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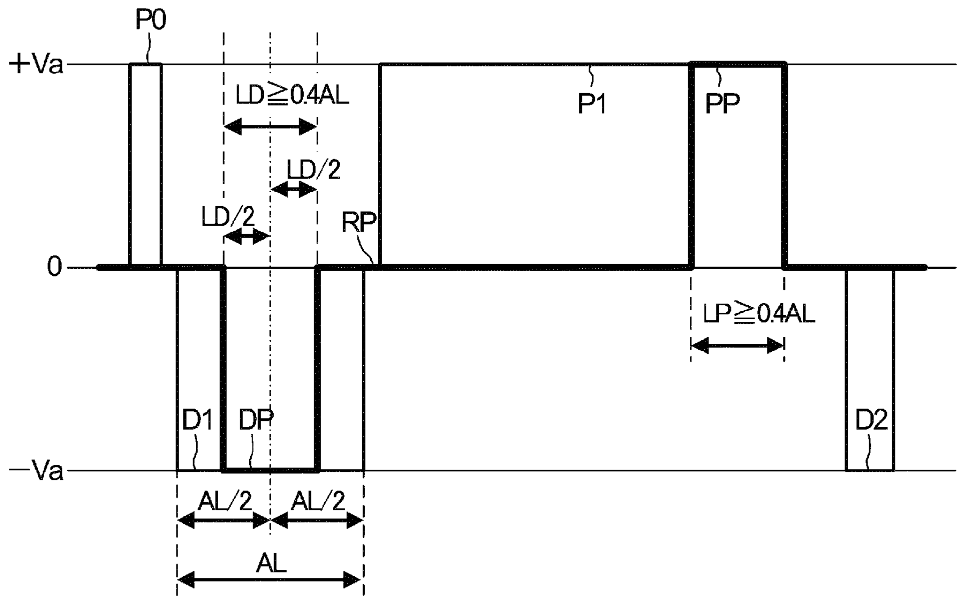
(54) LIQUID DROPLET DISCHARGE HEAD AND PRINTER

(57) According to one embodiment, there is provided a liquid droplet discharge head including a pressure chamber, an actuator, and a drive circuit. The drive circuit is configured to apply a discharge pulse including an expansion pulse for expanding the volume in the pressure chamber and a contraction pulse for contracting the volume in the pressure chamber to the actuator when the liquid droplet is discharged, and to apply, to the actuator, a micro-vibration pulse that changes the volume of the pressure chamber to the extent that the liquid droplet is not discharged from the nozzle at a timing when the liquid droplet is not discharged. The micro-vibration pulse includes an expansion pulse portion and a contraction pulse portion. A central position of the expansion pulse portion in the micro-vibration pulse corresponds to a central position of the expansion pulse in the discharge pulse and a falling position of the contraction pulse portion in the micro-vibration pulse corresponds to a falling position.

FIG. 24



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Description

FIELD

[0001] Embodiments described herein relate generally to a liquid droplet discharge head and a printer.

BACKGROUND

[0002] A shared wall type ink jet head is known as an ink jet head that is a liquid droplet discharge head that discharges a liquid droplet from a nozzle. In such shared wall type ink jet head, since an actuator is shared between adjacent nozzles, independently driving all the nozzles is difficult. Accordingly, in general, by performing a division driving such as a two-division driving or a three-division driving, driving to prevent an influence of the adjacent nozzles as much as possible is performed.

[0003] However, even if such a division driving is performed, completely eliminating the influence of the adjacent nozzles is difficult. Such an influence causes a change in a discharge speed of the liquid droplet for each phase, and as a result, the liquid droplet discharged onto a medium such as paper deviates from a target position in a conveyance direction of the medium and is landed, which leads to so-called landing deviation.

[0004] As one method of preventing such a change in the discharge speed of the liquid droplet for each phase, that is, the landing deviation, there is a micro-vibration pulse called a precursor. The precursor is a control capable of preventing a change in the discharge speed of the liquid droplet of the entire head and reducing the landing deviation by generating a minute pressure vibration to the extent that the liquid droplet is not discharged to each actuator at the timing when the liquid droplet is not discharged.

[0005] However, the magnitude of the effect obtained by the micro-vibration pulse differs depending on the timing and shape of insertion of the micro-vibration pulse.

DESCRIPTION OF THE DRAWINGS

[0006]

FIG. 1 is a block diagram illustrating a configuration example of a printer according to an embodiment;
FIG. 2 illustrates an example of a perspective view of an ink jet head according to an embodiment;
FIG. 3 is a cross-sectional view of the ink jet head;
FIG. 4 is a longitudinal sectional view of the ink jet head;
FIG. 5 is a diagram illustrating an example of nozzle disposition in the ink jet head;
FIG. 6 is a block diagram illustrating a configuration example of a head drive circuit according to an embodiment;
FIG. 7 is a diagram illustrating an operation example of the ink jet head;
FIG. 8 is a diagram illustrating another operation example of the ink jet head;
FIG. 9 is a diagram illustrating another operation example of the ink jet head;
FIG. 10 is a diagram illustrating an example of a discharge pulse applied to an actuator according to an embodiment
FIG. 11 is a table illustrating an example of a relationship between nozzles and the ink discharge number in multi-drop mode;
FIG. 12 is a timing chart illustrating an example of a drive waveform corresponding to the example of FIG. 11;
FIG. 13 is a table illustrating an example of a relationship between the nozzles, the ink discharge number, and the number of times of free time occurrence in the multi-drop mode;
FIG. 14 is a timing chart illustrating an example of a drive waveform corresponding to the example of FIG. 13;
FIG. 15 is a diagram illustrating an example of landing deviation of landing dots;
FIG. 16 is a graph illustrating a measurement example of linearity error for each phase;
FIG. 17 is a diagram illustrating an example of a micro-vibration pulse applied to the actuator;
FIG. 18 is a table illustrating an example of a relationship between the nozzles, the ink discharge number, and the micro-vibration pulse insertion number in the multi-drop mode in the head drive circuit;
FIG. 19 is a timing chart illustrating an example of a drive waveform corresponding to the example of FIG. 18;
FIG. 20 is a timing chart illustrating an example of a drive waveform in binary mode in the head drive circuit;
FIG. 21 is a table illustrating setting contents of tests for confirming location dependency of the micro-vibration pulse;
FIG. 22 is a graph illustrating an example of a check result of the location dependency of the micro-vibration pulse by each test of FIG. 21;
FIG. 23 is a graph illustrating an example of a check result of pulse width dependency of the micro-vibration pulse;
FIG. 24 is a waveform diagram illustrating a relationship between the timing and the shape of the discharge pulse and the micro-vibration pulse output from the head drive circuit;
FIG. 25 is a graph illustrating a measurement example of linearity error in the ink jet head; and
FIG. 26 is a timing chart illustrating an example of a drive waveform in the multi-drop mode in the head drive circuit.

DETAILED DESCRIPTION

[0007] Embodiments provide a liquid droplet discharge head and a printer capable of preventing variations in discharge speed of a liquid droplet.

[0008] In general, according to one embodiment, there is provided a liquid droplet discharge head including a pressure chamber, an actuator, and a drive circuit. The pressure chamber is filled with ink. The actuator is configured to change volume in the pressure chamber to discharge a liquid droplet from a nozzle communicating with the pressure chamber. The drive circuit is configured to apply a discharge pulse including an expansion pulse for expanding the volume in the pressure chamber and a contraction pulse for contracting the volume in the pressure chamber to the actuator when the liquid droplet is discharged. The drive circuit is configured to apply, to the actuator, a micro-vibration pulse that changes the volume of the pressure chamber to the extent that the liquid droplet is not discharged from the nozzle at a timing when the liquid droplet is not discharged. The micro-vibration pulse includes an expansion pulse portion and a contraction pulse portion. A central position of the expansion pulse portion in the micro-vibration pulse corresponds to a central position of the expansion pulse in the discharge pulse. A falling position of the contraction pulse portion in the micro-vibration pulse corresponds to a falling position of the contraction pulse in the discharge pulse.

[0009] Preferably, pulse widths of the expansion pulse portion and the contraction pulse portion in the micro-vibration pulse are 0.4 AL or more (AL is half of the natural vibration cycle of pressure in the pressure chamber).

[0010] Preferably, when the liquid droplet is not discharged, the drive circuit is configured to apply the micro-vibration pulse to the actuator at a timing of the discharge pulse to be applied to the actuator when the liquid droplet is discharged.

[0011] Preferably, the liquid droplet discharge head is configured to include a plurality of the nozzles. The drive circuit is configured to divide the nozzles into a plurality of groups each including the plurality of nozzles, and control application of the discharge pulse and the micro-vibration pulse in group units, and the drive circuit is further configured to apply the micro-vibration pulse to the actuator corresponding to a first nozzle in each group, prior to applying the discharge pulse to the actuator corresponding to the first nozzle.

