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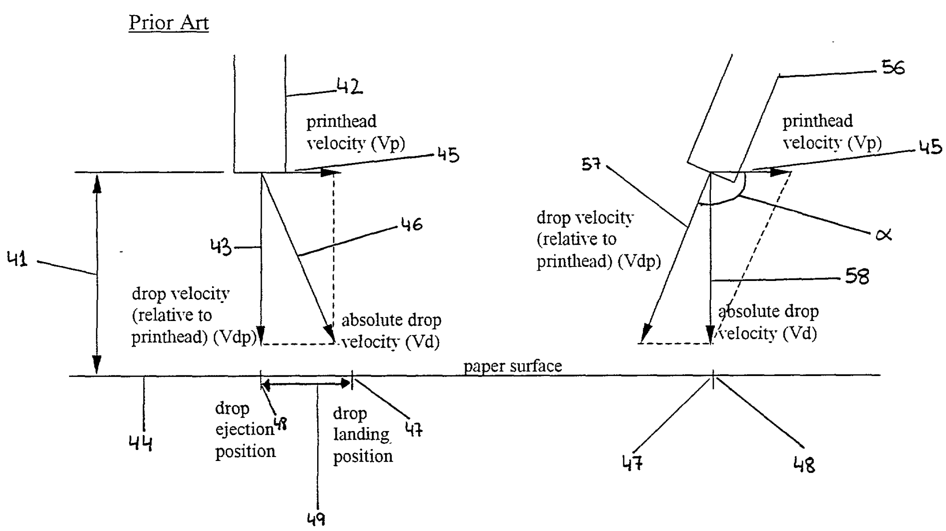
(54) Apparatus and method for improving printing quality

(57) A printing device, for example an inkjet printer, for marking print media by ejecting ink drops from a printhead in which there is relative movement between the printhead and the print media, while ink drops are being ejected from the printhead, compensates for this relative movement by angling the ejection direction of the ink drops relative to the print media. The appropriate angle may be provided by angling the mounting of the printhead, the media, a carriage scan axis, or ejection mechanisms of the printhead. The correct compensation provides for an ink drop trajectory that is normal to the print media at the point of impact which leads to improve printing quality. In particular printing errors due to variations in the separation of the printhead and the print media and due to non symmetrical dots are improved.

FIG. 5a

FIG. 5b



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Description

[0001] The present invention relates to an apparatus and method for improving printing quality, and particularly to printing devices and methods in which ink drops are ejected from a printhead towards a print media in which there is relative movement between the printhead and print media.

[0002] The present invention has particular application in the field of inkjet printing, although as will be appreciated is not limited to this field of application. In many, but not all, inkjet printers a scanning carriage carrying a number of inkjet printheads moves reciprocally above a print media while each printhead ejects drops of ink towards the print media. The print media is normally stationary during the deposition of ink drops and is incrementally advanced between printing passes of the carriage. Evidently, to ensure good image quality, the ink drops must be accurately positioned on the print media, for example paper. Errors in the positioning of drops of ink on paper (where they are known as dots), are a major cause of printing quality degradation. These errors are known as DPE (dot placement errors) and can be due to a large number of causes.

[0003] Some causes of DPE are specific to the printhead itself while others are caused by the printer in which the printhead is mounted. For example, since the printhead is usually moving when a drop of ink is ejected, variations in the ejection speed of the drop affect the position on the paper where the drop will land and this is a major cause of DPE. While attempts have been made to minimise these variations in drop velocity, both for thermally ejected inkjet drops and for piezo inkjet printheads, the variations are nevertheless still great enough to affect the quality of printing. A typical thermal inkjet ejection speed for an ink drop is about 10m/s and variations in this speed of up to 3 m/s are possible. A further known printhead source of DPE is that of the misdirected nozzle. Occasionally, one or more of the many nozzles of an inkjet printhead may be incorrectly formed or may be partially blocked by dried ink. This can lead to the nozzle ejecting ink at an angle other than 90 degrees to the nozzle plate of the printhead which will also lead to DPE.

[0004] Within the printer itself there are several sources of DPE such as variations in the scanning speed or positional location of the carriage, misalignment of the printheads within the carriage or errors in the timing of the signals for firing a nozzle. However, the greatest source of DPE, particularly for larger printers, is variation in the PPS (printhead to paper spacing). The PPS is kept as small as possible so as to minimise DPE (and to reduce ink aerosol) and must also be accurately controlled over the entire length of the print zone of the printer. For typical large format inkjet printers the PPS is of the order of 1mm and must be accurately maintained over a length of up to 60 inches. The carriage of these printers could be travelling at 20 or 40 ips (inches per second) while firing ink drops which are travelling at approximately 10m/s, so any variation in the PPS along the length of the print zone will be translated to DPE since, due to the trajectory of the ink drops through the air, the ink drops will land on the paper either before their target position (in the case of a locally reduced PPS) or after their target position (in the case of a locally increased PPS). Prior art attempts to solve this problem have focused in two areas. Firstly, rigorous mechanical design of the printer chassis and carriage mounting elements so as to attempt to minimise the actual variations in PPS, for example as disclosed in EP 1 029 697 and US serial No. 09/484185 filed on 18 January 2000. Secondly, given that variations do still exist in PPS, attempts have been made to measure these by printing a test pattern which is then scanned by an optical sensor for errors. The variations in PPS measured are then attempted to be corrected for by adjusting the timing delay of firing signals sent to the printheads when they are located at positions requiring PPS correction. Such techniques are disclosed in for example EP 0 622 237 and US serial No. 09/259070 filed on 26 February 1999. While these techniques have certainly had some success in ameliorating the problems caused by variations in PPS, it is expensive in terms of both materials and manufacturing tolerances to attempt to completely eliminate variations in PPS by mechanical means. As for the subsequent correction of errors in PPS, this requires additional functionality and complexity during the design of the printer since such test algorithms must normally be incorporated in ASIC controllers within the printer and, for the user of the printer, are time consuming and waste ink and media.

[0005] A further, separate problem that also degrades the quality of printers in which drops of ink are ejected towards a print media, is the shape of the resulting dot formed on the media. While most printer modelling assumes that the shape of dots are round, if they are examined microscopically, they are found to be of an irregular, somewhat pear shape. This shape will also vary dependent on the speed of the printhead while ejecting the drop and in some instances this problem can limit the scanning speed of the carriage and thus the printing speed of the printer. In some cases, the problem is made worse due to the unintentional ejection of satellite, smaller droplets by the printhead together with the main ink drop.

[0006] Both DPE and irregular dot shapes can lead to a number of problems in the images printed for example banding (in which horizontal or vertical bands in the image can be discerned), fuzzy lines and colour or tone problems. Since for many printers, such as four colour CMYK (cyan, magenta, yellow, black) printers, the majority of desired colours are achieved by a combination of a small set of basic colours, the combination of DPE and variable dot shape can lead to severe colour inconsistencies and inaccuracy.

[0007] According to a first aspect of the present invention, there is provided a printing device for marking print media, comprising a printhead for ejecting ink drops, a holder in which the printhead is mounted, and a mechanism for positioning print media relative to the printhead, wherein during printing operation of the printing device there is relative movement between the printhead and the print media, while ink drops are being ejected from the printhead, and wherein the ejection direction of the ink drops is angled relative to the print media so as to substantially compensate for said relative movement. The present inventors have thus realised that printing quality can be improved by controlling the angle of ejection of ink drops from the printhead with respect to the print media. In contrast to prior art attempts to reduce PPS related printing errors or DPE or dot shape, by controlling the tolerances of the printer or correcting for inaccuracies in the printer, the inventors have appreciated that by controlling the ejection direction of the ink drops the sensitivity of the printer to some of these sources of error may be reduced.

[0008] Preferably, the ejection direction of the ink drops forms a non-zero angle with the normal to the plane of the print media, as opposed to the usual prior art arrangement which attempts to align the ejection direction of the ink drops with the normal to the print media. In this manner the non-zero angle can be arranged to compensate for the relative movement between the print media and the printhead during the ejection of ink drops from the printhead. A particularly preferred result of the angling of the ink drops ejection direction is that the tangent to the trajectory of the ink drops, at the print media surface, is substantially parallel to the normal to the plane of the print media. Thus it has been realised by the present inventors that by angling the ink ejection direction appropriately, so that the ink drops have a trajectory normal to the print media at the point of contact with the print media, several printing quality related errors are reduced. For example, if the trajectory of the ink drops is substantially normal to the print media and there is an error in the PPS, while this would normally be translated directly into greater DPE in prior art printers, in embodiments of the present invention it will lead to a longer or shorter flight time of the ink drops but will cause less DPE. Furthermore, should the printhead eject one or more satellite ink drops in addition to the intended main ink drop, if they are all travelling substantially normally to the print media, in accordance with embodiments of the present invention, then all drops should land on the print media close to each other. This aids in forming a more regularly shaped ink dot on the print media, more consistently and thus aids image quality.

[0009] In preferred embodiments of the present invention, the ink drop ejection angle is determined so that the ink drops are ejected from the printhead with a first velocity component which is substantially equal in magnitude and substantially opposite in direction to the velocity between the printhead and the print media, relative to the print media, and with a second non-zero velocity component towards the print media. In this manner the relative velocity between the print media and the printhead can be compensated for, so that, relative to the print media, the ink drops are ejected with a low velocity vector, in ideal circumstance a substantially zero velocity vector, within the plane of the print media. It will be appreciated that unless the printing environment is a vacuum, air resistance and additionally gravity are likely to affect the velocity of the ink drops. Thus, in order to arrive at the print media surface with substantially a zero velocity vector within the plane of the print media, they are likely to require a velocity vector when ejected from the printhead that is not exactly equal in magnitude to the relative velocity between the printhead and the print media. The precise angle required in any particular circumstances can be readily determined by those skilled in the art, by following the teaching of the present application.

[0010] Preferably, the ejection direction of ink drops from the printhead makes an angle α of greater than 90 degrees with the relative velocity vector between the printhead and the print media in order to compensate for this relative velocity. Numerous embodiments of the present invention are disclosed in which such an angle can be achieved. The optimum angle for compensating for the relative velocity is generally dependent on the magnitude of this relative velocity and in preferred embodiments the angle α can be varied between a plurality of predetermined values each of which is optimised for a different predetermined relative velocity between the printhead and the print media.

[0011] The relative velocity between the print media and the printhead may be generated by a number of alternative or complementary arrangements, for example the printhead may be stationary while the print media is moved during ink drop ejection or vice versa. Advantageously, the printing device has a holder which comprises a carriage capable of moving at least one printhead at a predetermined velocity relative to the print media along a scanning axis, while ink drops are being ejected from the printhead, to generate said relative movement between the printhead and the print media .

[0012] The printing device may have a plurality of printheads mounted on the carriage, and advantageously at least two of the printheads may have different ink drop ejection directions relative to the direction of carriage motion along the scanning axis so that the leading printhead ejects drops at a smaller angle to the carriage motion direction than the trailing printhead. This arrangement is particularly useful when it is found that ink drops fired from the leading printhead experience greater air resistance than those fired from the trailing printhead.

[0013] As may be appreciated by those skilled in the art, if a printing device is arranged so that ink drops are ejected by a printhead that moves in two or more different directions relative to the print media, and the ejection direction is optimally angled for only one of these directions, printing quality may be degraded when the printhead is travelling in other directions. Embodiments of the present invention provide numerous arrangements for compensating for relative movement between a printhead and print media whose direction is periodically reversed.

[0014] While in several embodiments of the present invention it is preferred that the scanning axis of a carriage holding the printhead is substantially parallel to the plane of the print media, the present invention also encompasses printing devices wherein the scanning axis makes an angle with the plane of the print media so as to substantially compensate for the relative movement between the printhead and the media. This arrangement has the advantage that only the mounting of the scan axis of a conventional printer need be altered, which may be achieved at minimum cost. Additionally, a mechanism to alter the angle of the scan axis between two predetermined angles relative to the print media may be provided so that in operation the mechanism alters the angle for each direction of motion of the carriage so that for each direction the angle substantially compensates for the relative movement between the printhead and the print media.

