which provides a partial overlap of the nozzle array relative to the medium during the printing cycle.

12. A printing system according to Claim 11, further characterized in that said apparatus (60, 72, 80, 92) for providing relative motion between the nozzle array (54) and the medium is adapted to move the nozzle array radially at a rate which provides a partial underlap of the nozzle array relative to the medium.

13. A printing system according to Claim 11, further characterized by:

an ink jet pen (52), wherein said nozzle array (54) is mounted on said pen;
a pen carriage (60) for holding the pen, said pen carriage mounted for movement along a carriage axis (62) extending through an center of coordinates;
an arm structure for supporting the pen carriage for said movement along said carriage axis; and
wherein said apparatus for providing relative motion includes a carriage drive apparatus (72) for moving the pen outwardly on the arm from the center of coordinates and a turntable drive for rotating the medium about the center of coordinates.

14. A printing system according to Claim 13, further characterized in that the nozzle array (54) spans a first distance in a direction extending radially from the center of coordinates, and said carriage drive apparatus (72) is adapted to move the nozzle array radially at a rate such that the nozzle array is moved radially by a distance equal to the first distance for each complete rotation of the medium about the center of coordinates.

15. A printing system according to any of Claims 1014, further characterized by a controller (100) for generating nozzle firing commands to cause said nozzle array (54) to eject ink droplets from a given nozzle comprising the nozzle array at a constant rate for the printing cycle, and the apparatus for rotating the medium is adapted to vary the rotation rate of the medium to achieve a substantially constant tangential velocity of the ink jet nozzle array.

16. A printing system according to any of Claims 1014, further characterized by a controller (100) for generating nozzle firing commands to cause said nozzle array (54) to eject ink droplets at a varying rate for the printing cycle.