[0012] There is also provided a printer configured to discharge a predetermined number of liquid droplets to form one dot, the printer comprising a conveyance unit configured to convey a medium; and a liquid droplet discharge head as described above.

[0013] Hereinafter, a printer according to an embodiment will be described with reference to the accompanying drawings.

[0014] The printer according to the embodiment uses an ink jet head to form an image on a medium such as paper. The printer discharges ink in a pressure chamber included in an ink jet head onto the medium to form an image on the medium. The printer is, for example, an office printer, a bar code printer, a POS printer, an industrial printer, a 3D printer, and the like. The medium on which the printer forms an image is not limited to a specific configuration. The ink jet head included in the printer is an example of a liquid droplet discharge head, and the ink is an example of a liquid.

[0015] FIG. 1 is a block diagram illustrating a configuration example of a printer 200.

[0016] As illustrated in FIG. 1, the printer 200 includes a processor 201, a ROM 202, a RAM 203, an operation panel 204, a communication interface 205, a conveyance motor 206, a motor drive circuit 207, a pump 208, a pump drive circuit 209, an ink jet head 100, and the like. In FIG. 1, "interface" is abbreviated as "I/F". The ink jet head 100 includes a head drive circuit 101, a channel group 102, and the like. The printer 200 also includes a bus line 211 such as an address bus and a data bus. The processor 201 is connected to the ROM 202, the RAM 203, the operation panel 204, the communication interface 205, the motor drive circuit 207, the pump drive circuit 209, and the head drive circuit 101 through the bus line 211, either directly or through an input and output circuit. The motor drive circuit 207 is connected to the conveyance motor 206. The pump drive circuit 209 is connected to the pump 208.

[0017] In addition to the configuration illustrated in FIG. 1, the printer 200 may further include a configuration as needed, or a specific configuration may be excluded from the printer 200.

[0018] The processor 201 has a function of controlling the operation of the entire printer 200. The processor 201 may include an internal cache, various interfaces, and the like. The processor 201 realizes various processes by executing a program stored in an internal cache or the ROM 202 in advance. The processor 201 realizes various functions as the printer 200 according to an operating system, an application program, and the like.

[0019] Some of the various functions realized by the processor 201 executing the program may be realized by hardware circuits such as an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and a graphics processing unit (GPU). Here, the processor 201 controls the functions executed by the hardware circuits.

[0020] The ROM 202 is a non-volatile memory in which a control program, control data, and the like are stored in advance. The control program and control data stored in the ROM 202 are incorporated in advance according to the specifications of the printer 200. For example, the ROM 202 stores the operating system, the application program, and the like.

[0021] The RAM 203 is a volatile memory. The RAM 203 temporarily stores data and the like being processed by the processor 201. The RAM 203 stores various application programs and the like based on instructions from the processor 201. The RAM 203 may store data needed to execute the application program, an execution result of the application program, and the like. The RAM 203 may function as an image memory in which print data is loaded.

[0022] The operation panel 204 is an interface that receives input of an instruction from the operator and displays various information to the operator. The operation panel 204 includes an operation unit that receives input of the instruction and a display unit that displays information.

[0023] The operation panel 204 transmits a signal indicating an operation received from the operator to the processor 201 as an operation of the operation unit. For example, function keys such as a power key, a paper feed key, and an error release key are disposed on the operation unit.

[0024] The operation panel 204 displays, as the operation of the display unit, various information based on the control of the processor 201. For example, the operation panel 204 displays a state of the printer 200 and the like. For example, the display unit is configured with a liquid crystal monitor. The operation unit may be configured with a touch panel. Here, the display unit may be formed as one with the touch panel as the operation unit.

[0025] The communication interface 205 is an interface for transmitting and receiving data to and from an external device through a network such as a local area network (LAN). For example, the communication interface 205 is an interface that supports LAN connection. For example, the communication interface 205 receives print data from a client terminal through a network. For example, when an error occurs in the printer 200, the communication interface 205 transmits a signal notifying the error to the client terminal.

[0026] The motor drive circuit 207 controls driving of the conveyance motor 206 according to the signal from the processor 201. For example, the motor drive circuit 207 transmits power or a control signal to the conveyance motor 206.

[0027] The conveyance motor 206 functions as a drive source for a conveyance mechanism that conveys a medium such as paper under the control of the motor drive circuit 207. When the conveyance motor 206 is driven, the conveyance mechanism starts conveying the medium. The conveyance mechanism conveys the medium to a printing position by the ink jet head 100. The conveyance mechanism discharges a printed medium to the outside of the printer 200 from a paper discharge port (not illustrated). The motor drive circuit 207 and the conveyance motor 206 configure a conveyance unit that conveys the medium.

[0028] The pump drive circuit 209 controls driving of the pump 208. When the pump 208 is driven, ink is supplied from an ink tank to the ink jet head 100.

[0029] The ink jet head 100 discharges a liquid droplet, that is, an ink droplet, onto the medium based on print data. The ink jet head 100 includes the head drive circuit 101, the channel group 102, and the like.

[0030] Hereinafter, the ink jet head according to the embodiment will be described with reference to the drawings. In the embodiment, the shared wall type ink jet head 100 (see FIG. 2) is illustrated. The ink jet head 100 will be described as discharging ink onto paper. The medium onto which the ink jet head 100 discharges ink is not limited to a specific configuration.

[0031] Next, a configuration example of the ink jet head 100 will be described with reference to FIGS. 2 to 4. FIG. 2 is a perspective view illustrating a part of the ink jet head 100 in an exploded manner. FIG. 3 is a cross-sectional view of the ink jet head 100. FIG. 4 is a longitudinal sectional view of the ink jet head 100. FIG. 5 is a diagram illustrating an example of nozzle disposition in the ink jet head.

[0032] The ink jet head 100 includes a base substrate 9. In the ink jet head 100, a first piezoelectric member 1 is bonded to the upper surface of the base substrate 9, and a second piezoelectric member 2 is bonded onto the first piezoelectric member 1. The bonded first piezoelectric member 1 and the second piezoelectric member 2 are polarized in opposite directions along a plate thickness direction as illustrated by the arrows in FIG. 3.

[0033] The base substrate 9 is formed by using a material having a small dielectric constant and a small difference in thermal expansion coefficient between the first piezoelectric member 1 and the second piezoelectric member 2. As the material of the base substrate 9, for example, alumina ($Al_2 03$), silicon nitride (Si3N4), silicon carbide (SiC), aluminum nitride (A1N), lead zirconate titanate (PZT), and the like are preferable. As the material of the first piezoelectric member 1 and the second piezoelectric member 2, lead zirconate titanate (PZT), lithium niobate ($LiNbO_3$), lithium tantalate ($LiTaO_3$), and the like are used.

[0034] The ink jet head 100 is provided with a large number of long grooves 3 from the front end side to the rear end side of the first piezoelectric member 1 and the second piezoelectric member 2 that are bonded together. The grooves 3 are regularly spaced and parallel. The front end of each groove 3 is open, and the rear end thereof is inclined upward.

[0035] The ink jet head 100 is provided with electrodes 4 on the side walls and the bottom surface of each groove 3. The electrode 4 has a two-layer structure of nickel (Ni) and gold (Au). The electrode 4 is uniformly formed in each groove 3 by a plating method, for example. The method of forming the electrode 4 is not limited to the plating method. A sputtering method, a vapor deposition method, or the like can also be used.

[0036] The ink jet head 100 is provided with lead-out electrodes 10 from the rear end of each groove 3 toward the rear upper surface of the second piezoelectric member 2. The lead-out electrode 10 extends from the electrode 4.

[0037] The ink jet head 100 includes a top plate 6 and an orifice plate 7. The top plate 6 closes the upper parts of the grooves 3. The orifice plate 7 closes the tips of the grooves 3. The ink jet head 100 forms a plurality of pressure chambers 15 by the grooves 3 surrounded by the top plate 6 and the orifice plate 7. The pressure chambers 15 are filled with ink supplied from the ink tank. The pressure chambers 15 have a shape having, for example, a depth of 300 μm and a width of 80 μm, respectively, and are arranged in parallel at a pitch of 169 μm. Such a pressure chamber 15 is also referred to as an ink chamber.

[0038] The top plate 6 is provided with a common ink chamber 5 on the inner rear side thereof. The orifice plate 7 is provided with nozzles 8 at positions facing the grooves 3. The nozzle 8 communicates with the facing groove 3, that is, the pressure chamber 15. The nozzle 8 has a tapered shape tapering from the pressure chamber 15 side toward an ink discharge side on the opposite side. The nozzles 8 corresponding to three adjacent pressure chambers 15 are set as one set, and as illustrated in FIG. 5, the nozzles 8 are formed to be deviated at regular intervals in the height direction of the groove 3 (vertical direction of the paper surface of FIGS. 3 and 5). In the example of FIG. 5, the number of nozzles 8 is 318, but the number of nozzles 8 included in the ink jet head 100 is obviously not limited to 318.

[0039] When the pressure chamber 15 is filled with ink, a meniscus 20 of ink is formed in the nozzle 8. The meniscus 20 is formed along the inner wall of the nozzle 8.