[0015] Alternatively, rather than angling the scanning axis, the print media positioning mechanism may hold the print media at an angle to the relative direction of movement between the printhead and the print media so as to substantially compensate for relative movement between the printhead and the media.

[0016] According to a further aspect of the present invention, there is provided, a method of printing comprising the steps of mounting a print media in a printing device in a printing relationship with a printhead, generating relative movement between the printhead and the print media so that the printhead accesses different parts of the print media for printing, ejecting ink drops from the printhead in a direction, relative to the print media, which makes an angle with the print media so that, when the ink drops impact the print media, the effects of the relative movement between the printhead and the print media are substantially ameliorated.

[0017] The use of the words "ink" and "ink drops" in the present application should be understood to be a shorthand reference to any form of marking material that a printing device may utilise and that may be ejected from a printhead in quantised amounts towards a print media. Thus "ink" and "ink drops" encompass for example dry toner particles, solid ink, carbon, dye based inks, pigment based inks. The present invention in its broadest aspects has equal application for all such marking particles, as will be appreciated by those skilled in this art. However, greatest benefit from certain embodiments of the present invention will be obtained when liquid ink drops are utilised.

[0018] Specific embodiments of the present invention will now be described by way of example only and with reference to the following drawings, in which:

Figure 1 is a perspective view of a large format inkjet printer incorporating features of the present invention;

Figure 2 is a close-up view of the carriage portion of the printer of Figure 1, showing the carriage in which printheads are mounted and the carriage scan axis;

Figure 3 is a close-up view of the print media positioning mechanism of the printer of Figure1, showing the carriage portion in phantom lines;

Figure 4 is a close-up front elevation view of the carriage showing the printheads angled according to embodiments of the present invention;

Figure 5a is a schematic drawing of a prior art printer arrangement and Figure 5b is a schematic drawing of a printer arrangement according to an embodiment of the present invention;

Figure 6a is a schematic drawing showing how DPE is generated in the prior art printer arrangement of Figure 5a and Figure 6b is a schematic drawing showing how DPE is avoided by the printer arrangement according to an embodiment of the present invention of Figure 5b;

Figure 7 is a perspective three quarter view of a printer carriage in which shims are mounted within the stalls of the printheads;

Figure 8 is a group of four microscope photos of dots printed by the carriage of Figure 7 at a carriage speed of 10ips, printing to the left and to the right, with and without the shims present;

Figure 9 is a group of four microscope photos of dots printed by the carriage of Figure 7 at a carriage speed of 25ips, printing to the left and to the right, with and without the shims present;

Figure 10 is a table of measurements taken from the photos of Figures 8 and 9;

Figure 11 is a graph of the offset distance from the drop ejection position to the drop landing position as a function of carriage speed, for an experiment designed to aid in the setting of an angle according to embodiments of the present invention;

Figure 12 is a schematic drawing of a printhead according to an embodiment of the present invention in which the ink ejection surface of the printhead has been angled relative to the side walls of the printhead;

Figure 13 is a schematic drawing of a printhead according to an embodiment of the present invention in which the internal design of the printhead has been altered so that a internal ink pathway is angled relative to the ink ejection surface of the printhead;

Figure 14 shows a schematic of a carriage mounted for a movement along a carriage bar which itself is mounted at an angle to the print media according to an embodiment of the present invention;

Figure 15 is a schematic drawing of a printer according to an embodiment of the present invention in which the mounting of the print media positioning mechanism is at an angle to the carriage scan axis;

Figure 16 is a schematic drawing of a printer according to an embodiment of the present invention in which each of the printheads of the printer is mounted for rotation about a central axis;
Figure 17 is a schematic drawing of a printhead according to an embodiment of the present invention in which an ink ejection surface of the printhead comprises two angled surfaces meeting at an internal acute angle;
Figure 18 is a schematic drawing of a printhead according to an embodiment of the present invention in which an ink ejection surface of the printhead comprises two angled surfaces meeting at an internal obtuse angle; and
Figure 19 is a view along the Y-axis of a page wide array printing system according to an embodiment of the present invention in which the print media is moved past an angled array of printheads while they eject ink drops towards the media.

[0019] Typical embodiments of the invention are exemplified in a large format colour inkjet printer (sometimes know as a plotter) and will be described in relation to the such a printer. However, it will be appreciated by those skilled in the art, that the present invention has application to many other types of printer.

[0020] Figure. 1 is a perspective view of a large format inkjet printer 1 having a housing 2 mounted on a stand 3. The housing has left and right drive mechanism enclosures 4 and 5. A control panel 6 is mounted on the right enclosure 5 via which the user may input data to the printer. A carriage assembly 7, illustrated in phantom under a cover 8, is adapted for reciprocal motion along a carriage bar 9, also shown in phantom. The position of the carriage assembly 7 in a horizontal or carriage scan axis is determined by a carriage positioning mechanism 10 with respect to an encoder strip 11 (see Figure 2). A print media 12 such as paper is positioned along a vertical or media advance axis by a media axis drive mechanism (not shown). The media advance axis, also known as the X axis is denoted as 13, and the scan axis, also know as the Y axis, is denoted as 14. As shown in Figure 1, the printer 1 is loaded with a roll of print media 12 which is held in rollfeed housing 15. The end of the roll of media extends out of the housing 15 through the print zone of the printer, located below the carriage assembly 7, and out the front of the printer. Although not shown in Figure 1, a cut sheet of media may be loaded into the front of the printer 1 where the media positioning system shown in Figure 3 will draw the sheet into the printer. The user may switch between printing on roll media and printing on cut sheet at will.

[0021] Figure 2 is a perspective view of the carriage assembly 7, the carriage positioning mechanism 16 and the encoder strip 17. The carriage positioning mechanism 16 includes a carriage position motor 16A which has a shaft 16B which drives a belt 16C which is secured by idler 16D and which is attached to the carriage 7.

[0022] The position of the carriage assembly in the scan axis is determined precisely by the encoder strip 11. The encoder strip 11 is secured by a first stanchion 17A on one end and a second stanchion 17B on the other end. An optical reader (not shown) is disposed on the carriage assembly and provides carriage position signals which are utilised to achieve image registration when printing and distance measurement when the carriage is scanning a printed test pattern.

[0023] Figure 3 is a perspective view of a simplified representation of a media positioning system 18 which can be utilised in the printer 1. The media positioning system 18 includes a motor 18A which is normal to and drives a media roller 18B. The position of the media roller 18B is determined by a media position encoder 18C on the motor. An optical reader 18D senses the position of the encoder 18C and provides a plurality of output pulses which indirectly determines the position of the roller 18B and, therefore, the position of the media 12 in the Y axis. Also seen in Figure 3 is the carriage mounted optical sensor 19, used for scanning printed test patterns. The media and carriage position information from the encoder strip and the media position optical reader 18D is provided to a processor 26 on a circuit board 27 disposed on the carriage assembly 7. Also on circuit board 27 is a memory element 28 in which the various printing parameters are stored for access by processor 26.

[0024] As also seen in Figure 4, the printer 1 has four inkjet printheads 29, 30, 31 and 32 that store ink of different colours, e.g. cyan, magenta, yellow and black ink, respectively. Each of the printheads is mounted in a stall 50, 51, 52 and 53 within the carriage 7 and a nose of the printhead protrudes through the base of the carriage towards the print media 12. The distance from the ink ejection surface 40 at the end of the nose of the printhead to the print media 12 is known as the PPS 41. The usual mode of operation of the printer 1 is for the media 12 to be advanced along the X-axis by the media positioning system while the printheads of the carriage 7 are not ejecting ink. Then, once the media 12 is stationary in its new position the carriage 7 is scanned along the Y-axis as ink is ejected by the printheads 29, 30, 31 and 32 onto the media 12. Selected nozzles in the inkjet printheads are activated by signals received from processor 26 when the carriage is at certain positions along the Y-axis determined by the encoder strip 11 so as to deposit ink at appropriate locations on the media to form a desired image. Relative movement between the print media 12 and the printheads 29, 30, 31 and 32 during the ejection of ink is thus generated by the movement of the carriage 7. As can be seen in Figure 4, each of the printheads 29, 30, 31 and 32 is mounted at a slight angle within its respective stall 50, 51, 52 and 53 so that the ink ejection direction 57 for each printhead is at an angle α to the carriage scan direction 54 of greater than 90 degrees.

[0025] Some principles of operation of the present embodiment of the invention compared to the prior art will now be described with reference to the schematic diagrams of Figure 5 and 6. Figure 5a is a schematic diagram of a prior art printer arrangement in which the printhead 42 is positioned to eject ink drops at velocity Vd and in a direction 43 which, when the printhead is stationary, is normal to the plane of the print media 44. However, when the printhead 42 is moving in a direction 45 relative to the print media at a velocity Vp the direction 46 of ejection of the ink drops relative to the print media 12 is no longer parallel to the normal of the print media surface. The effect of this arrangement is that the ink drop landing position 47 where a dot is formed on the media 44 is offset by a distance 49 from the drop ejection position 48, that is the point on the media above which the ink drop leaves the printhead. Normally, this offset can be compensated for by the printer processor 26. Values for the offset 49 for each printhead 42 and for each predetermined printhead velocity 45 are stored in memory 28 and when printing the processor calculates the appropriate timing delay or advance in sending a firing signal to the printhead so as to ensure that the ink drop lands in the correct position on the media. However, referring now to Figure 6a, if as the carriage 7 moves along the scan axis 14 there is an unintended difference in the PPS 41 at a certain point along the scan axis, this will lead to DPE. An exaggerated PPS error is shown in Figure 6a, where a phantom printhead 55 is shown at a greater PPS y2 than the expected PPS y1. This leads to an offset distance x2 which is greater than the expect offset distance of x1 and thus to a DPE = x2 - x1. This DPE is given by

$$DPE = x2 - x1 = Vp/Vd(y2 - y1)$$

where the printhead velocity is Vp, ink drop velocity Vd.
A typical PPS error y2 -y1 in a large format printer is 0.2mm and a typical drop velocity for thermal inkjet printheads is 10 m/s. For a typical printhead velocity of 20 ips (inches per second) this leads to a DPE of 0.01 mm. At a printer resolution of 600dpi (dots per inch), this is equivalent to a DPE of a quarter dot i.e. of a quarter of the printer pixel grid size.

[0026] Figure 5b shows a schematic diagram of a printer arrangement of the present embodiment. The printhead 56 is mounted within the carriage 7 at an angle α so that the ejection direction 57 of ink drops, relative to the media 44, is not normal to the media surface. The angle α is chosen so that the absolute trajectory 58 of the ink drop, when fired from a printhead which is moving at a velocity Vp relative to the media, is normal to the media. This arrangement has the effect that the ink drop landing position 47 is coincident with the drop ejection position 48. In this manner the relative velocity between the printhead and the print media can be compensated so that, from the perspective of the print media, the ejection of the ink drops is similar to that seen from a stationary prior art printhead. As shown in Figure 6b, if there is a PPS error so that the angled printhead is locally displaced upwards as shown in phantom at 59, this will have no effect on the drop landing position 47 and there will thus be no DPE due to the PPS error.

[0027] In addition to considerably improving DPE due to PPS errors, the arrival of ink drops perpendicularly to the print media surface will also improve the dot shape formed on the print media surface. As can be from Figure 5a, the striking of the print media surface at an angled trajectory by the ink drops in prior art arrangements is likely to spread any tail or satellite effects the ink drop may have over a larger area of the print media than if the ink drop trajectory is perpendicular to the media. Both these effects will contribute to an improved image quality. A further important advantage of embodiments of the invention is that both of these effects are substantially independent of the printhead velocity. Thus the carriage scan speed, the major limiting factor in printing speed, can be increased without a proportionate decrease in image quality, as is the case for prior art arrangements.