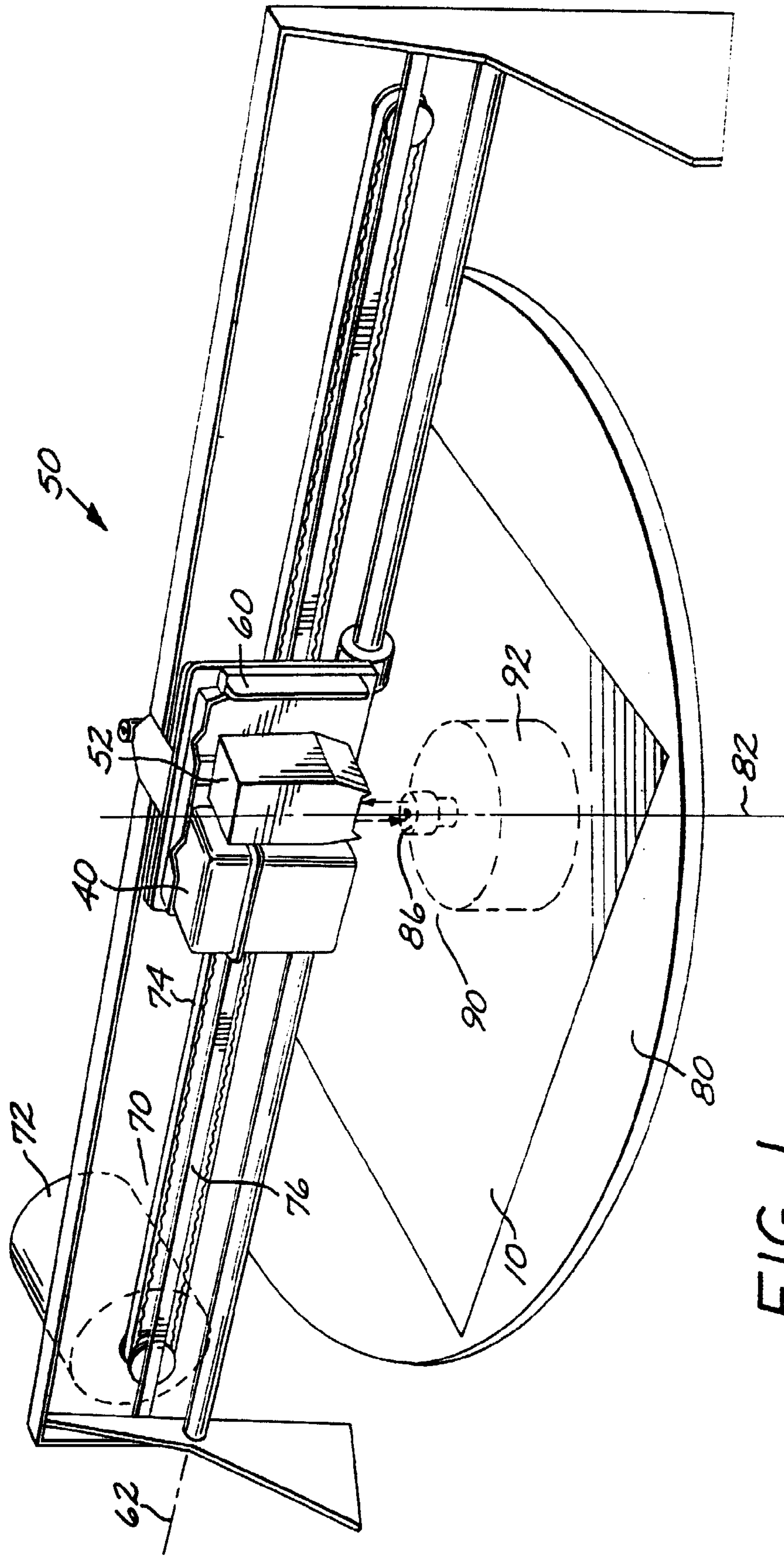
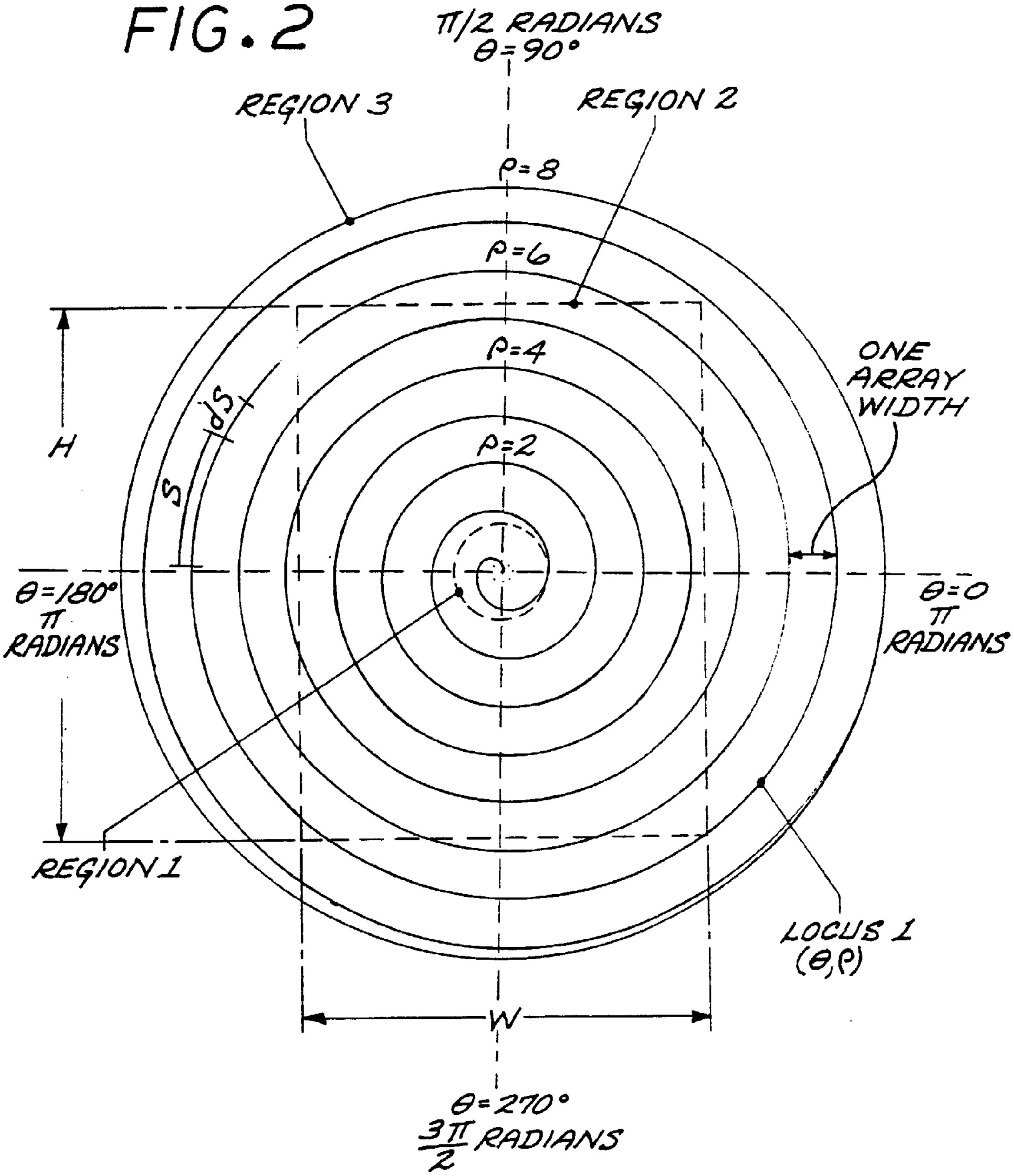