[0040] The first piezoelectric member 1 and the second piezoelectric member 2 configuring partition walls of the pressure chambers 15 are sandwiched by the electrodes 4 provided in the pressure chambers 15 to form actuators 16 for driving the pressure chambers 15.

[0041] In the ink jet head 100, a printed substrate 11 on which conductive patterns 13 are formed is bonded to an upper surface on the rear side of the base substrate 9. In the ink jet head 100, a drive IC 12 on which a head drive circuit 101 (control unit) described later is installed is mounted on the printed substrate 11. The drive IC 12 is connected to the conductive patterns 13. The conductive patterns 13 are respectively joined to the lead-out electrodes 10 by wire bonding with conducting wires 14.

[0042] A set of the pressure chamber 15, the electrode 4, and the nozzle 8 included in the ink jet head 100 is referred to as a channel. The ink jet head 100 has channels ch as many as the number N of the grooves 3, that is, has channel #1 (ch. 1) to channel #N (ch. N). In the example of FIG. 5, N is 318.

[0043] Next, the head drive circuit 101 will be described. FIG. 6 is a block diagram for illustrating a configuration example of the head drive circuit 101. As described above, the head drive circuit 101 is disposed in the drive IC 12.

[0044] The head drive circuit 101 drives the channel group 102 of the ink jet head 100 based on print data.

[0045] The channel group 102 is composed of a plurality of (N) channels (ch. 1, ch. 2, ..., ch. N) including the pressure chambers 15, the electrodes 4, the nozzles 8, and the like. That is, the channel group 102 discharges ink by an expansion and contraction operation of each pressure chamber 15 driven by the actuator 16 based on a control signal from the head drive circuit 101.

[0046] As illustrated in FIG. 6, the head drive circuit 101 includes a pattern generator 301, a frequency setting unit 302, a drive signal generation unit 303, a switch circuit 304, and the like.

[0047] The pattern generator 301 generates various waveform patterns using a waveform pattern of an expansion pulse that expands the volume of the pressure chamber 15, a pause period during which the volume of the pressure chamber 15 is released, and a waveform pattern of a contraction pulse that contracts the volume of the pressure chamber 15.

[0048] The pattern generator 301 generates a waveform pattern of a discharge pulse that discharges one ink droplet. A period of the discharge pulse is a section for discharging one ink droplet, a so-called one drop cycle. The discharge pulse will be described in detail later.

[0049] The pattern generator 301 generates a pattern of a micro-vibration pulse, that is, a precursor that does not discharge an ink droplet. The precursor will be described in detail later.

[0050] The frequency setting unit 302 sets a drive frequency of the ink jet head 100. The drive frequency is a frequency of a drive pulse generated by the drive signal generation unit 303. The head drive circuit 101 operates according to the drive pulse.

[0051] The drive signal generation unit 303 generates a pulse for each channel based on the waveform pattern generated by the pattern generator 301 and the drive frequency set by the frequency setting unit 302, according to print data input from the bus line 211. The pulse for each channel is output from the drive signal generation unit 303 to the switch circuit 304.

[0052] The switch circuit 304 switches a voltage to be applied to the electrode 4 of each channel according to the pulse for each channel output from the drive signal generation unit 303. That is, the switch circuit 304 applies a voltage to the actuator 16 of each channel based on the energization time of the expansion pulse or the like set by the pattern generator 301.

[0053] The switch circuit 304 expands or contracts the volume of the pressure chamber 15 of each channel by switching the voltage, and discharges ink droplets from the nozzle 8 of each channel by the gradation number.

[0054] Next, an operation example of the ink jet head 100 configured as described above will be described with reference to FIGS. 7 to 9.

[0055] FIG. 7 illustrates a state of the pressure chamber 15b during the pause period. As illustrated in FIG. 7, the head drive circuit 101 applies a voltage +Va to any of the electrodes 4 arranged on respective wall surfaces of a pressure chamber 15b and pressure chambers 15a and 15c on both sides adjacent to the pressure chamber 15b. Here, a partition wall 16a sandwiched between the pressure chamber 15a and the pressure chamber 15b and a partition wall 16b sandwiched between the pressure chamber 15b and the pressure chamber 15c do not cause any distortion.

[0056] FIG. 8 illustrates an example of a state in which the head drive circuit 101 applies an expansion pulse to the actuator 16 of the pressure chamber 15b. As illustrated in FIG. 8, the head drive circuit 101 sets a potential of the electrode 4 of the central pressure chamber 15b as the ground potential GND, and applies the voltage +Va to the electrodes 4 of the pressure chambers 15a and 15c on both sides of the pressure chamber 15b. Here, an electric field of voltage +Va acts on each of the partition walls 16a and 16b in a direction orthogonal to the polarization directions of the first piezoelectric member 1 and the second piezoelectric member 2. Therefore, each of the partition walls 16a and 16b is deformed outward to expand the volume of the pressure chamber 15b.

[0057] FIG. 9 illustrates an example of a state in which the head drive circuit 101 applies a contraction pulse to the actuator 16 of the pressure chamber 15b. As illustrated in FIG. 9, the head drive circuit 101 applies the positive voltage +Va to the electrode 4 of the central pressure chamber 15b, and sets the potentials of the electrodes 4 of the pressure chambers 15a and 15c on both sides thereof as the ground potential GND. Here, the electric field of voltage +Va acts on each of the partition walls 16a and 16b in a direction opposite to the direction in the state of FIG. 8. Therefore, each of the partition walls 16a and 16b is deformed inward to contract the volume of the pressure chamber 15b.

[0058] When the volume of the pressure chamber 15b is expanded or contracted, pressure vibration is generated in the pressure chamber 15b. By the pressure vibration, the pressure in the pressure chamber 15b increases, and the ink droplet is discharged from the nozzle 8 communicating with the pressure chamber 15b.

[0059] As such, the partition walls 16a and 16b that separate the pressure chambers 15a, 15b and 15c serve as the actuator 16 for applying pressure vibration to the inside of the pressure chamber 15b having the partition walls 16a and 16b as wall surfaces thereof. That is, the pressure chamber 15 is expanded or contracted by the operation of the actuator 16.

[0060] Each pressure chamber 15 shares the actuator 16 (partition walls) with an adjacent pressure chamber 15. Therefore, the head drive circuit 101 cannot drive each pressure chamber 15 individually. The head drive circuit 101 drives the pressure chambers 15 by dividing the pressure chambers 15 into (m + 1) groups every m (m is an integer of 2 or more) chambers. In the present embodiment, a case of so-called three-division driving in which the head drive circuit 101 drives the pressure chambers 15 by dividing the pressure chambers 15 into three groups every two pressure chambers is exemplified. Therefore, in the present example, as described above, the nozzles 8 corresponding to three adjacent pressure chambers 15 are set as one set, and are formed to be deviated at regular intervals in the height direction of the groove 3. The three-division driving is just an example, and may be a four-division driving or a five-division driving.

[0061] Next, the discharge pulse applied to the actuator 16 by the head drive circuit 101 will be described.

[0062] FIG. 10 is a diagram for illustrating a configuration example of a discharge pulse. The discharge pulse illustrates a waveform of one discharge of the ink droplet. +Va, 0, and -Va in FIG. 10 indicate a potential difference between the potential applied to the electrode 4 of the pressure chamber 15, for example, the pressure chamber 15b, and the potential applied to the electrode 4 of the pressure chamber 15 adjacent to the pressure chamber 15b, for example, the pressure chamber 15a. As illustrated in FIG. 10, the discharge pulse includes an expansion pulse D1 for a first predetermined time and a contraction pulse P1 for a second predetermined time. The discharge pulse includes a pause period (cutting-off time CP) for a third predetermined time, an expansion pulse D2 for a fourth predetermined time, and a contraction pulse P0 for a fifth predetermined time. The discharge pulse is applied to the electrode in order of the contraction pulse P0, the expansion pulse D1, the contraction pulse P1, the cutting-off time CP, and the expansion pulse D2. The contraction pulse P0 is a pulse to apply +Va to a stationary state 0v, and to return +Va to 0v. The expansion pulse D1 is a pulse to apply -Va to the stationary state 0v, and to return -Va to 0v. The contraction pulse P1 is a pulse to apply +Va to the stationary state 0v, and to return +Va to 0v. The expansion pulse D2 is a pulse to apply -Va to the stationary state 0v, and to return -Va to 0v.

[0063] When discharging the ink droplet, first, the expansion pulse D1 is applied to the actuator 16. The expansion pulse D1 expands the volume of the pressure chamber 15 formed by the actuator 16. That is, the expansion pulse D1 brings the pressure chamber 15 into the state illustrated in FIG. 8. Here, the pressure in the pressure chamber 15 is reduced, and ink is supplied to the pressure chamber 15 from the common ink chamber 5. The expansion pulse D1 is formed to have a predetermined pulse width. That is, the expansion pulse D1 expands the volume of the pressure chamber 15 for the first predetermined time. For example, a pulse width of the expansion pulse D1 is about half (AL) of the natural vibration cycle of the pressure in the pressure chamber 15, that is, an acoustic resonance cycle.