[0028] It will be appreciated that the above discussion of the operation of an embodiment of the invention is from a theoretical perspective. It should thus form a starting point for the practical implementation of embodiments of the invention, but as will be appreciated by those skilled in this field a degree of experimentation will be required in order to determine the optimum angle for the printheads under any particular operating conditions. Some considerations and tests for determining the optimum angle to be set will now be described.

[0029] Without considering other dynamic effects than the printhead velocity and drop velocity, the angle α that a printhead should be set at is given by:

$$A = 90 \text{ degrees} + \text{arctangent}\ (Vp / Vd)$$

Table 1 below gives the offset angle β from 90 degrees ($\alpha = 90° + \beta$) for a range of typical printhead, or carriage velocities Vp and for a drop velocity of Vd = 10m/s.

Table 1

V_p (ips)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
β (°)	0.7	1.5	2.2	2.9	3.6	4.4	5.1	5.8	6.5	7.2	8	8.7	9.4	10.1	10.8	11.5

[0030] In practise one of the most important factors, particularly affecting inkjet printers having small drop volumes, in the setting of the angle α, is air resistance. In general this is likely to reduce the angle at which the printhead should be set since air resistance will act to reduce the velocity Vp of the ink drops. However, under some circumstances of drop velocity, printhead velocity and aerodynamics around the carriage the theoretical angle may need to be increased to obtain optimum performance. The effect of air resistance may also be different for each of the printheads within the carriage, due the shielding effect of one printhead by the other printheads. This may mean that, for example the angle α for the leading printhead 29 in the carriage should be set lower than the angle α for the trailing printhead 32 of the carriage because drops ejected by printhead 29 experience more air resistance than those ejected by printhead 32.

[0031] An experiment showing the improvement in print quality due to the use of an embodiment of the invention will now be described. Referring to Figure 7, a shim 60 of thickness 0.4mm was inserted into the side of each of the carriage stalls between the printhead and the stall wall. This had the effect of angling each of the printheads by approximately 1° from their normal position (β=1°). Since the shim was placed at the top right hand side of the printhead (when facing the printer) the 1° angle caused the angle α between the ink drop ejection direction and the carriage scan direction to be 91° when the carriage scanned from right to left, and 89° when the carriage scanned from left to right. From Table 1 it can be seen that theoretically an angle of 1° is optimum for a carriage scan speed of approximately 7ips from right to left, however the carriage was actually scanned at a speed of 10 ips due to hardware limitations. The drop velocity in all cases was approximately Vd=10m/s. A test pattern of 8 space dots was printed when scanning the carriage both from right to left and from left to right, both with the shim in place and without the shim in place (i.e. β=0, α=90°). These four test pattern conditions were then repeated with a carriage scanning speed of 25ips.

[0032] The 8 dot test patterns were photographed through a microscope and are shown in Figure 8 for the 10ips tests and Figure 9 for the 25ips tests. Referring to Figure 8, photo 81 shows the 8 dot pattern printed at 10ips with the carriage moving from left to right and with no shim i.e. β=0. Photo 84 shows the 8 dot pattern printed at 10ips with the carriage moving from right to left and with the 0.4mm shim in place i.e. β=1°. The length L and height H of each of the 8 dots of each of the eight test patterns was then measured under the microscope and these results are tabulated in Table 2 of Figure 10. The ratio of L/H was calculated for each dot and then these values were averaged for each set of 8 dots in a test pattern.

[0033] Finally the average values of L/H were used to rank the eight test patterns so that the test pattern with the closest average value of L/H to one is ranked highest. As can be seen from the column of Table 2 of Figure 10, headed "Ranking", test pattern 84 obtained the highest ranking. This means that on average the dots of test pattern 84 are more circular than those of the other test pattern and thus if used to print an image will give the highest quality. It can be seen that test pattern 84 was printed using an arrangement in accordance with embodiments of the invention i.e. with α=91°, somewhat less than the theoretically calculated value for Vp=10ips and Vd=10m/s. Furthermore, all of the subsequent ranking positions confirm that this embodiment of the invention improves printing quality. For the 10ips test, photos 81 and 82 are ranked in 2nd and 3rd position and photo 83 is ranked in last position. This is to be expected since, if angling the printhead away from the direction of motion of the carriage (so that α is greater than 90°) improves the print quality, then when the carriage direction is reversed (so that α is less than 90°), it is likely that print quality will be worse that the prior art standard printhead position (where α=90°). This ranking order is also seen for the 25ips tests, where from table 2 it can be seen that the order is photo 98 first, followed by photos 96, 95 and 97. All of the average values of the L/H ratio for the 25 ips tests are higher than those for the 10 ips tests, showing worse print quality due to the higher carriage speed but the ranking of print quality within the 25 ips tests is the same as for the 10ips tests. The reason that the print quality in this test is not better for photo 98 is that the value of β theoretically required for this carriage speed is 3.6° (see table 1) whereas the actual value used was only 1°.

[0034] Such a print quality test can be used to help to optimise the angle α for each printhead of a particular printer. For example a process as follows could be employed:

1. Chose a carriage speed at which you which a printmode of the printer to operate
2. Calculate the theoretical value for α for this carriage speed and a known drop velocity
3. Chose a printhead within the carriage to optimise and set α to the theoretical value
4. Print a test pattern of dots and examine under a microscope, calculate average circularity
5. Increase or decrease α dependent on the dot shape
6. Repeat 4 and 5 until α optimise for this printhead
7. Repeat 3, 4 and 5 for other printheads within the carriage

[0035] A further experiment has been carried out to explore the aerodynamic affects on the ink drop trajectory for a particular large format ink printer. A printhead mounted in the conventional manner (with α=90°) was triggered to print at the same carriage position (same drop ejection position of Figure 5a) when travelling at different carriage speeds. The offset distance 49 from the drop ejection position to the drop landing position was then measured and plotted as a function of the carriage speed as shown on curve 100 of Figure 11. Also plotted as curve 101 is the theoretical contribution to the offset distance 49 from the carriage velocity, which given that the PPS is constant and that the drop velocity is constant is a linear function of the carriage speed. The third curve 102 of Figure 11 is the result of subtracting curve 101 from curve 100 and represents a measure of the variation with carriage speed of the remaining factors that affect the offset distance 49. These curves could be used to help decide for a particular printer whether to increase the angle α beyond that calculated theoretically for a specific carriage speed or whether to decrease it from the calculated value. For example it would seem that for the printer and carriage arrangement tested, at lower carriage speeds the value of α should be increased from the theoretical value, while for higher carriage speeds the value of α should be decreased from that calculated theoretically.

[0036] While the specific embodiment described in detail above achieves the desired angle α between the ink drop ejection direction and the relative velocity between the printhead and the print media by angling the mounting of the printhead within the carriage, it will be appreciated that may other components of a printing device may be appropriately angled in order to achieve the objectives of the present invention. A non-exhaustive number of these alternative embodiments will now be described.

[0037] Figure 12 is a schematic drawing of a printhead according to a further embodiment in which the ink ejection surface 104 of the printhead has been angled relative to the side walls 105 and 106 of the printhead. The appropriate angle α is then generated between Vd and Vp since the ink drops are ejected normally from the ink ejection surface 104. This embodiment has the advantage that no special mounting arrangements within the printer carriage are required and such printheads could be utilised with existing printer hardware.

[0038] A further alternative embodiment is shown in Figure 13. The internal design of the printhead 107 has been altered so that a internal ink pathway 108 is angled relative to the ink ejection surface so that the ink ejection direction is not at 90° to the surface 104. Again the angle α between the ink ejection direction and the printhead movement direction is achieved. This embodiment has the advantages of the embodiment of Figure 12, but additionally does not increase the PPS potentially required due to the angled ejection surface 104 of the Figure 12 embodiment.

[0039] Figures 14 and 15 show two further embodiments which both differ somewhat from previously described embodiments. Figure 14 schematically shows a carriage 7 mounted for a movement along a carriage bar 9, the carriage bar itself being mounted at an angle to the print media 44. In this case the ejection direction is at 90° to the printhead direction of motion, but is angled relative to the print media so that the resultant of the two velocity vectors Vp and Vd is normal to the print media surface. This embodiment has the advantage that no modifications are required to a standard printer carriage or printhead and the required angle is simply achieved by a slight offset when mounting the carriage bar 9.

[0040] In the embodiment of Figure 15 the ejection direction is also at 90° to the printhead direction of motion, but is angled relative to the print media so that the resultant of the two velocity vectors Vp and Vd is normal to the print media surface. In this case the angle is achieved via the mounting of the print media positioning mechanism.

[0041] As has been mentioned above, one of the disadvantages of some embodiments of the invention is that when the printhead or other component of the printer is angled so as to optimise printing for a specific printhead movement direction, the opposite movement direction may be caused to print at worse quality. A non-exhaustive number of further alternative embodiments will now be described which address this issue.

[0042] One alternative embodiment which allows for bi-directional printing at improved image quality for both printing directions, is simply to have two sets of printheads. One set may be angled for printing in one direction and the other oppositely angled for printing in the opposite direction.

[0043] A second alternative bi-directional printing embodiment is shown schematically in Figure 16. Each of the printheads of a printer is mounted for rotation about a central axis 110 within the printer carriage. The rotation is achieved via an electromagnetic pusher 111 which acts against a spring 112 and the rotation of the printhead is limited by a pair of stops 113. At each end of the carriage scan axis, prior to returning to the print zone of the printer, the angle of inclination of each of the printheads may be reversed. In this manner the optimum angle is achieved for both printing directions without requiring two sets of printheads. A further enhancement to this embodiment may be achieved by manually or automatically adjusting the position of the stops 113. This would enable different angles of inclination of the printhead to be achieved, each of which could be optimised for different carriage speed.

[0044] Figures 17 and 18 show modifications to the ejection surface 104 of a printhead which would allow it to print at high quality in accordance with the present invention in two printing directions and to be mounted in a carriage in a normal manner.

[0045] Figure 17 is a schematic showing a printhead with an ink ejection surface which comprises two angled surfaces meeting at an internal acute angle. Each of the surfaces, as can be seen in Figure 17c, has a row of nozzles 114 which fires ink drops in different directions. Each of the two ejection directions is optimised for a particular carriage speed and direction.

[0046] Figure 18 is a schematic showing a printhead with an ink ejection surface which comprises two angled surfaces meeting at an internal obtuse angle. As for the Figure 17 embodiment, each of the surfaces, as seen in Figure 18c, has a row of nozzles 114 which fires ink drops in different directions and each of the two ejection directions is optimised for a particular carriage speed and direction.

[0047] A final embodiment for bi-directional printing is based on the embodiment of Figure 14. The carriage bar 9 is provided with a mechanism for altering its angle relative to the print media 44, for example a stepper motor located at one end of the carriage bar 9 that is able to lift or lower this end. If the moving end of the carriage bar is lowed past the height of the opposite end of the carriage bar the angle between the ejection direction of the printhead and the print media can be changed for each direction of movement of the carriage. This embodiment may also advantageously be used to optimise the ejection angle for printing at different carriage speeds, whether bi-directional or uni-directionally.

[0048] Embodiments of the present invention described thus far all comprise a printhead which is moved relative to the print media. As will be appreciated by those skilled in the art, the present invention may also be applied to printer systems in which the printhead is fixed and the print media moves relative to the printhead. A particular example of such a system within the inkjet printer field is the so called page wide array. Such a device comprises an array of fixed printheads which span across the width of a print media so that no movement of the printheads in the Y-axis is required to print on the print media. The print media is then moved in the X-axis past the printheads. The media could be moved in an incremental manner so that at each printing operation the media is stationary, or it could be moved continuously so that there is relative movement between the print media and the printheads during the ejection of ink drops. In the latter case the principles of the present invention can advantageously be applied to improve print quality.