FIG. 1

FIG. 2



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REGION 3
REGION 2
ρ=8
ρ=6
ρ=4
ρ=2
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ARRAY
WIDTH
H
S
dS
θ=180°
π
RADIANS
θ=0
π
RADIANS
REGION 1
LOCUS 1
(θ,ρ)
W
θ=270°
3π/2 RADIANS

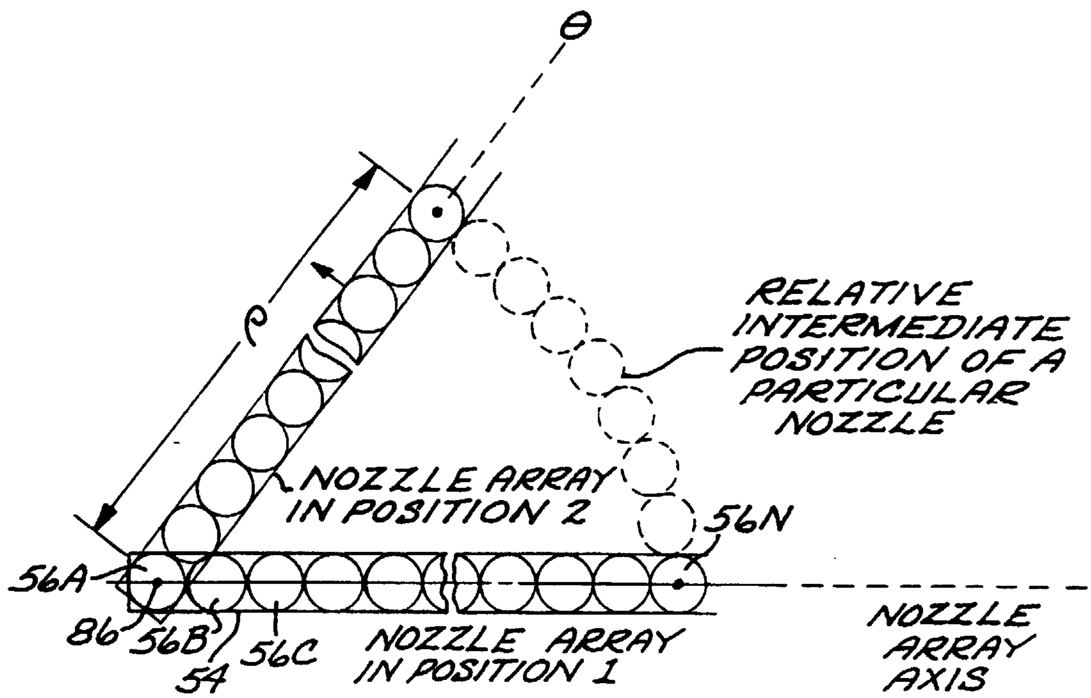
θ
ρ
RELATIVE INTERMEDIATE POSITION OF A PARTICULAR NOZZLE
NOZZLE ARRAY IN POSITION 2
56N
56A
86
56B
54
56C
NOZZLE ARRAY IN POSITION 1
NOZZLE ARRAY AXIS