[0064] After the lapse of the first predetermined time, the contraction pulse P1 is applied to the actuator 16. The contraction pulse P1 reduces the volume of the pressure chamber 15 formed by the actuator 16. That is, the contraction pulse P1 brings the pressure chamber 15 into the state illustrated in FIG. 9. As the pressure in the pressure chamber 15 rises due to the contraction pulse P1, the velocity of the meniscus 20 formed in the nozzle 8 exceeds a threshold value at which the ink droplet is discharged. The ink droplet is discharged from the nozzle 8 of the pressure chamber 15 at a timing when the velocity of the meniscus 20 exceeds the discharge threshold value.

[0065] After the lapse of the second predetermined time, the pressure chamber 15 is released. That is, the pressure chamber 15 returns to a default state (state illustrated in FIG. 7). The pressure in the pressure chamber 15 drops while the pressure chamber 15 maintains the default state. As the pressure in the pressure chamber 15 drops, the velocity of the meniscus 20 formed in the nozzle 8 becomes equal to or lower than the threshold value at which the ink droplet is discharged. At the timing when the velocity of the meniscus 20 becomes equal to or less than the discharge threshold value, the discharge of ink droplet from the nozzle 8 of the pressure chamber 15 is cut off.

[0066] After the lapse of the third predetermined time, the expansion pulse D2 is applied to the actuator 16. The expansion pulse D2 cancels the pressure vibration in the pressure chamber after the discharge of ink droplet so that the next discharge is not influenced by the previous ejection. Since the expansion pulse D2 is sufficiently narrower than the pulse width of the expansion pulse D1, the expansion pulse D2 does not expand the volume of the pressure chamber 15 to the extent that ink is supplied from the common ink chamber 5 to the pressure chamber 15. The effect of canceling the remaining vibration can be adjusted by the pulse width of the expansion pulse D2, that is, the fourth predetermined time, and the pulse application timing, that is, the third predetermined time of the cutting-off time CP.

[0067] The contraction pulse P0 is inserted before the expansion pulse D1 in order to make the expansion of the volume of the pressure chamber 15 by the expansion pulse D1 stronger. The width of the contraction pulse P0 is 1 AL or less. When the pulse width is 1 AL or less, the amplitude of the pressure vibration in the pressure chamber 15 can be increased.

[0068] When the ink droplet is consecutively discharged a plurality of times, the discharge pulse of FIG. 10 is consecutively repeated for the number of discharges.

[0069] The ink jet head 100 has two printing modes of a multi-drop mode and a binary mode. The multi-drop mode is a mode in which one dot is formed on the medium by discharging any number of drops from one drop to the maximum drop number depending on a size of the dot to be formed. The binary mode is a mode in which one dot is formed on the medium with the number of drops to be discharged constant, for example the maximum drop number.

[0070] FIG. 11 is a table illustrating an example of the relationship between the nozzles 8 and the ink discharge number in the multi-drop mode. Here, an example in which printing for two lines is performed in a set of three adjacent nozzles 8, that is, with #100 nozzle, #101 nozzle, and #102 nozzle is illustrated. These nozzles 8 correspond to (3n + 1), (3n + 2), and (3n + 3) phases. The same relationship also holds for sets of other nozzles 8 not illustrated here. The example of FIG. 11 is an example in which all discharges for two lines are performed with three-drop, which is the maximum drop number.

[0071] FIG. 12 is a timing chart illustrating an example of a drive waveform for realizing printing similarly as in the example of FIG. 11. The head drive circuit 101 of the ink jet head 100 of three-division driving controls discharge pulses to be applied to the actuator 16 as illustrated in this drive waveform. That is, the head drive circuit 101 first consecutively applies the discharge pulse illustrated in FIG. 10 to the actuator 16 corresponding to #100 nozzle, which is the nozzle 8 of (3n + 1) phase, three times for printing line 1. Next, the head drive circuit 101 consecutively applies a discharge pulse to the actuator 16 corresponding to #101 nozzle of (3n + 2) phase three times. Then, the head drive circuit 101 consecutively applies a discharge pulse to the actuator 16 corresponding to #102 nozzle of (3n + 3) phase three times. After that, the head drive circuit 101 consecutively applies a discharge pulse to the actuator 16 corresponding to #100 nozzle three times for printing line 2, in the same manner similarly as in the case of line 1. Next, the head drive circuit 101 consecutively applies a discharge pulse to the actuator 16 corresponding to #101 nozzle three times. Then, the head drive circuit 101 consecutively applies a discharge pulse to the actuator 16 corresponding to #102 nozzle three times.

[0072] FIG. 13 is a table illustrating another example of the relationship between the nozzles 8 and the ink discharge number in the multi-drop mode. The present example is a case where printing is not performed with the maximum drop number of three-drop exists. That is, in line 1, three-drop, which is the maximum drop number, is set for #100 nozzle of (3n + 1) phase, 2 drops for #101 nozzle of (3n + 2) phase, and 1 drop for #102 nozzle of (3n + 3) phase. In line 2, zero-drop is set for #100 nozzle of (3n + 1) phase, and three-drop, which is the maximum drop number, for #101 nozzle of (3n + 2) phase and #102 nozzle of (3n + 3) phase.

[0073] FIG. 14 is a timing chart illustrating an example of a drive waveform for realizing printing similarly as in the example of FIG. 13. That is, the head drive circuit 101 first consecutively applies the discharge pulse to the actuator 16 corresponding to #100 nozzle three times for printing line 1. Next, the head drive circuit 101 consecutively applies the discharge pulse to the actuator 16 corresponding to #101 nozzle twice. Then, the head drive circuit 101 applies the discharge pulse to the actuator 16 corresponding to #102 nozzle once. For subsequent printing of line 2, the head drive circuit 101 does not apply the discharge pulse to the actuator 16 corresponding to #100 nozzle. Next, the head drive circuit 101 consecutively applies the discharge pulse to the actuator 16 corresponding to #101 nozzle three times. Then, the head drive circuit 101 consecutively applies the discharge pulse to the actuator 16 corresponding to #102 nozzle three times.

[0074] As such, for the nozzle 8 having a drop number smaller than the maximum drop number, a free time during which the discharge pulse is not applied is generated. That is, in the examples of FIGS. 13 and 14, in line 1, the free time for one discharge pulse is generated for #101 nozzle and the free time for two discharge pulses is generated for #102 nozzle, and in line 2, the free time for three discharge pulses is generated for #100 nozzle.

[0075] A performance evaluation index of the ink jet head 100 is calculated with an amount of landing position deviation in the conveyance direction of the medium, which is called "linearity error". FIG. 15 is a diagram illustrating an example of landing deviation of landing dots. When a straight line with dots is formed by the ink jet head 100 of three-division driving having the disposition of nozzles 8 as illustrated in FIG. 5, landing deviation as illustrated by the arrow in FIG. 15 occurs. The amount of positional deviation of the landing dot in the conveyance direction similarly as indicated by the arrow is defined as a linearity error of each nozzle. As the dotted line that serves as the reference for the arrow, for example, a straight line obtained by using the least squares method of all landing dots is used.

[0076] In the three-division driving ink jet head 100, the discharge speed changes depending on phases ((3n + 1) phase, (3n + 2) phase, and (3n + 3) phase) of each division. FIG. 16 is a graph illustrating a measurement example of linearity error for each phase. In FIG. 16, the solid line indicates (3n + 1) phase, the thin line indicates (3n + 2) phase, and the thick line indicates (3n + 3) phase.

[0077] In order to prevent such landing deviation, a micro-vibration pulse called a precursor is inserted into the drive waveform. The micro-vibration pulse is a pulse that does not discharge ink from the pressure chamber 15. That is, the micro-vibration pulse is a pulse that does not discharge ink from the pressure chamber 15 but causes pressure vibration in the pressure chamber 15.

[0078] FIG. 17 is a diagram for illustrating a configuration example of the micro-vibration pulse. As illustrated in FIG. 17, the micro-vibration pulse includes an expansion pulse DP for a predetermined time. That is, the micro-vibration pulse is an expansion pulse that expands the volume in the pressure chamber 15 formed by the actuator 16. The expansion pulse brings the pressure chamber 15 to the state illustrated in FIG. 8. Here, the pressure in the pressure chamber 15 is reduced, and pressure vibration occurs in the pressure chamber 15.

[0079] The micro-vibration pulse can include a contraction pulse PP shorter than the contraction pulse P1 of the discharge pulse. After applying the expansion pulse DP to the electrode, the micro-vibration pulse maintains 0v for a predetermined time, and then applies the contraction pulse PP to the electrode. The expansion pulse DP is a pulse to apply -Va to the stationary state 0v, and to return -Va to 0v. The contraction pulse PP is a pulse to apply +Va to the stationary state 0v, and to return +Va to 0v.