[0049] Figure 19 is a view along the Y-axis of a page wide array printing system in which the print media 44 is moved past an array 115 of printheads while they eject ink drops towards the media in direction 116. By angling the array of printheads 115 toward the movement direction 117 of the media the relative movement between the media and the printhead array can be compensated for so that the ink drops land on the print media with substantially no velocity vector within the plane of the media, i.e. they impact the media normally relative to the media.

Claims

1. A printing device for marking print media, the printing device comprising:

a printhead for ejecting ink drops,
a holder in which the printhead is mounted, and
a mechanism for positioning print media relative to the printhead,

wherein during a printing operation of the printing device there is relative movement between the printhead and the print media, while ink drops are being ejected from the printhead, and wherein the ejection direction of the ink drops is angled relative to the print media so as to substantially compensate for said relative movement.

2. A printing device as claimed in claim 1, wherein the ejection direction of the ink drops forms a non-zero angle with the normal to the plane of the print media.

3. A printing device as claimed in claim 1 or 2, wherein the tangent to the trajectory of the ink drops at the print media surface is substantially parallel to the normal to the plane of the print media.

4. A printing device as claimed in any preceding claim, wherein the ink drops are ejected from the printhead with a first velocity component which is substantially equal in magnitude and substantially opposite in direction to the velocity between the printhead and the print media, relative to the print media, and with a second non-zero velocity component towards the print media.

5. A printing device as claimed in any preceding claim, wherein the ejection direction of ink drops from the printhead makes an angle α of greater than 90 degrees with the relative velocity vector between the printhead and the print media.

6. A printing device as claimed in claim 5, wherein the angle α is achieved by mounting the printhead within the holder at an angle.

7. A printing device as claimed in claim 5, wherein the angle α is achieved by angling a face of the printhead through which ink drops are ejected.

8. A printing device as claimed in claim 5, wherein the angle α is achieved by angling an ink pathway within the printhead relative to a face of the printhead through which ink drops are ejected.

9. A printing device as claimed in any one of claims 5 to 8, wherein the angle α is substantially equal to:

$$90 \text{ degrees} + \arctan(Vp / Vd) \pm 50\%$$

where Vp is the velocity of the printhead and Vd is the ink drop velocity.

10. A printing device as claimed in any one of claims 5 to 9, wherein the angle α can be varied between a plurality of predetermined values each of which is optimised for a different predetermined relative velocity between the printhead and the print media.

11. A printing device as claimed in any preceding claim, comprising a plurality of printheads for ejecting ink drops, each of the printheads ejecting ink drops with an ejection direction which makes an angle α of greater than 90 degrees with the relative velocity vector between the printhead and the print media.

12. A printing device as claimed in any preceding claim, wherein the mechanism for positioning print media is capable of moving the print media relative to the printhead(s) at a predetermined velocity, while ink drops are being ejected from the printhead, to generate said relative movement between the printhead and the print media.

13. A printing device as claimed in any preceding claim, wherein the holder comprises a carriage capable of moving at least one printhead at a predetermined velocity relative to the print media along a scanning axis, while ink drops are being ejected from the printhead, to generate said relative movement between the printhead and the print media .

14. A printing device as claimed in claim 13, having a plurality of printheads mounted on the carriage, wherein at least two of the printheads have different ink drop ejection directions relative to the direction of carriage motion along the scanning axis and the leading printhead ejects drops at a smaller angle to the carriage motion direction than the trailing printhead.

15. A printing device as claimed in claim 13 or 14, wherein the carriage is mounted for reciprocating movement in opposite linear directions and the printhead(s) are capable of ejecting ink drops in a direction greater than 90 degrees away from the direction of movement of the carriage for each of the two carriage movement directions.

16. A printing device as claimed in claim 15, wherein the carriage comprises two sets of printheads, one of which is utilised when the carriage moves in one direction and the other set of printheads is utilised when the carriage moves in the other direction.

17. A printing device as claimed in claim 15, wherein each of the printheads is rotatably mounted within the carriage about an axis substantially perpendicular to the direction of movement of the carriage and parallel to the print media and arranged so that between each traverse of the carriage each printhead is rotated between two positions, one of which provides for the direction of ejection of ink drops to be greater than 90 away from one of the directions of movement of the carriage and the other position provides for the direction of ejection of ink drops to be greater than 90 away from the other direction of movement of the carriage.

18. A printing device as claimed in claim 15, wherein the printhead(s) is mounted in a generally perpendicular position with respect to the directions of movement of the carriage and wherein the face of the printhead through which ink drops are ejected comprises two angled surfaces each of which direct ink drops to be ejected in two different ejection directions from different nozzles each of the ejection directions making a angle of greater than 90 degrees with one of the linear directions of movement of the carriage.

19. A printing device as claimed in any one of claims 13 to 18, wherein the scanning axis of the carriage is substantially parallel to the plane of the print media.

20. A printing device as claimed in claim 1, 2 or 3, wherein the print media positioning mechanism holds the print media at an angle to the relative direction of movement between the printhead and the print media so as to substantially compensate for said relative movement.

21. A printing device as claimed in claim 1, 2 or 3, wherein the holder comprises a carriage capable of moving at least one printhead at a predetermined velocity relative to the print media along a scanning axis, while ink drops are being ejected from the printhead, to generate said relative movement between the printhead and the print media and wherein the scanning axis makes an angle with the plane of the print media so as to substantially compensate for said relative movement.

22. A printing device as claimed in claim 21, wherein the printing device further comprises a mechanism to alter the angle of the scan axis between two predetermined angles relative to the print media and in operation said mechanism alters the angle for each direction of motion of the carriage so that for each direction the angle substantially compensates for the relative movement between the printhead and the print media.

23. A method of printing comprising the steps of:

mounting a print media in a printing device in a printing relationship with a printhead,
generating relative movement between the printhead and the print media so that the printhead accesses different parts of the print media for printing,
ejecting ink drops from the printhead in a direction, relative to the print media, which makes an angle with the print media so that, when the ink drops impact the print media, the effects of the relative movement between the printhead and the print media are substantially ameliorated.