FIG. 3

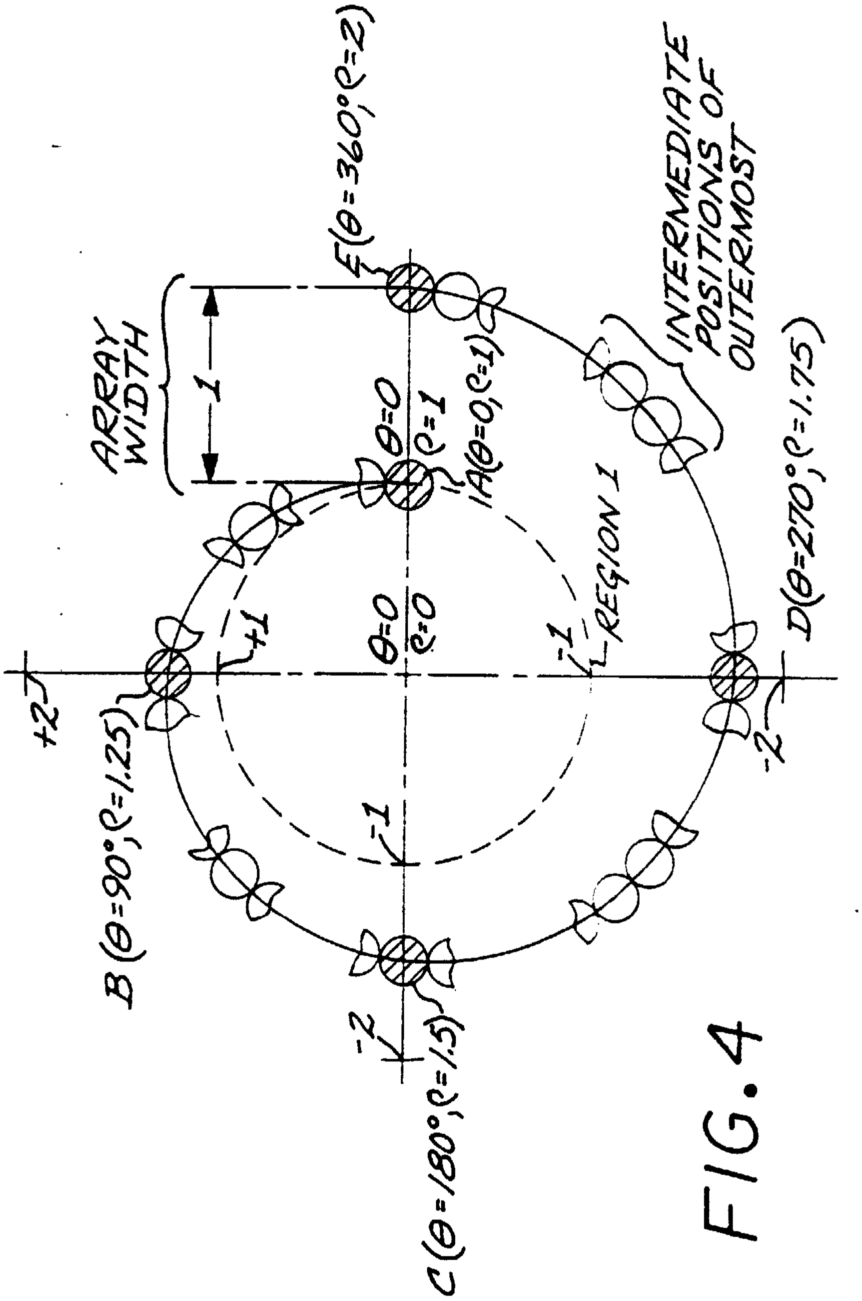
ARRAY WIDTH
1
E(θ=360°, ρ=2)
INTERMEDIATE POSITIONS OF OUTERMOST
θ=0
ρ=1
A(θ=0, ρ=1)
REGION 1
θ=0
ρ=0
+1
-1
+2
-2
-1
-2
B(θ=90°, ρ=1.25)
C(θ=180°, ρ=1.5)
D(θ=270°, ρ=1.75)