[0080] The head drive circuit 101 adjusts the pressure in the pressure chamber 15 by applying such a micro-vibration pulse, and stabilizes the speed (discharge speed) of the discharged ink. FIG. 18 is a table illustrating an example of the relationship between the nozzles, the ink discharge number, and the micro-vibration pulse insertion number. FIG. 19 is a timing chart illustrating an example of the drive waveform corresponding to the example of FIG. 18. As illustrated in FIGS. 18 and 19, the head drive circuit 101 inserts the micro-vibration pulse into the free time during which the discharge pulses PD illustrated in the examples of FIGS. 13 and 14 are not output. In the examples of FIGS. 18 and 19, the head drive circuit 101 outputs a micro-vibration pulse PC after outputting the discharge pulse PD once or twice out of the maximum drop number of three. That is, with respect to #101 nozzle of (3n + 2) phase in the printing of line 1, after the discharge pulse PD is output twice, the head drive circuit 101 outputs the micro-vibration pulse PC at the timing of one discharge pulse PD, that is, at the timing at which the discharge pulse PD is to be output when the liquid droplet is discharged. In other words, the micro-vibration pulse PC is output in synchronization with the output timings of one discharge pulse PD for the other nozzles of the same (3n + 2) phase. With respect to #102 nozzle of (3n + 3) phase in the printing of line 1, after outputting the discharge pulse PD once, the head drive circuit 101 outputs the micro-vibration pulse PC at each of the timings of two discharge pulses PD, that is, in synchronization with the respective output timings of the discharge pulse PD for the other nozzles of the same (3n + 3) phase. When the discharge pulse PD is not output even once similarly as in the case of #100 nozzle of (3n + 1) phase in the printing of line 2, the head drive circuit 101 outputs the micro-vibration pulse PC at each of the timings of three discharge pulses PD, that is, in synchronization with the respective output timings of the discharge pulse PD for the other nozzles of the same (3n + 1) phase.

[0081] FIG. 20 is a timing chart illustrating an example of the drive waveform in the binary mode. The number of discharge pulses PDs in the binary mode depends on the design, but here the number of discharge pulses PDs is set to one discharge. As illustrated in FIG. 20, the head drive circuit 101 inserts the micro-vibration pulse PC into the free time during which the discharge pulse PD is not output, similarly as in the multi-drop mode, in the binary mode as well.

[0082] The head drive circuit 101 can further stabilize the discharge speed by appropriately controlling an application position, that is, a timing, and a pulse width, that is, a shape of the micro-vibration pulse PC.

[0083] The timing and shape of the micro-vibration pulse PC can be determined as follows.

[0084] FIG. 21 is a table illustrating setting contents in 32 tests for checking location dependency of the micro-vibration pulse PC. In the tests, the shape of the micro-vibration pulse PC is fixed, that is, the pulse width of the expansion pulse DP and the contraction pulse PP is set to 5 μs and the application position of the expansion pulse

DP and/or the contraction pulse PP is changed to check straightness.

[0085] Here, "front" in the expansion pulse D1 indicates that the expansion pulse DP of the micro-vibration pulse PC is subjected to front-justification, that is, the falling timing of the expansion pulse DP is matched with the falling timing of the expansion pulse D1 of the discharge pulse PD. "Center" in the expansion pulse D1 indicates that the expanded pulse DP of the micro-vibration pulse PC is subjected to center-alignment, that is, the timing of the center of the pulse width of the expanded pulse DP is matched with the timing of the center of the pulse width of the extended pulse D1 of the discharge pulse PD. "Back" in the expansion pulse D1 indicates that the expansion pulse DP of the micro-vibration pulse PC is subjected to back-justification, that is, the rising timing of the expansion pulse DP is matched with the rising timing of the expansion pulse D1 of the discharge pulse PD.

[0086] Similarly, regarding "front", "center", and "back" in the expansion pulse D2, the expansion pulse DP is subjected to "front-justification", "center-alignment", and "back-justification" with respect to the expansion pulse D2.

[0087] "Back" in the contraction pulse P1 indicates that the contraction pulse PP of the micro-vibration pulse PC is subjected to back-justification, that is, the falling timing of the contraction pulse PP is matched with the falling timing of the contraction pulse P1 of the discharge pulse PD.

[0088] FIG. 22 is a graph illustrating an example of the check result of the location dependency of the micro-vibration pulse PC by each test of FIG. 21. Here, the test results illustrated by the white circles and solid lines illustrate three-cycle linearity in three nozzles at both ends in the three-division driving inkjet head 100, in other words, in the example of FIG. 5, #001 nozzle to #003 nozzle and #316 nozzle to #318 nozzle. The test results illustrated by the black circles and dotted lines illustrate three-cycle linearity in the central nozzles excluding the three nozzles at both ends, in other words, in the example of FIG. 5, #004 nozzle to #315 nozzle. In the three-division driving ink jet head 100, as illustrated in FIG. 16, there is a tendency in the linearity error depending on the phases ((3n + 1) phase, (3n + 2) phase, and (3n + 3) phase) of each division. Therefore, it is possible to judge whether the linearity error is good or bad by taking the average of all nozzles of the difference between the maximum value and the minimum value for every three nozzles. However, the tendency of the linearity error is different between end portions of the ink jet head 100 and a central portion thereof excluding the end portions. Therefore, here, the three-cycle linearity is measured by the average of the three nozzles at both ends and the average of the other nozzles.

[0089] As illustrated in FIG. 22, when the settings of test 03, test 05, and test 09 are used, good straightness is achieved at both the end portions and the central portion of the ink jet head 100.

[0090] FIG. 23 is a graph illustrating an example of a check result of pulse width dependency of the micro-vibration pulse PC in these tests 03, 05 and 09. That is, FIG. 23 illustrates the results of measuring the three-cycle linearity by changing the shape, that is, the pulse width, at the timings of the expansion pulse DP and/or the contraction pulse PP of test 03, test 05, and test 09. However, the present example is a measurement example with the ink jet head 100 having AL of 2.8 μs. In FIG. 23, similarly as in FIG. 22, the measurement results illustrated by the white circles and solid lines indicate the three-cycle linearity of three nozzles at both ends of the three-division driving inkjet head 100, and the measurement results illustrated by the black circles and the dotted lines indicate the three-cycle linearity of the central nozzles.

[0091] Therefore, as illustrated in FIG. 23, in test 09, when the pulse width is 1.3 μs or more, good straightness is achieved at both the end portions and the central portion of the ink jet head 100.

[0092] FIG. 24 is a waveform diagram illustrating the relationship between the timings and shapes of the discharge pulse PD and the micro-vibration pulse PC. Here, the solid line indicates the discharge pulse PD, and the thick line indicates the micro-vibration pulse PC. Although the discharge pulse PD and the micro-vibration pulse PC are output separately, the pulses PD and PC are illustrated to be superimposed in FIG. 24 in order to illustrate the timing and shape of the waveform in an easy-to-understand manner. LD indicates the pulse width of the expansion pulse DP of the micro-vibration pulse PC, and LP indicates the pulse width of the contraction pulse PP of the micro-vibration pulse PC. When it is estimated from the respective straight lines connecting 0.9 μs and 1.3 μs in FIG. 23, if the pulse with is 1.1 to 1.2 μs or more, sufficiently good straightness can be obtained. Therefore, the micro-vibration pulse PC desirably includes an expansion pulse DP having a pulse width LD of 0.4 AL or more in the center alignment and a contraction pulse PP having a pulse width LP of 0.4 AL or more and subjected to back-justification. If the ink jet head 100 has AL of 2.8 μs, the pulse width LD of the expansion pulse DP and the pulse width LP of the contraction pulse PP are preferably 1.3 μs or more, that is, 0.46 AL or more. The upper limits of the pulse widths LD and LP may be any width at which erroneous discharge is not caused. A width that does not cause such erroneous discharge is not specified here because the width depends on conditions such as viscosity of ink other than the timing and shape of the micro-vibration pulse PC.

[0093] With respect to FIGS. 18 and 19, the head drive circuit 101 outputs the micro-vibration pulse PC in synchronization with output timings of the discharge pulse PD for the other nozzles of the same phase. As illustrated in FIG. 24, such synchronization means that the expanded pulse DP of the micro-vibration pulse PC is center-aligned with the expanded pulse D1 of the discharge pulse PD for the other nozzles of the same phase, and the contraction pulse PP of the micro-vibration pulse PC is back-justified with respect to the contraction pulse P1 of the discharge pulse PD for the other nozzles of the same phase.

[0094] FIG. 25 is a graph illustrating a measurement example of linearity error in the ink jet head according to the embodiment. That is, the graph illustrates a case where the micro-vibration pulse PC having a center alignment timing at which the expanded pulse DP having a pulse width of 1.3 μs is center aligned with respect to the expanded pulse D1 and a back-justifying timing at which the contraction pulse PP having a pulse width of 1.3 μs is back-justified with respect to the contraction pulse P1 is inserted into the free time for the discharge pulse PD. In FIG. 25, the solid line, the thin line, and the thick line indicate (3n + 1) phase, (3n + 2) phase, and (3n + 3) phase, respectively, similarly as in FIG. 16. When comparing FIGS. 25 and 16, by adopting the timing and shape of such a micro-vibration pulse PC, printing with a small linearity error can be realized at both the end portions and the central portion of the ink jet head 100.