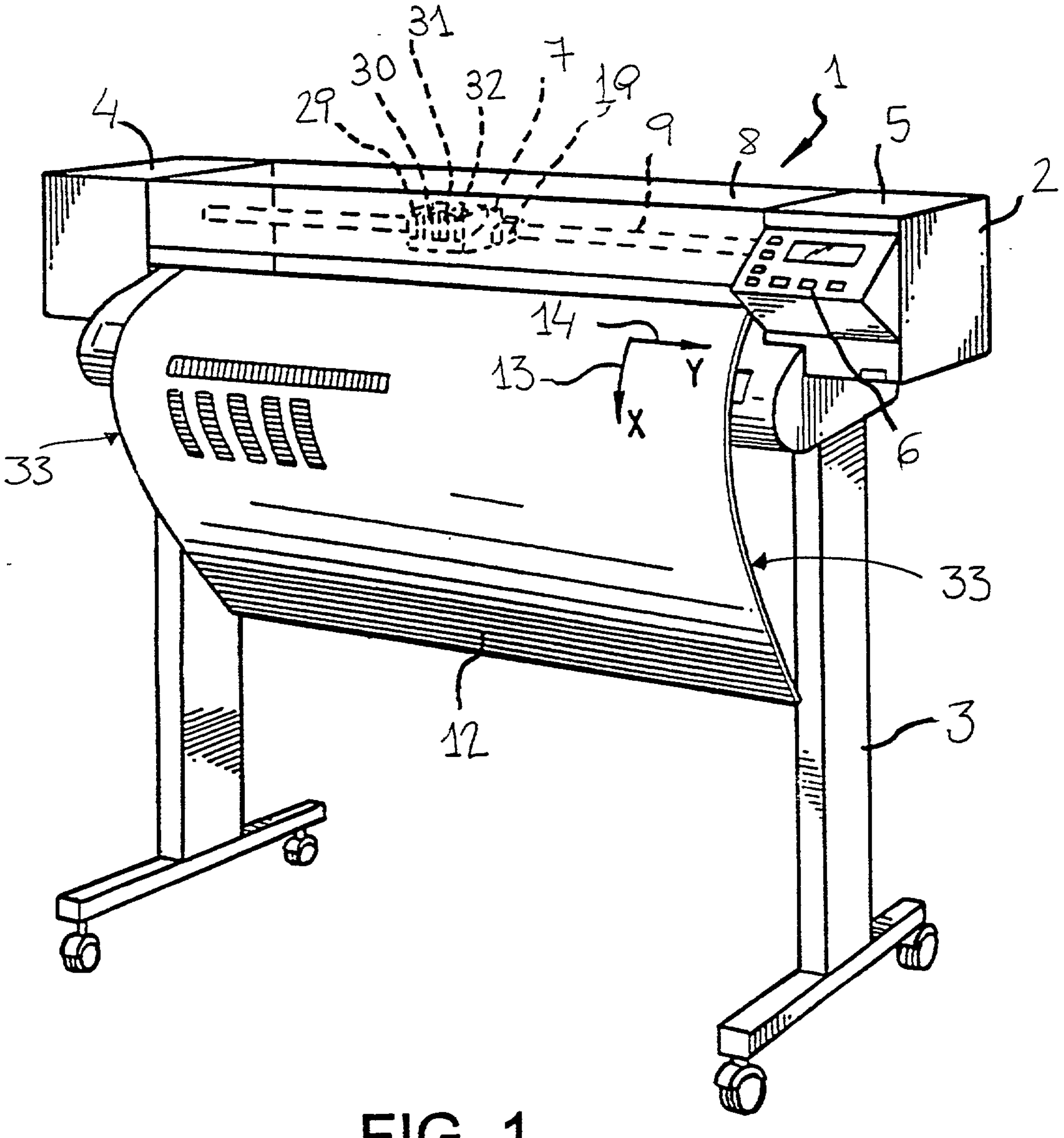


FIG. 1

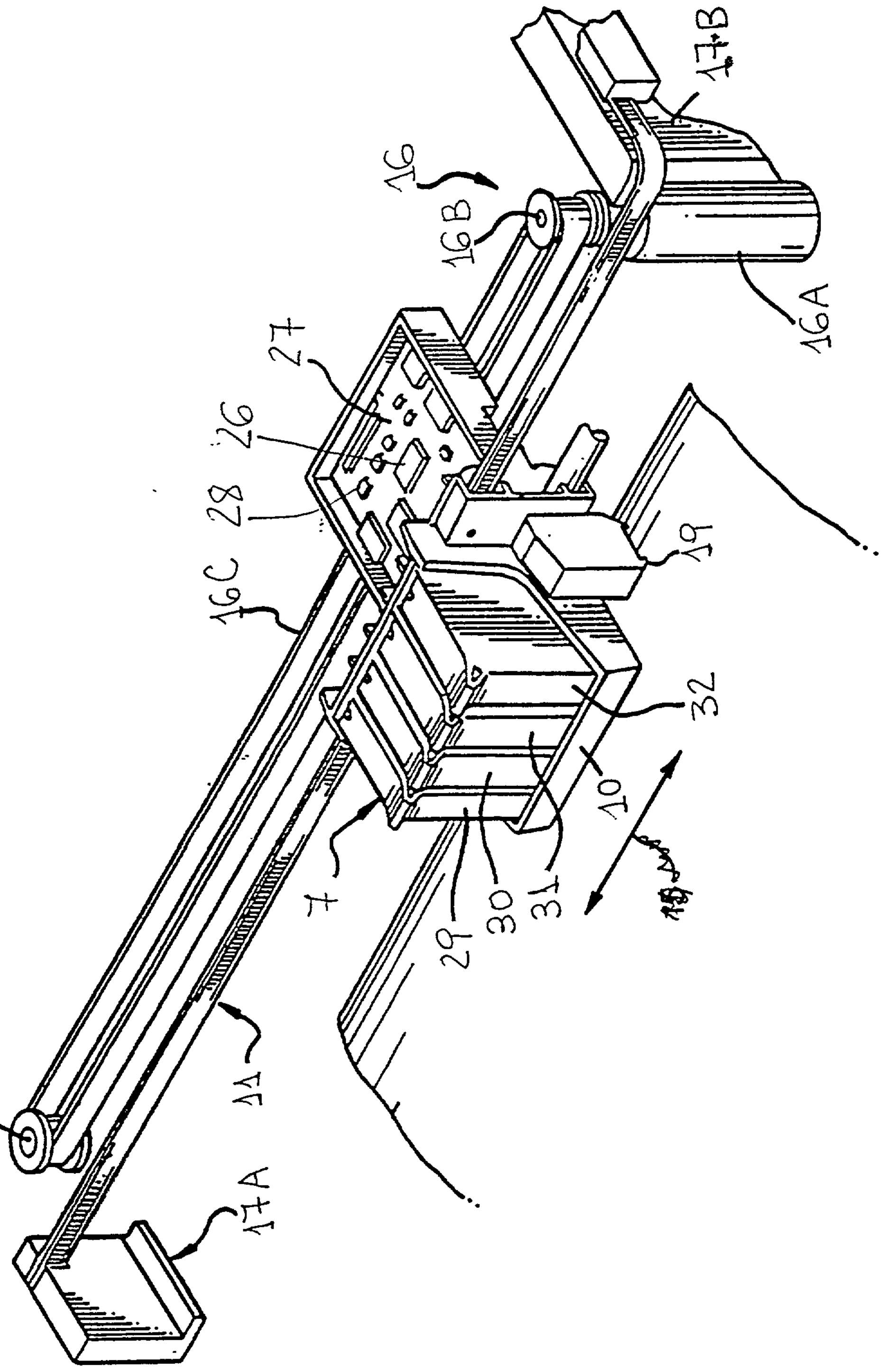


FIG. 2

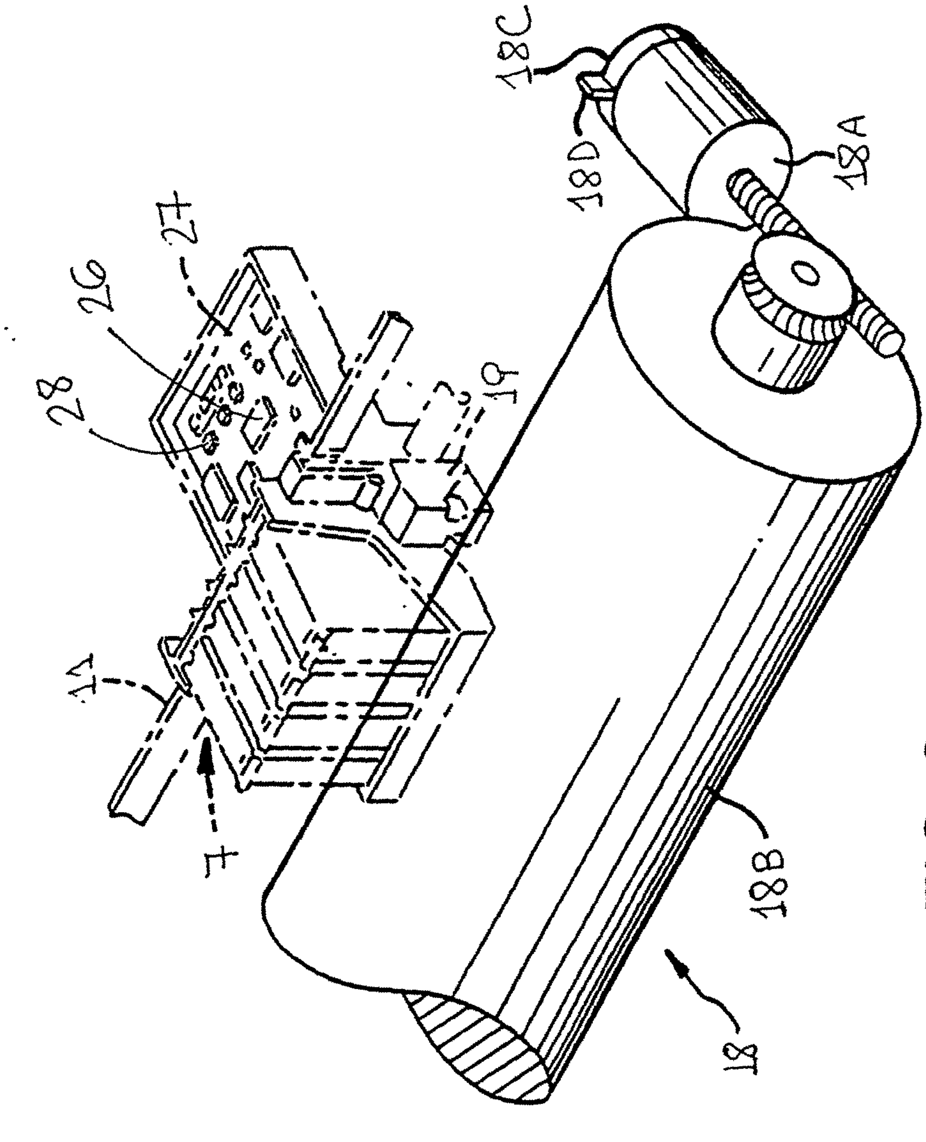


FIG. 3

FIG. 4

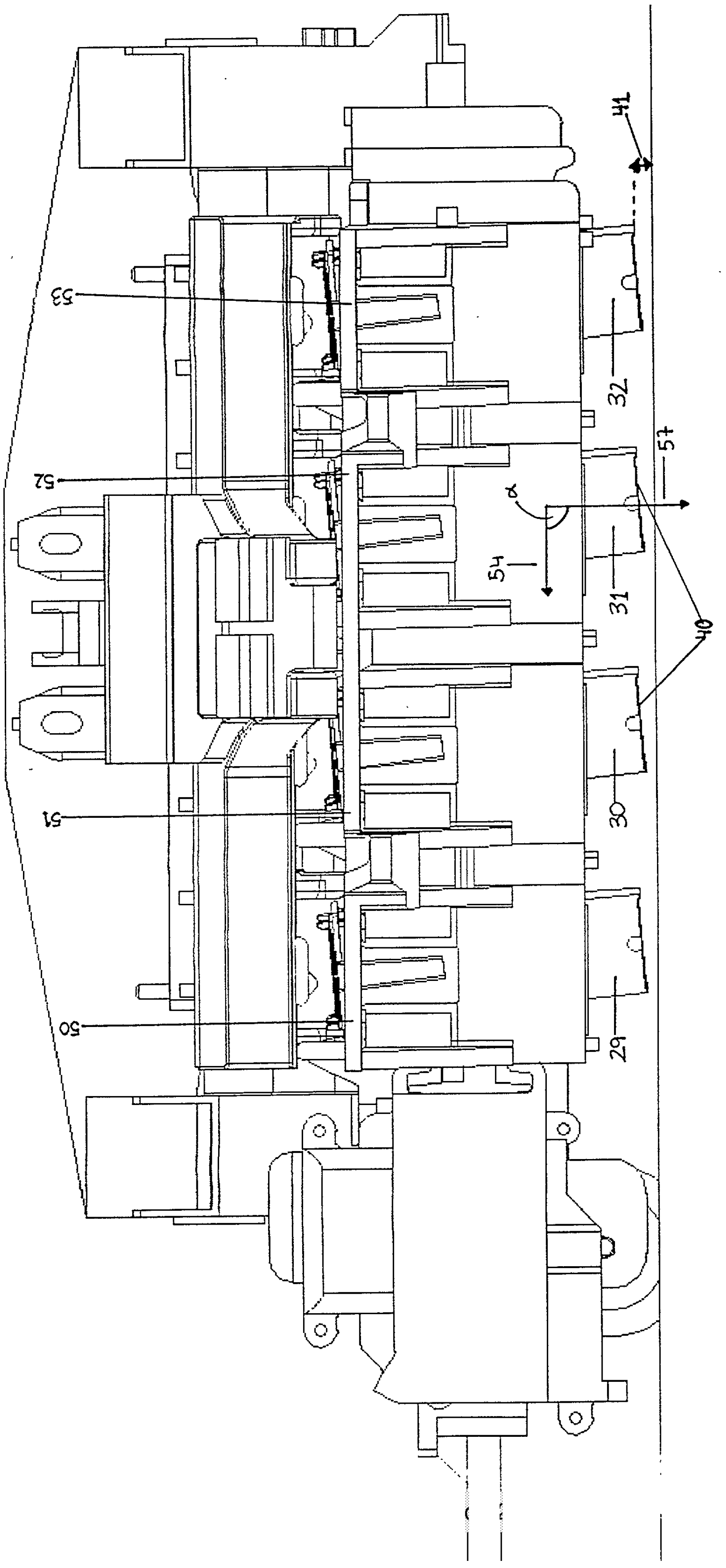


FIG. 5a

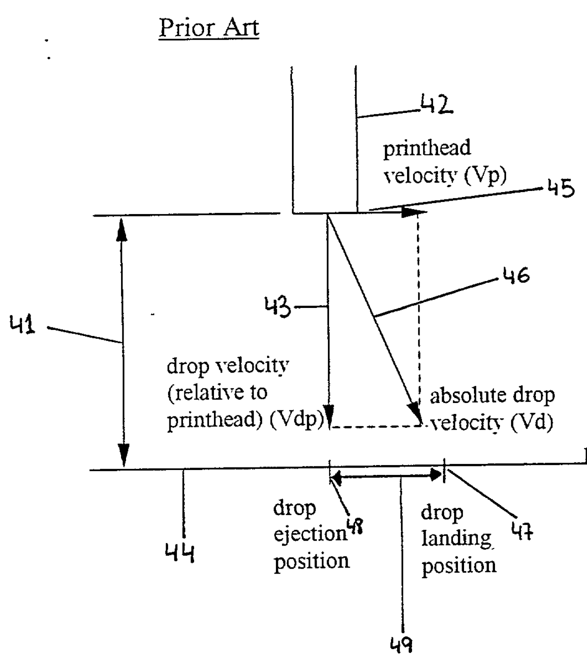
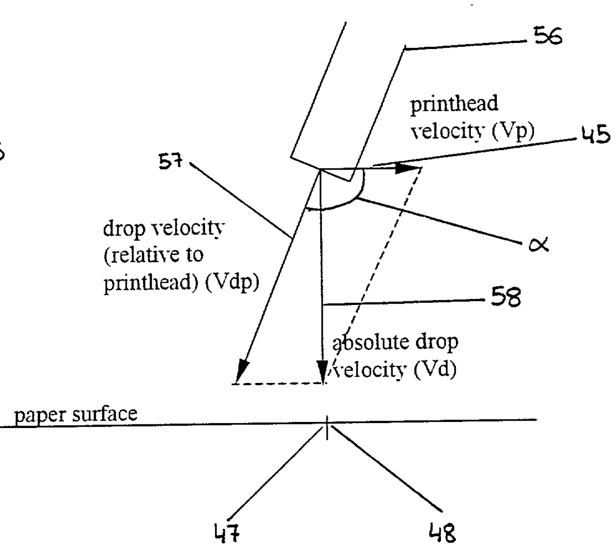

Prior Art
42
printhead
velocity (Vp)
45
46
43
41
drop velocity
(relative to
printhead) (Vdp)
absolute drop
velocity (Vd)
drop
ejection
position
48
drop
landing
position
47
44
49

FIG. 5b


56
printhead
velocity (Vp)
45
57
drop velocity
(relative to
printhead) (Vdp)
α
58
absolute drop
velocity (Vd)
paper surface
47
48