FIG. 4

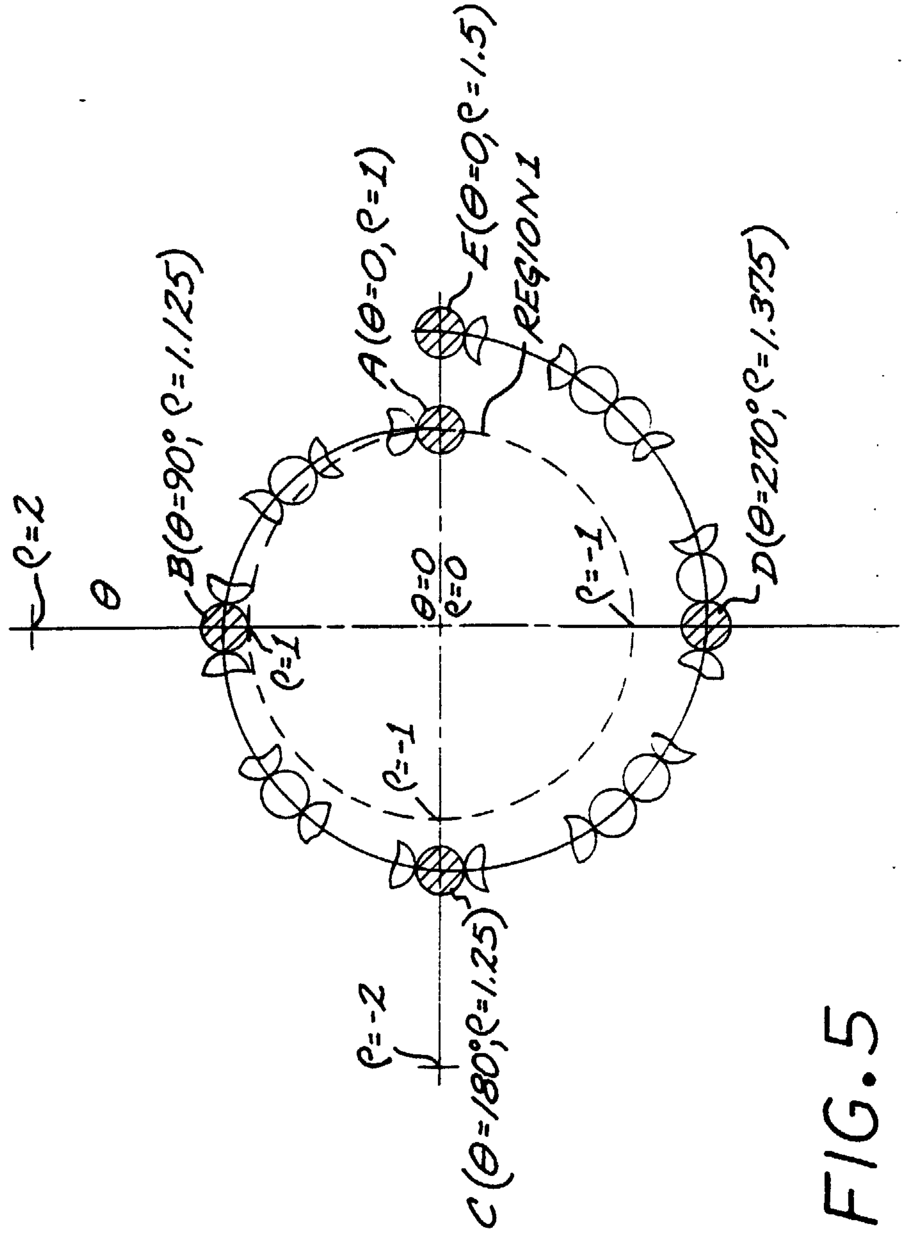
ρ=2
θ
B(θ=90°, ρ=1.125)
A(θ=0, ρ=1)
E(θ=0, ρ=1.5)
REGION 1
D(θ=270°, ρ=1.375)
θ=0
ρ=0
ρ=1
ρ=-1
ρ=-1
ρ=-2
C(θ=180°, ρ=1.25)