[0095] FIG. 26 is a timing chart illustrating an example of a drive waveform at the start of printing in the multi-drop mode. In particular, in the printing result, the linearity error is visually conspicuous in the thin horizontal straight line image and the edge portion at the start of solid printing. In particular, at the edge portion at the start of solid printing, in (3n + 1) phase, which is the phase at which discharge is performed first, no vibration is generated from the adjacent nozzle immediately before the phase. Therefore, the discharge speed of (3n + 1) phase is faster than that of (3n + 2) phase and (3n + 3) phase. In other words, (3n + 2) phase and (3n + 3) phase are influenced by the vibrations of the immediately preceding (3n + 1) phase and (3n + 2) phase, so that the discharge speed of (3n + 2) phase and (3n + 3) phase is slower than that of (3n + 1) phase. Therefore, the head drive circuit 101 generates at least one micro-vibration pulse PC, in the present example, three micro-vibration pulse PC at the timing when the discharge pulse PD is not applied, before the actual printing start time illustrated at time t1 in FIG. 26. That is, the head drive circuit 101 outputs the micro-vibration pulse PC prior to outputting the discharge pulse according to print data from the client, and then outputs the discharge pulse according to the print data. By doing as described above, in (3n + 1) phase, which is the first phase to be discharged at the start of printing, the discharge speed decreases due to the influence of the immediately preceding micro-vibration pulse PC, and approaches the discharge speeds of (3n + 2) phase and (3n + 3) phase influenced by the discharge in (3n + 1) phase, and as a result, the linearity error improves.

[0096] In the inkjet head 100 configured as described above, in the multi-drop mode, when the discharge pulse PD with the number of drops less than the maximum drop number is applied to the actuator, the micro-vibration pulse PC is applied to the actuator during the remaining period in which the discharge pulse PD is not applied. The micro-vibration pulse PC is applied to the actuator to which the discharge pulse PD is not applied in the multi-drop mode and the binary mode. The micro-vibration pulse PC to be applied includes the expansion pulse DP having a timing for center-alignment with respect to the expansion pulse D1 of the discharge pulse PD, and the contraction pulse PP having a timing for back-justification with respect to the contraction pulse P1 of the discharge pulse PD. As a result, the ink jet head 100 can prevent variations in the discharge speed of ink droplets for each phase and reduce landing deviation.

[0097] Each of the expansion pulse DP and the contraction pulse PP has a pulse width of 0.4 AL or more. For example, if the ink jet head 100 has AL of 2.8 μs, the micro-vibration pulse PC desirably includes the expansion pulse DP and the contraction pulse PP of 1.3 μs or more. As a result, the ink jet head 100 can further prevent variations in the discharge speed of ink droplets for each phase and further reduce the landing deviation.

[0098] In the embodiment described above, the ink jet head 100 that performs three-division driving is described as an example. However, of course, the ink jet head 100 may perform division driving of other division numbers.

[0099] In the embodiment described above, the discharge pulse PD including the expansion pulse D2 and the contraction pulse P0 in addition to the expansion pulse D1 and the contraction pulse P1 is described as an example. However, the discharge pulse PD may not include the expansion pulse D2 and/or the contraction pulse P0.

[0100] In the embodiment described above, a case where the timing of the expansion pulse DP is changed by setting the contraction pulse PP in the micro-vibration pulse PC as the timing for back-justification with respect to the contraction pulse P1 of the discharge pulse PD is described. However, the timing and shape of the micro-vibration pulse PC may be determined by also changing and testing the timing of the contraction pulse PP.

[0101] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the scope of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope of the inventions.

Claims

1. A liquid droplet discharge head comprising:

a pressure chamber configured to be filled with ink;

an actuator configured to change volume in the pressure chamber to discharge a liquid droplet from a nozzle communicating with the pressure chamber; and
a drive circuit configured to apply a discharge pulse including an expansion pulse for expanding the volume in the pressure chamber and a contraction pulse for contracting the volume in the pressure chamber to the actuator when the liquid droplet is discharged, and to apply, to the actuator, a micro-vibration pulse that changes the volume of the pressure chamber to the extent that the liquid droplet is not discharged from the nozzle at a timing when the liquid droplet is not discharged, wherein
the micro-vibration pulse includes an expansion pulse portion and a contraction pulse portion,
a central position of the expansion pulse portion in the micro-vibration pulse corresponds to a central position of the expansion pulse in the discharge pulse, and
a falling position of the contraction pulse portion in the micro-vibration pulse corresponds to a falling position of the contraction pulse in the discharge pulse.

2. The liquid droplet discharge head according to claim 1, wherein
pulse widths of the expansion pulse portion and the contraction pulse portion in the micro-vibration pulse are 0.4 AL or more (AL is half of the natural vibration cycle of pressure in the pressure chamber).

3. The liquid droplet discharge head according to claim 1, wherein
when the liquid droplet is not discharged, the drive circuit is configured to apply the micro-vibration pulse to the actuator at a timing of the discharge pulse to be applied to the actuator when the liquid droplet is discharged.

4. The liquid droplet discharge head according to claim 1, wherein
the liquid droplet discharge head is configured to include a plurality of the nozzles,
the drive circuit is configured to divide the nozzles into a plurality of groups each including the plurality of nozzles, and control application of the discharge pulse and the micro-vibration pulse in group units, and
the drive circuit is further configured to apply the micro-vibration pulse to the actuator corresponding to a first nozzle in each group, prior to applying the discharge pulse to the actuator corresponding to the first nozzle.

5. A printer configured to discharge a predetermined number of liquid droplets to form one dot, the printer comprising:

a conveyance unit configured to convey a medium; and
a liquid droplet discharge head according to any one of claims 1 to 4.

FIG. 1

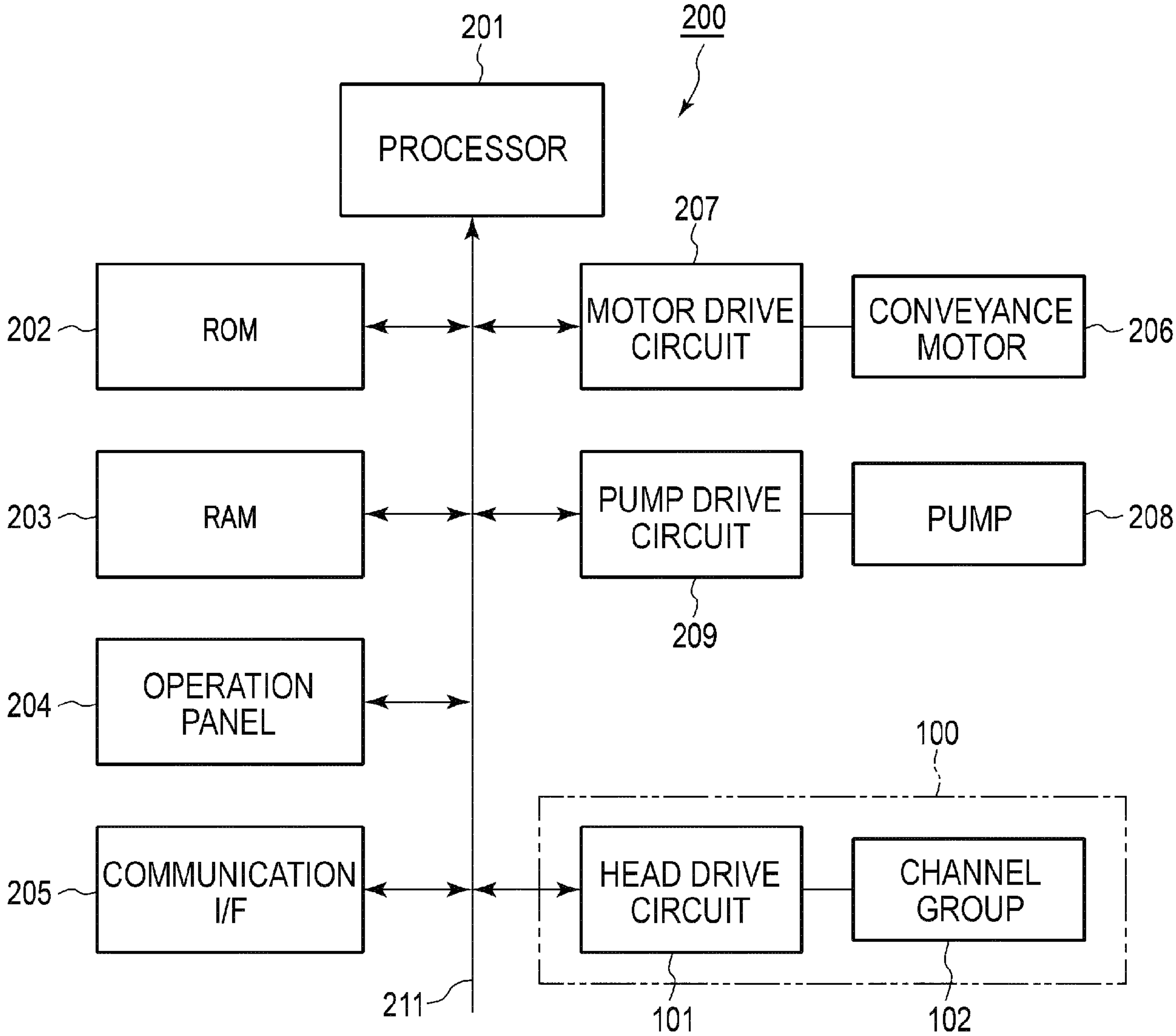

200
201
PROCESSOR
207
202
ROM
MOTOR DRIVE CIRCUIT
CONVEYANCE MOTOR
206
203
RAM
PUMP DRIVE CIRCUIT
PUMP
208
209
204
OPERATION PANEL
100
205
COMMUNICATION I/F
HEAD DRIVE CIRCUIT
CHANNEL GROUP
211
101
102