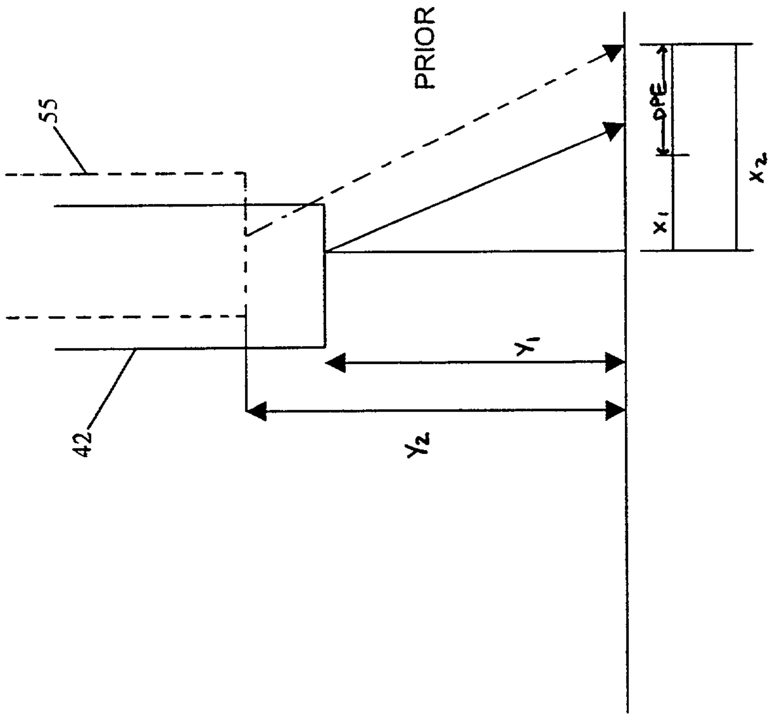


FIG. 6a

PRIOR ART

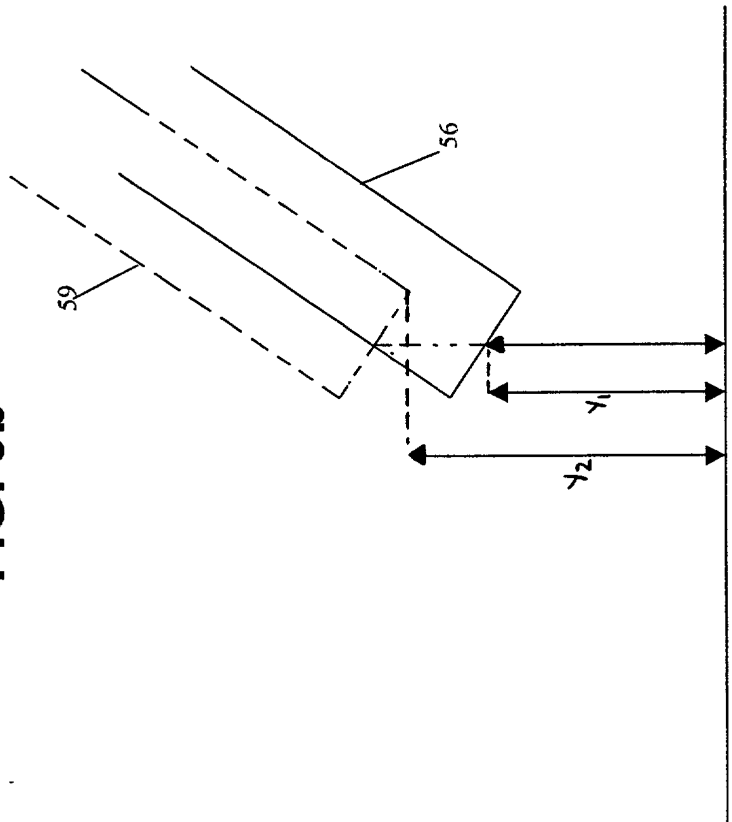


FIG. 6b

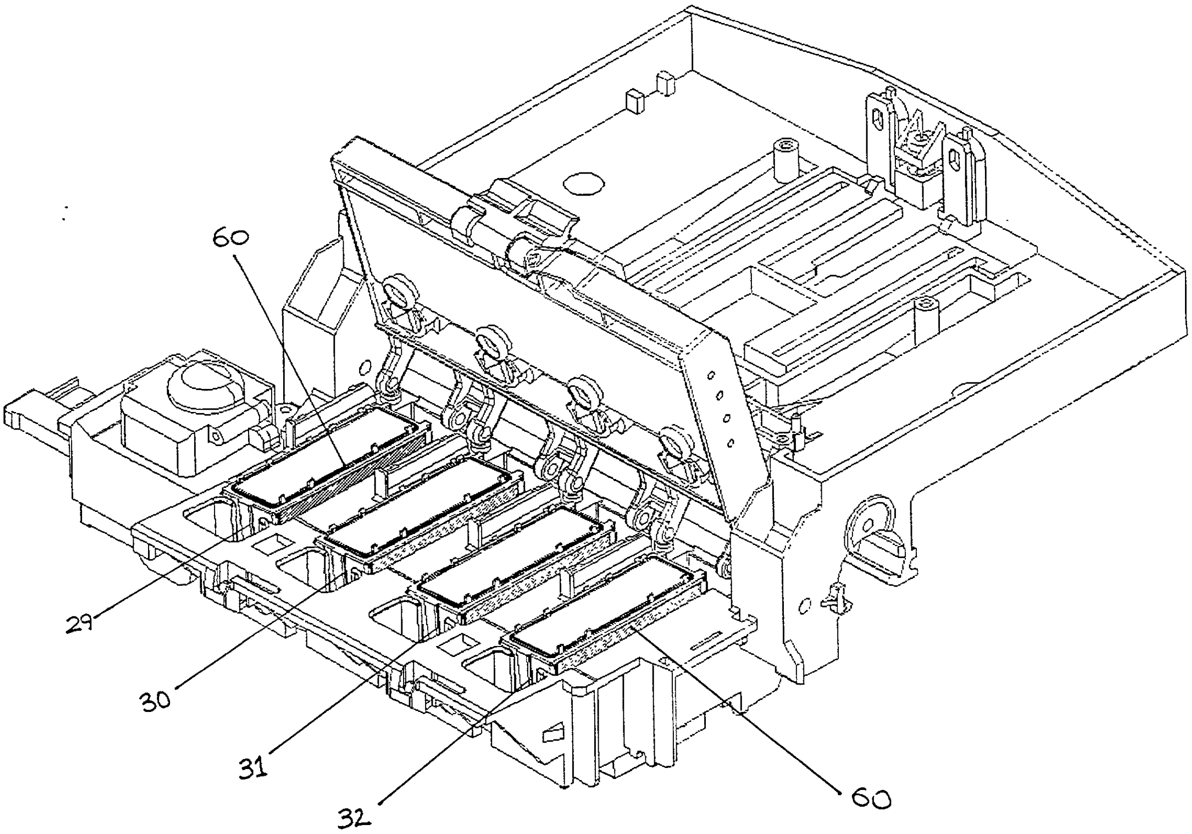


FIG. 7

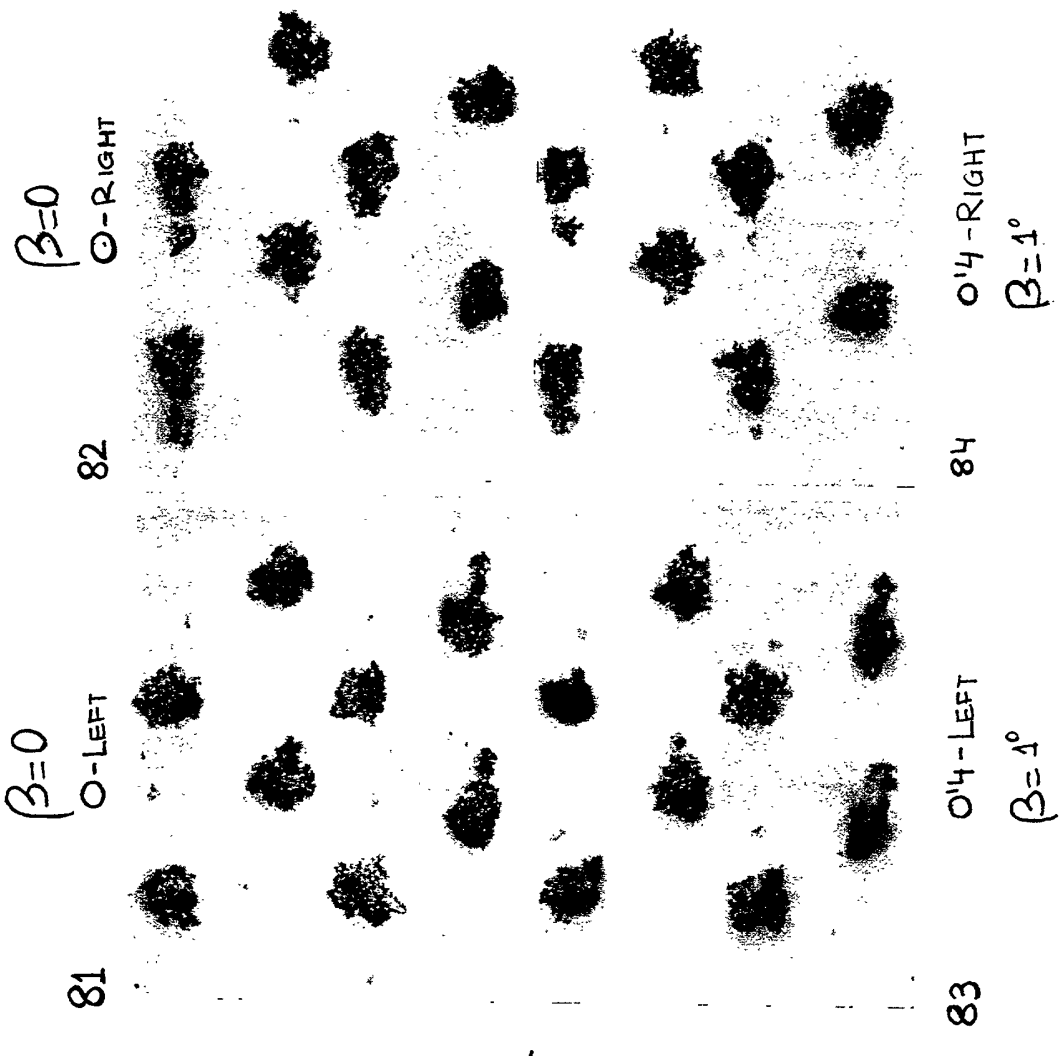


FIG.8

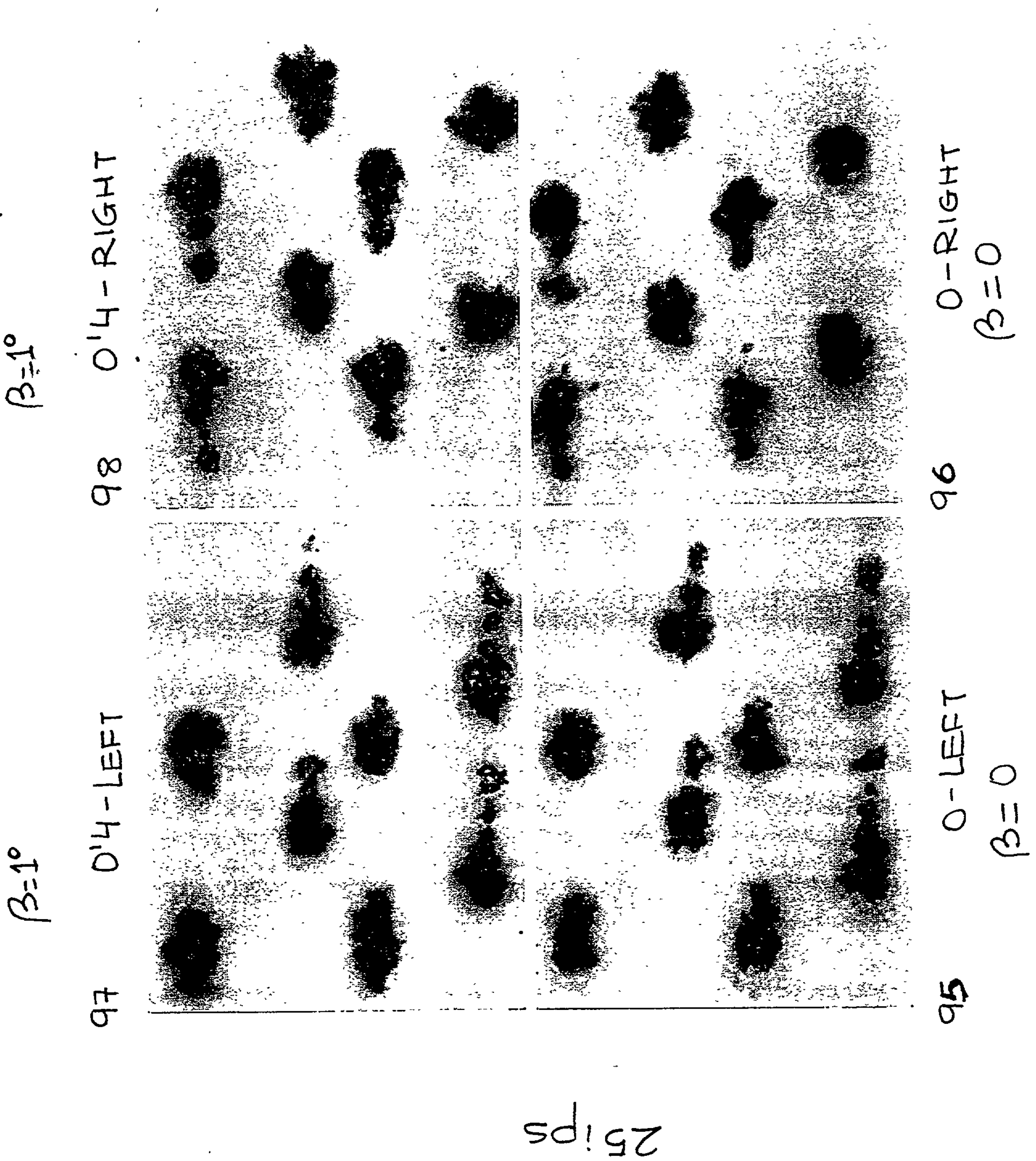


FIG. 9

FIG. 10

					L								H																					
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8					
Photo Number	Speed (ips)	Shim (mm)	Direc-tion	# of drops	L 1	L 2	L 3	L 4	L 5	L 6	L 7	L 8	H 1	H 2	H 3	H 4	H 5	H 6	H 7	H 8	L1/ H1	L2/ H2	L3/ H3	L4/ H4	L5/ H5	L6/ H6	L7/ H7	L8/ H8	AVG	SD	MIN	MAX	Ranking
81	10	0	L	10	10	10	12	10	11	10	15	16	9	9	9	10	12	8	8	8	1.1	1.1	1.3	1	0.9	1.3	1.9	2	1.325	0.401	0.917	2	2
82	10	0	R	10	17	16	11	10	12	13	10	9	9	8	9	10	8	9	8	10	1.9	2	1.2	1	1.5	1.4	1.3	0.9	1.401	0.392	0.9	2	3
83	10	0.4	L	10	10	10	13	11	10	9	16	16	9	8	8	8	9	9	7	7	1.1	1.3	1.6	1.4	1.1	1	2.3	2.3	1.505	0.518	1	2.286	4