FIG. 5

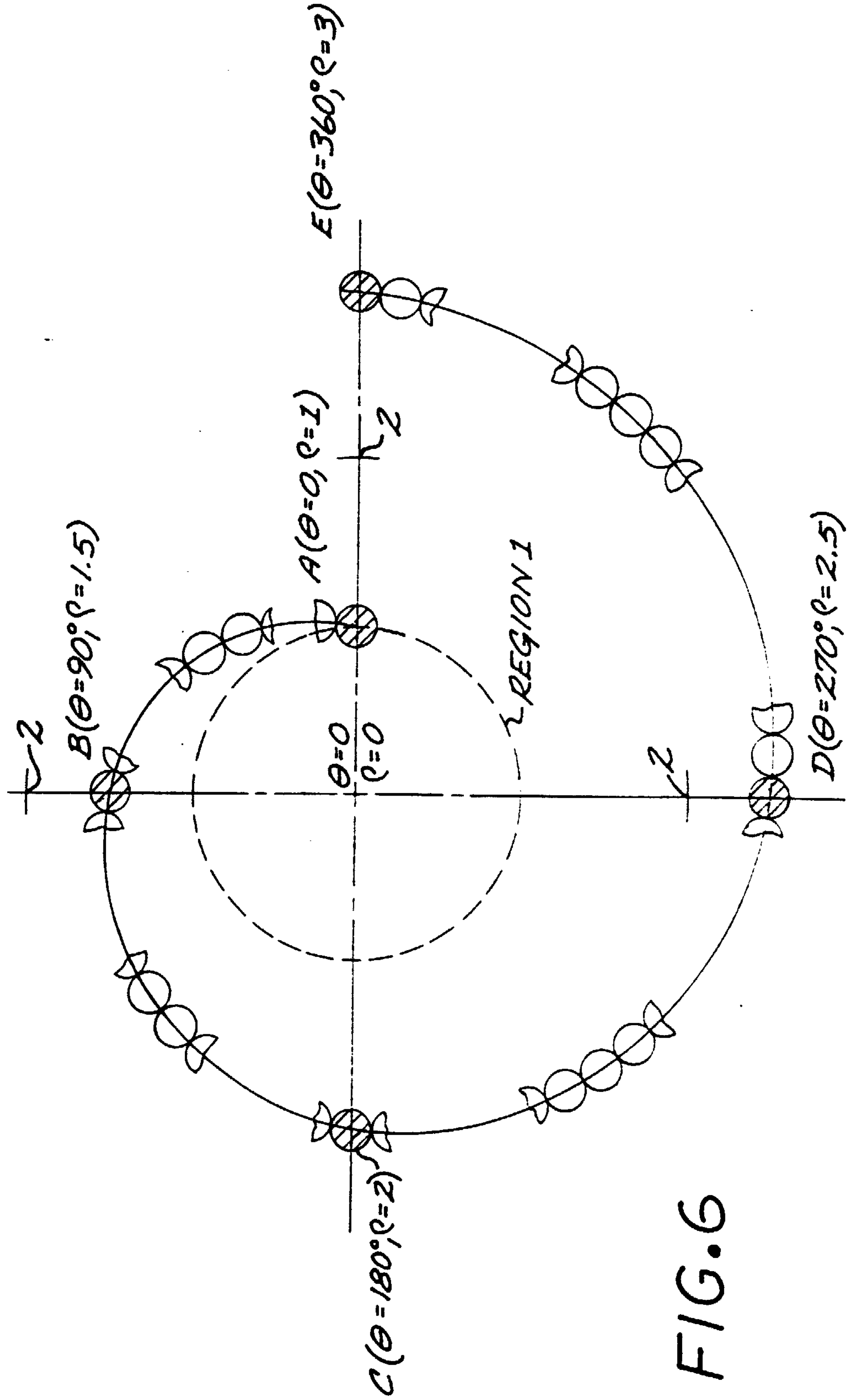

FIG.6

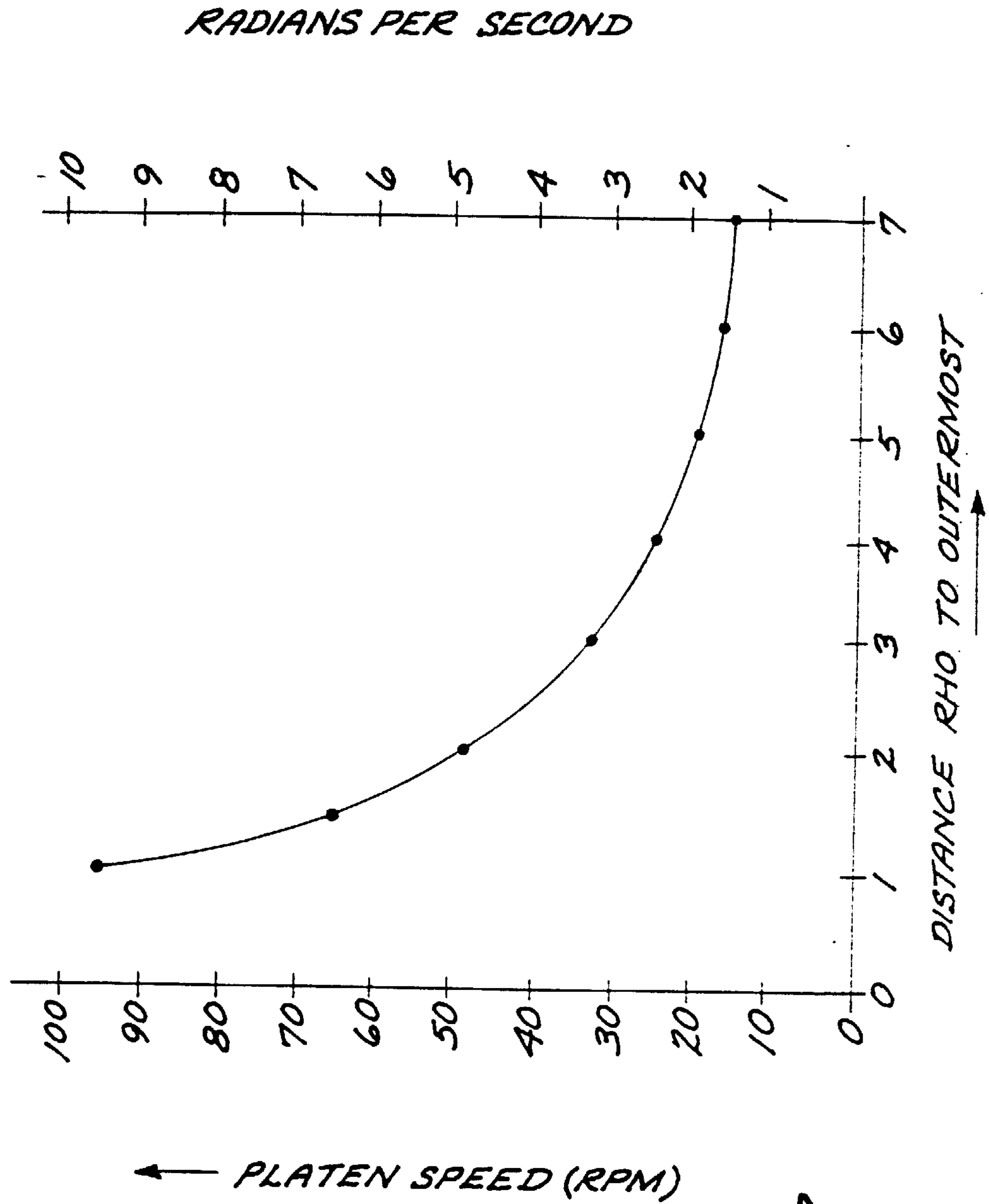
RADIANS PER SECOND
10 9 8 7 6 5 4 3 2 1
DISTANCE RHO TO OUTERMOST
0 1 2 3 4 5 6 7
100 90 80 70 60 50 40 30 20 10 0
PLATEN SPEED (RPM)