FIG. 2

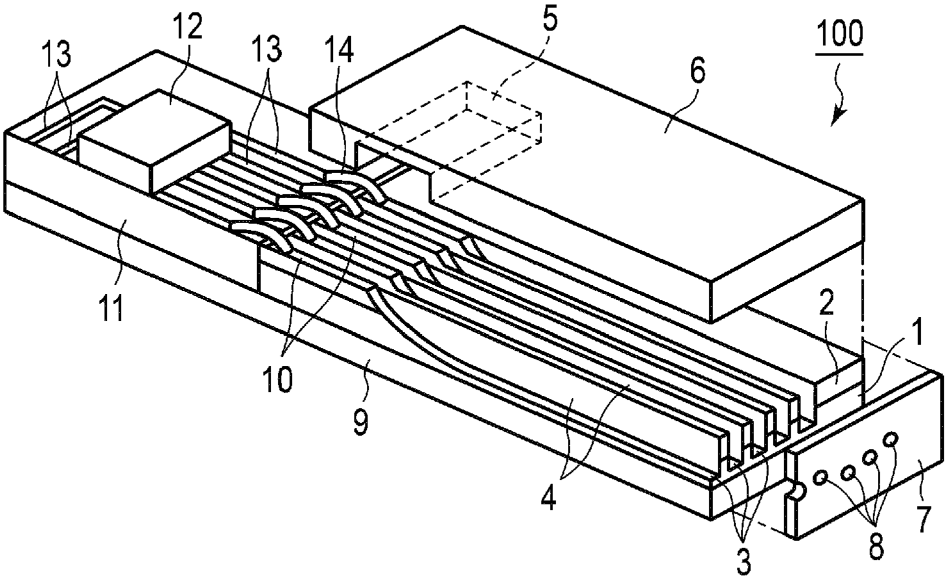


FIG. 3

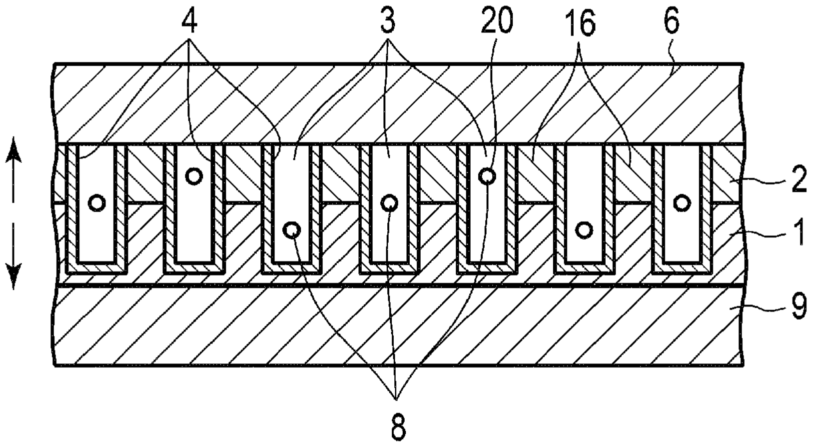


FIG. 4

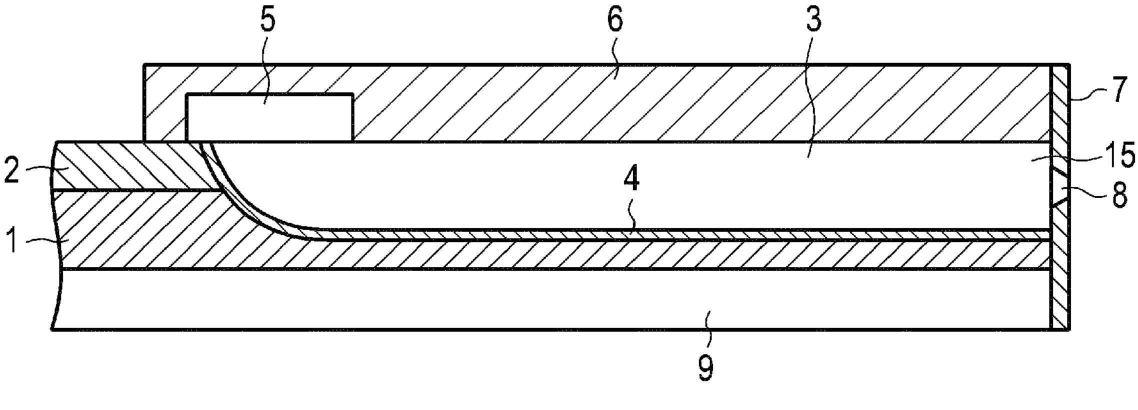


FIG. 5

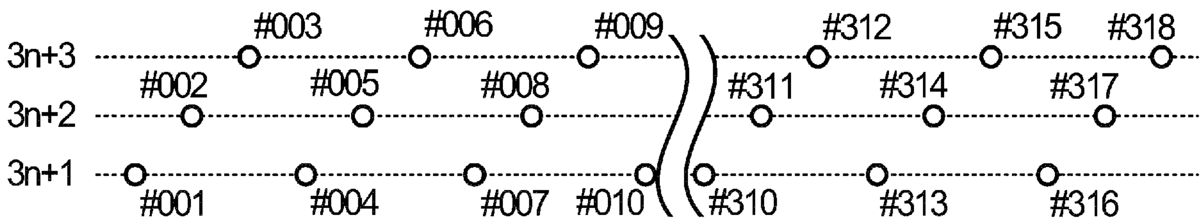

3n+3
3n+2
3n+1
#001
#002
#003
#004
#005
#006
#007
#008
#009
#010
#310
#311
#312
#313
#314
#315
#316
#317
#318