84	10	0.4	R	9	12	12	10	9	9	10	9	9	7	7	9	8	8	8	8	8	1.7	1.7	1.1	1.1	1.1	1.3	1.1	1.1	1.286	0.268	1.111	1.714	1
95	25	0	L	11	13	13	16	16	16	13	22	24	9	8	7	8	8	7	8	8	1.4	1.6	2.3	2	2	1.9	2.8	3	2.12	0.534	1.444	3	7
96	25	0	R	13	20	20	13	15	15	16	9	10	8	8	7	9	8	7	9	10	2.5	2.5	1.9	1.7	1.9	2.3	1	1	1.836	0.599	1	2.5	6
97	25	0.4	L	12	12	11	18	19	14	11	24	23	7	8	7	8	7	7	7	7	1.7	1.4	2.6	2.4	2	1.6	3.4	3.3	2.29	0.769	1.375	3.429	8
98	25	0.4	R	10	17	18	11	13	14	14	11	9	7	7	8	9	7	9	9	8	2.4	2.6	1.4	1.4	2	1.6	1.2	1.1	1.715	0.551	1.125	2.571	5

Table 2

FIG. 11

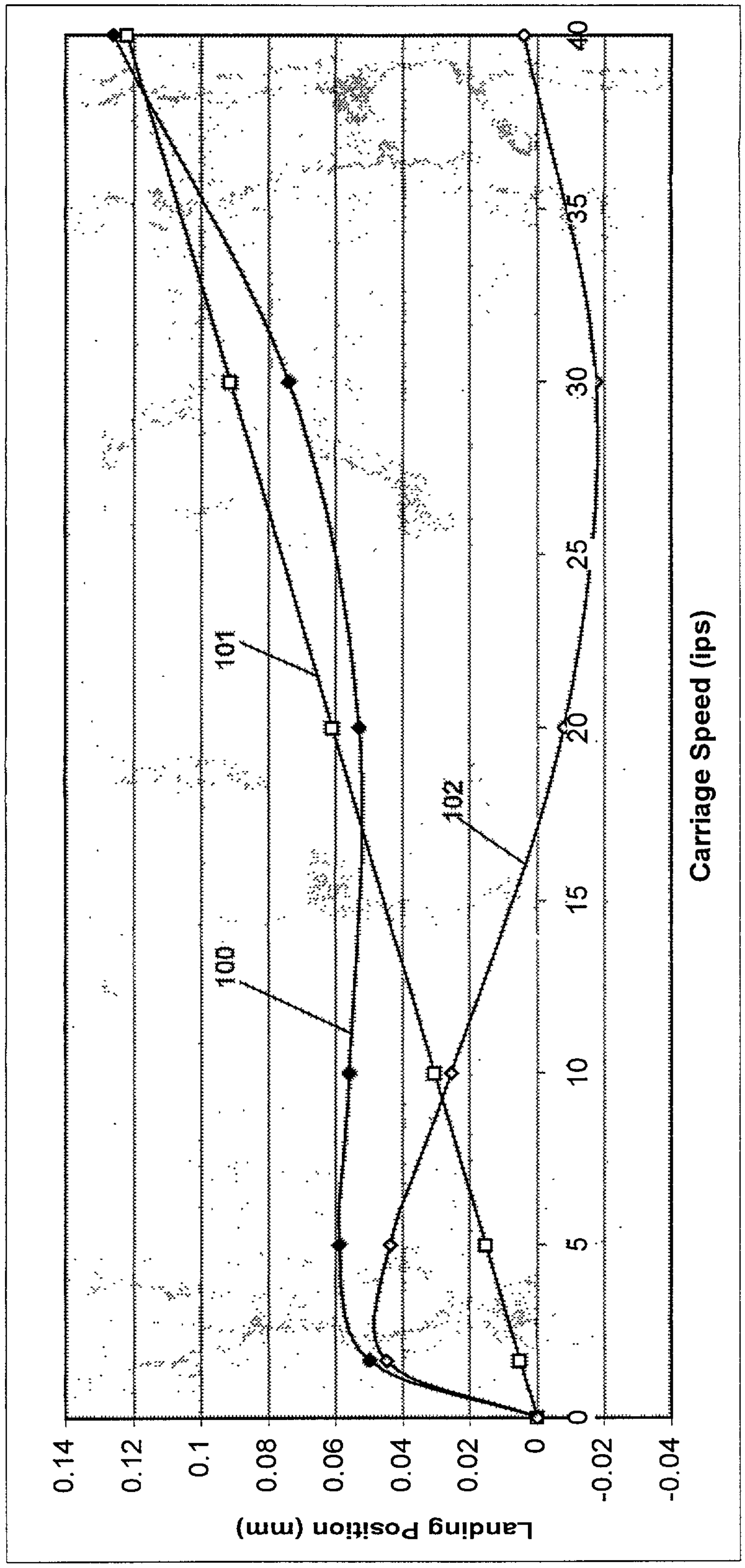

Landing Position (mm)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
Carriage Speed (ips)
0
5
10
15
20
25
30
35
40
100
101
102

FIG. 12

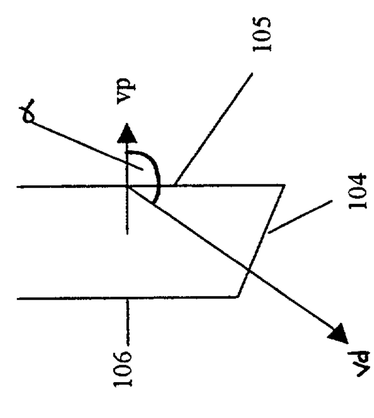
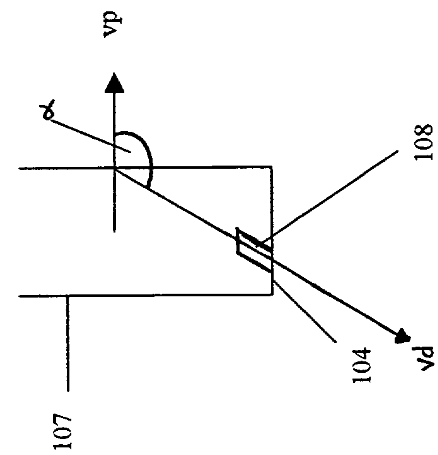