FIG. 7

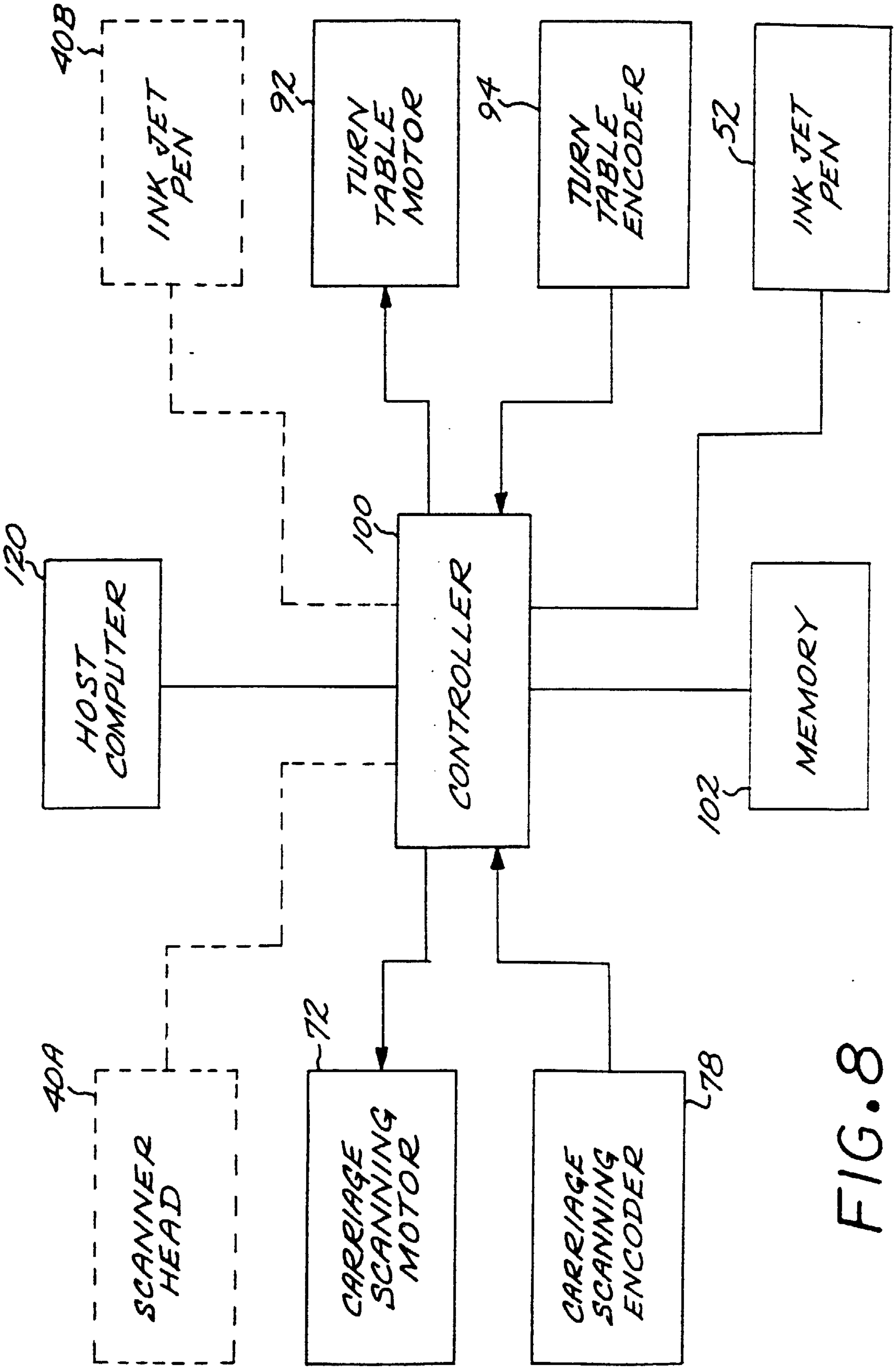
40B
INK JET PEN
92
TURN TABLE MOTOR
94
TURN TABLE ENCODER
52
INK JET PEN
120
HOST COMPUTER
100
CONTROLLER
MEMORY
102
40A
SCANNER HEAD
72
CARRIAGE SCANNING MOTOR
CARRIAGE SCANNING ENCODER
78

FIG.8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 3072

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	GB 1 406 482 A (MARCONI CO LTD) 17 September 1975 (1975-09-17) * page 1, line 46 - page 3, line 48; figure 1 *	1,10	B41J19/16
A	US 2 389 408 A (BOYD) 20 November 1945 (1945-11-20) * page 2, column 2, line 12 - page 3, column 1, line 20; figures *	1,10	
A	WILLS, L.J.: "jet printer with rotatable jet head" RESEARCH DISCLOSURE, no. 228, April 1983 (1983-04), page 22817 XP002109052 Havant Hampshire, Great-Britain	1,10	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 July 1999	De Groot, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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13-07-1999

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		AU 5074673 A	04-07-1974
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82