FIG. 13



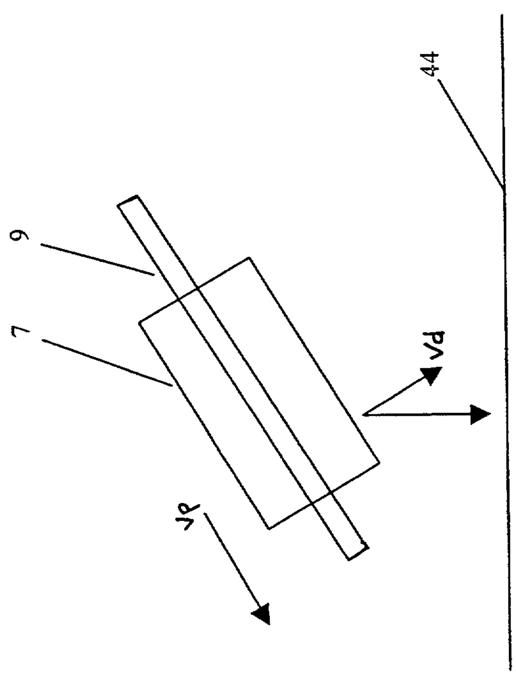


FIG. 14

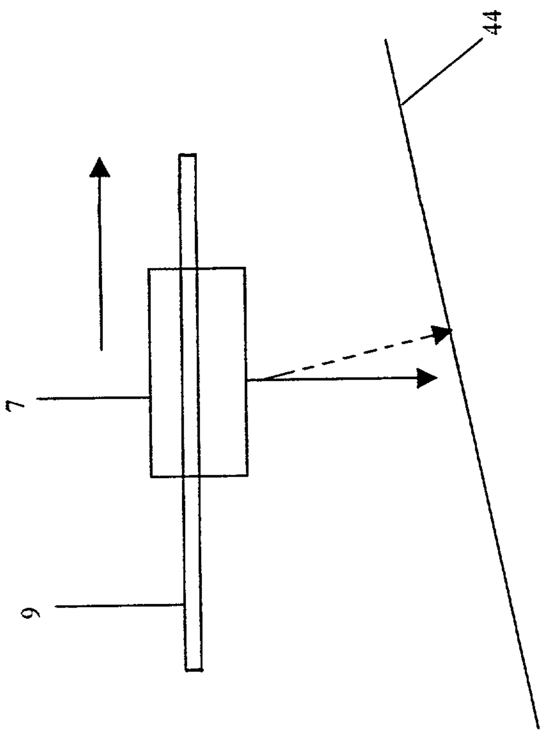


FIG. 15

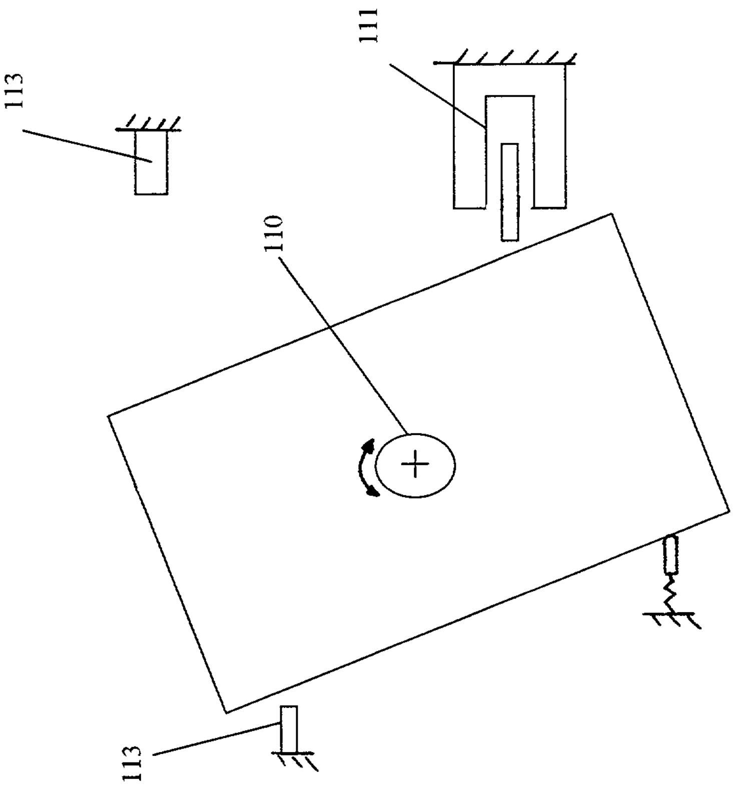


FIG. 16

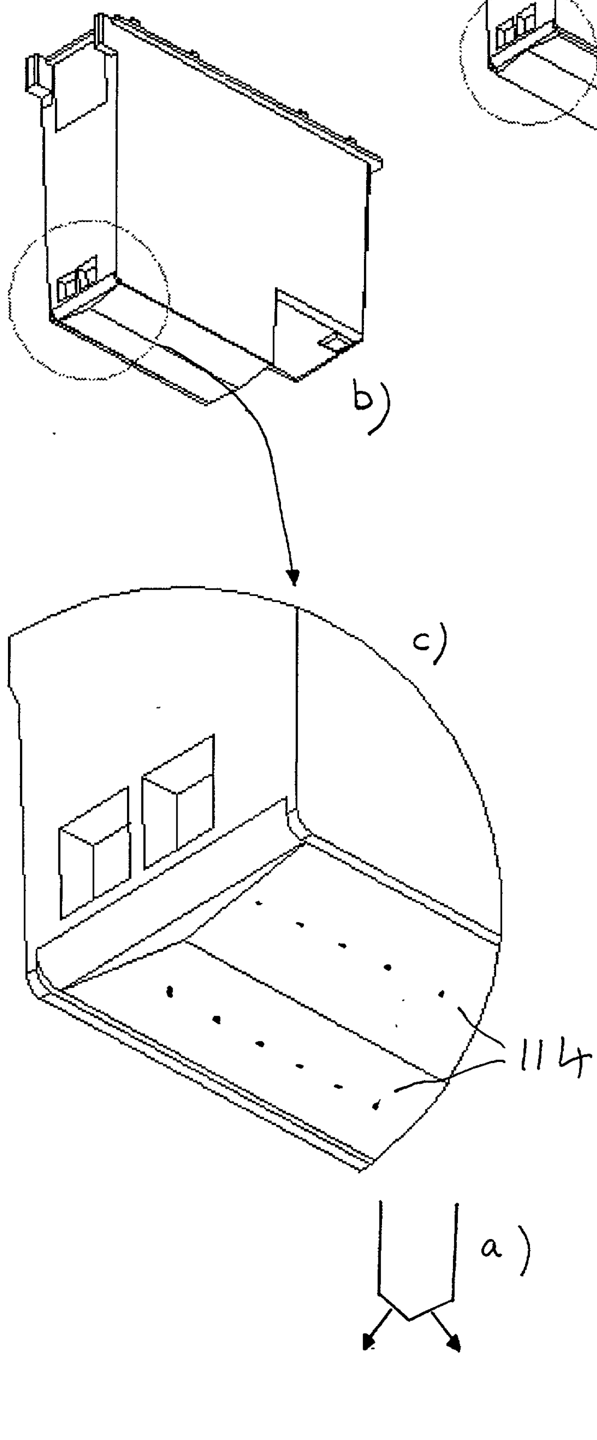


FIG. 17

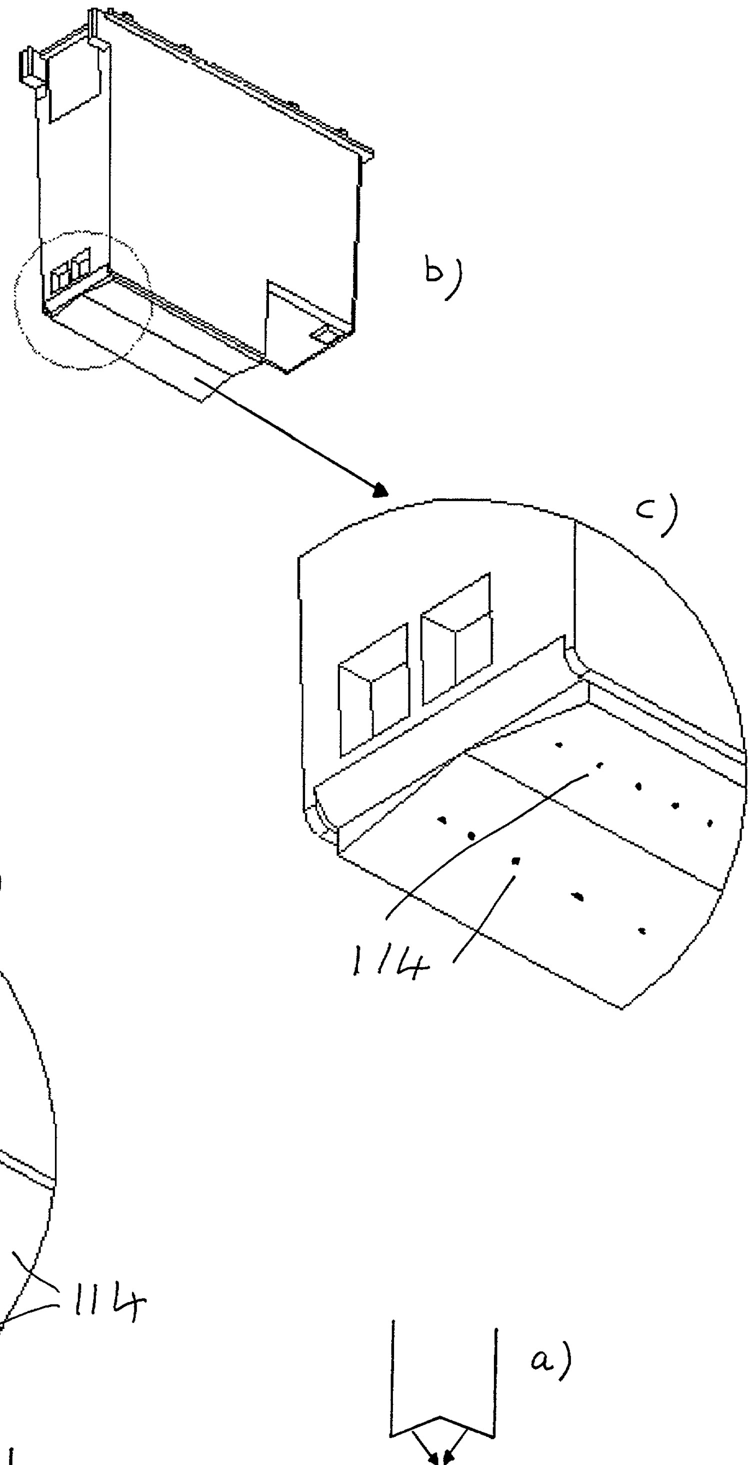
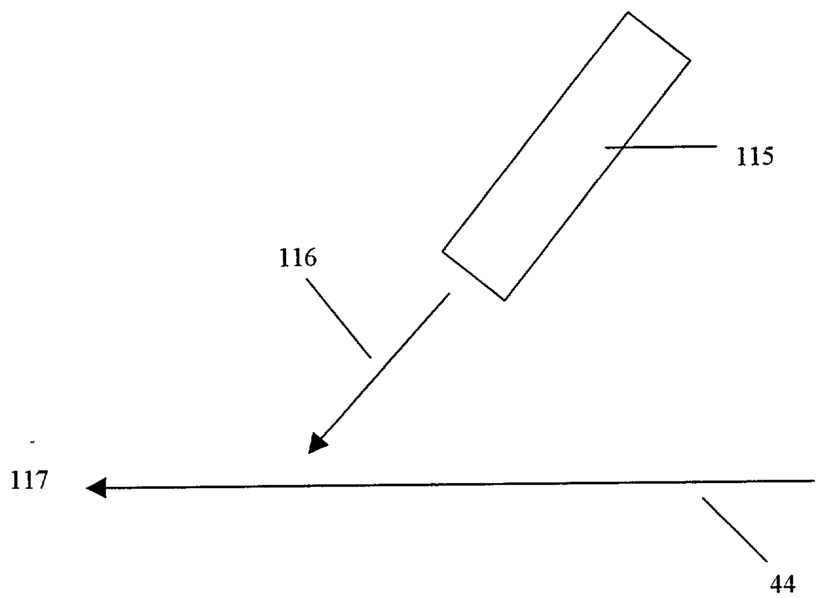


FIG. 18

FIG. 19



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 12 3724

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.7)
X	PATENT ABSTRACTS OF JAPAN vol. 017, no. 286 (M-1422), 2 June 1993 (1993-06-02) & JP 05 016340 A (CANON INC), 26 January 1993 (1993-01-26)	1-7, 10-15, 17,19,23	B41J2/04 B41J19/14
A	* abstract; figures *	9	
X	JP 2000 218779 A (SHARP KK) 8 August 2000 (2000-08-08)	1-6,8, 10-16, 18,19,23	
A	* the whole document *	9	
X	US 4 703 333 A (HUBBARD DAVID W) 27 October 1987 (1987-10-27) * the whole document *	1-7, 11-14,23	
X	US 5 992 968 A (HIRABAYASHI HIROMITSU ET AL) 30 November 1999 (1999-11-30) * abstract * * column 8, line 1 - line 22 * * figures 6,7 *	1,8	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 March 2001	Didenot, B

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16-03-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 05016340 A	26-01-1993	NONE	
JP 2000218779 A	08-08-2000	NONE	
US 4703333 A	27-10-1987	NONE	
US 5992968 A	30-11-1999	JP 8058083 A	05-03-1996

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