FIG. 6

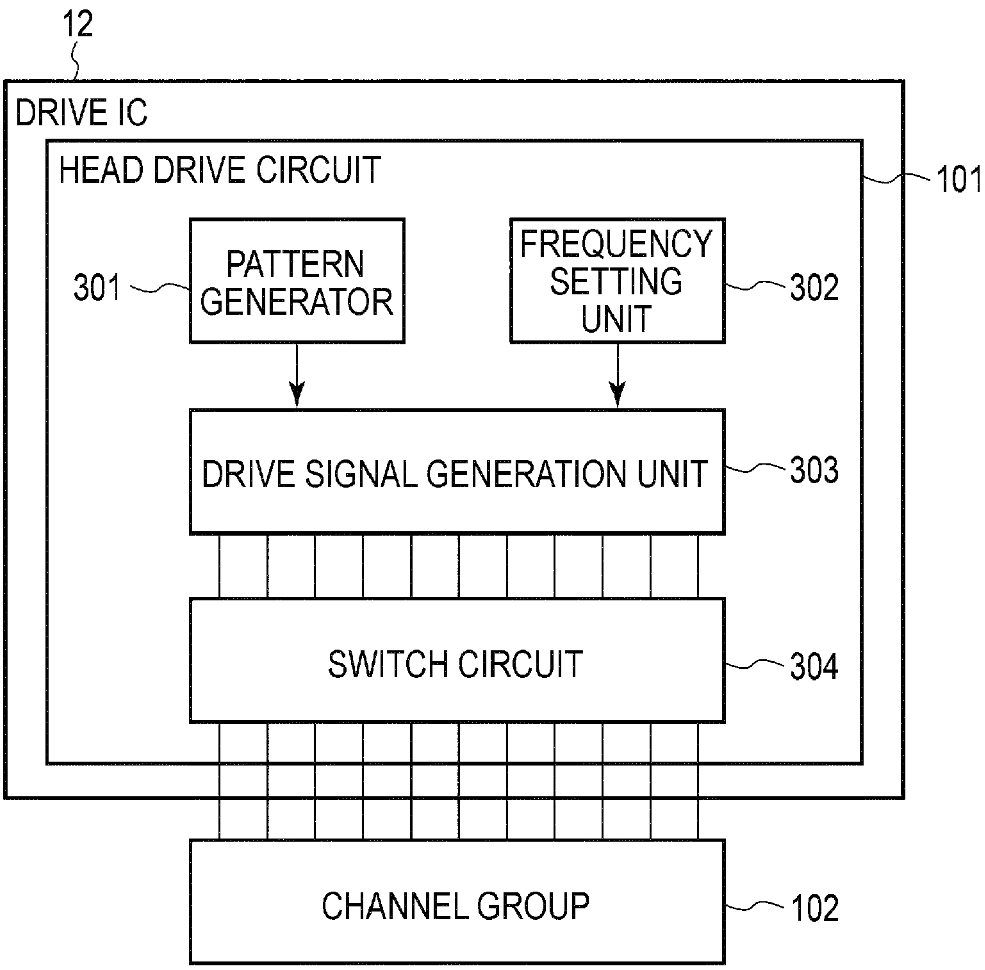

12
DRIVE IC
HEAD DRIVE CIRCUIT
101
301
PATTERN GENERATOR
FREQUENCY SETTING UNIT
302
DRIVE SIGNAL GENERATION UNIT
303
SWITCH CIRCUIT
304
CHANNEL GROUP
102

FIG. 7

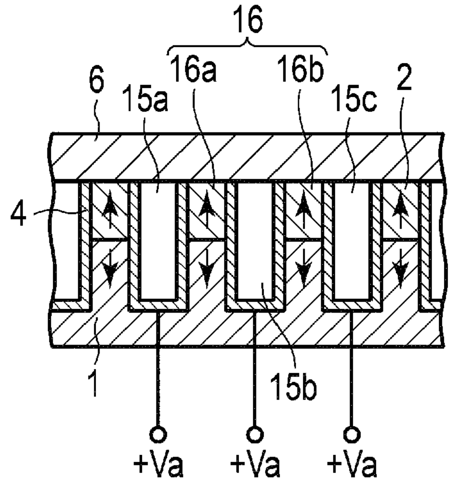


FIG. 8

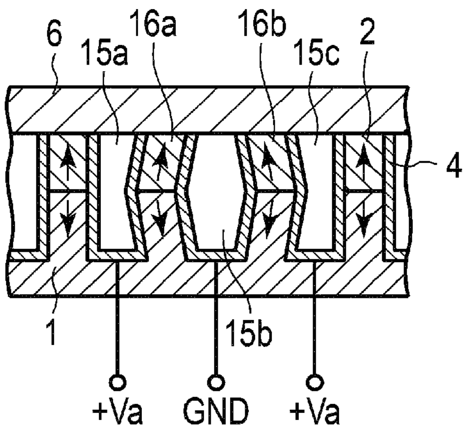


FIG. 9

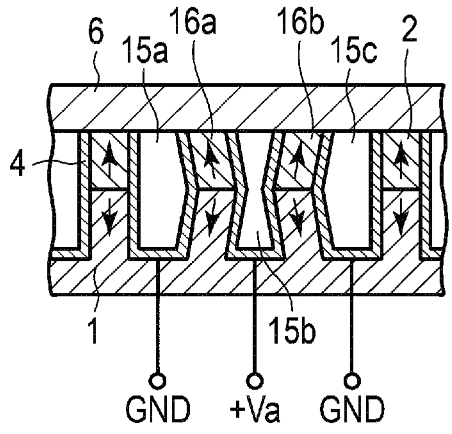


FIG. 10

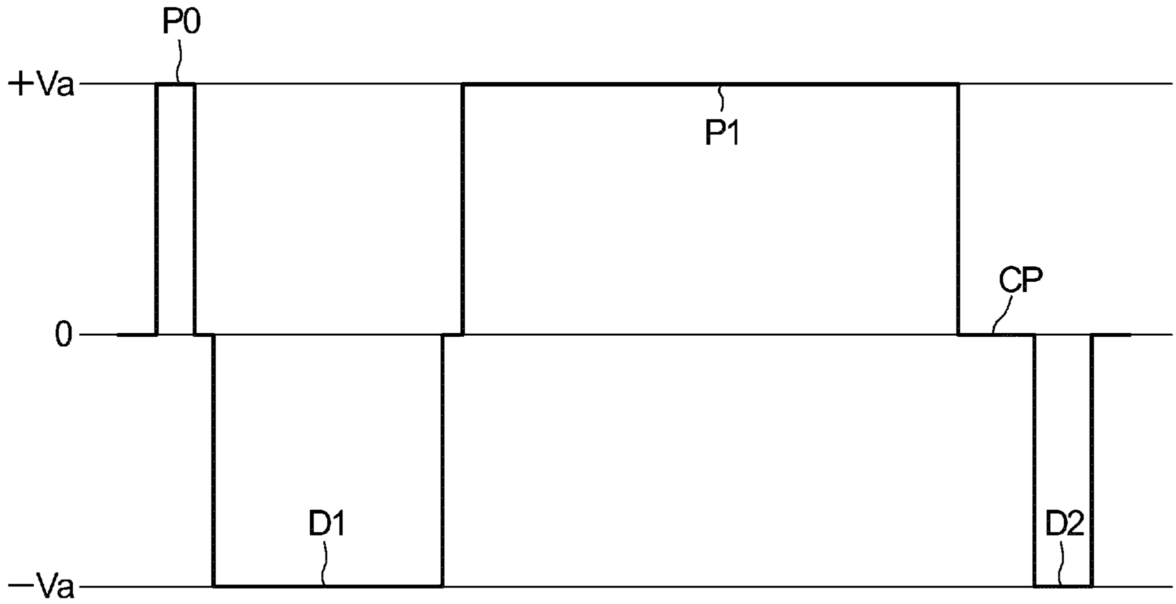


FIG. 11

Nozzle No.	1Line	2Line
#100	DISCHARGE 3 TIMES	DISCHARGE 3 TIMES
#101	DISCHARGE 3 TIMES	DISCHARGE 3 TIMES
#102	DISCHARGE 3 TIMES	DISCHARGE 3 TIMES

FIG. 12

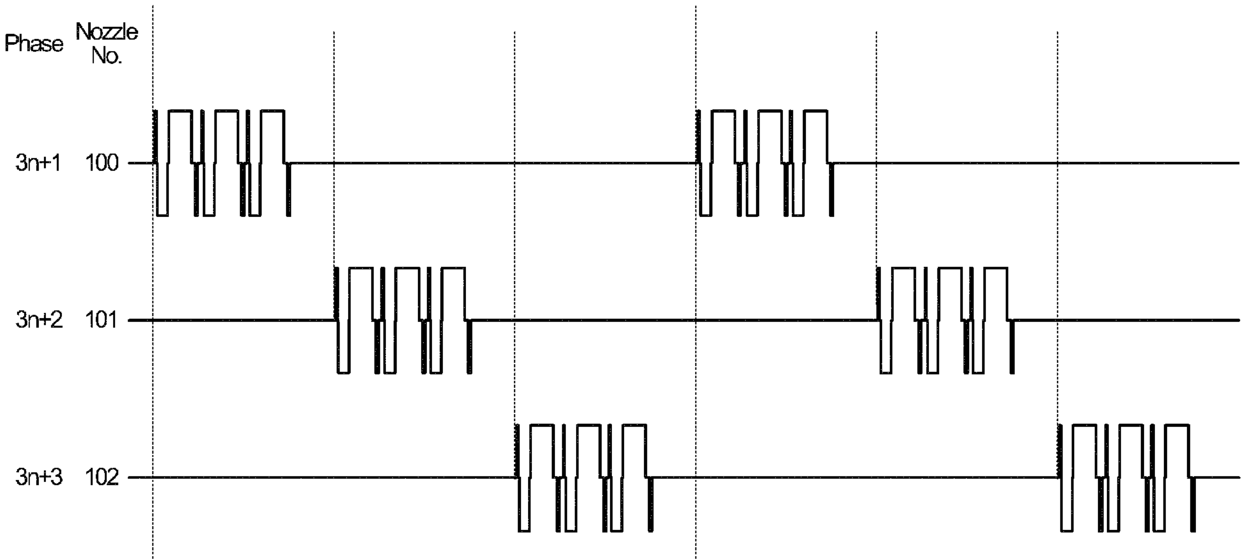


FIG. 13

Nozzle No.	1Line	2Line
#100	DISCHARGE 3 TIMES / FREE TIME 0 TIMES	DISCHARGE 0 TIMES / FREE TIME 3 TIMES
#101	DISCHARGE 2 TIMES / FREE TIME 1 TIME	DISCHARGE 3 TIMES / FREE TIME 0 TIMES
#102	DISCHARGE 1 TIME / FREE TIME 2 TIMES	DISCHARGE 3 TIMES / FREE TIME 0 TIMES

FIG. 14

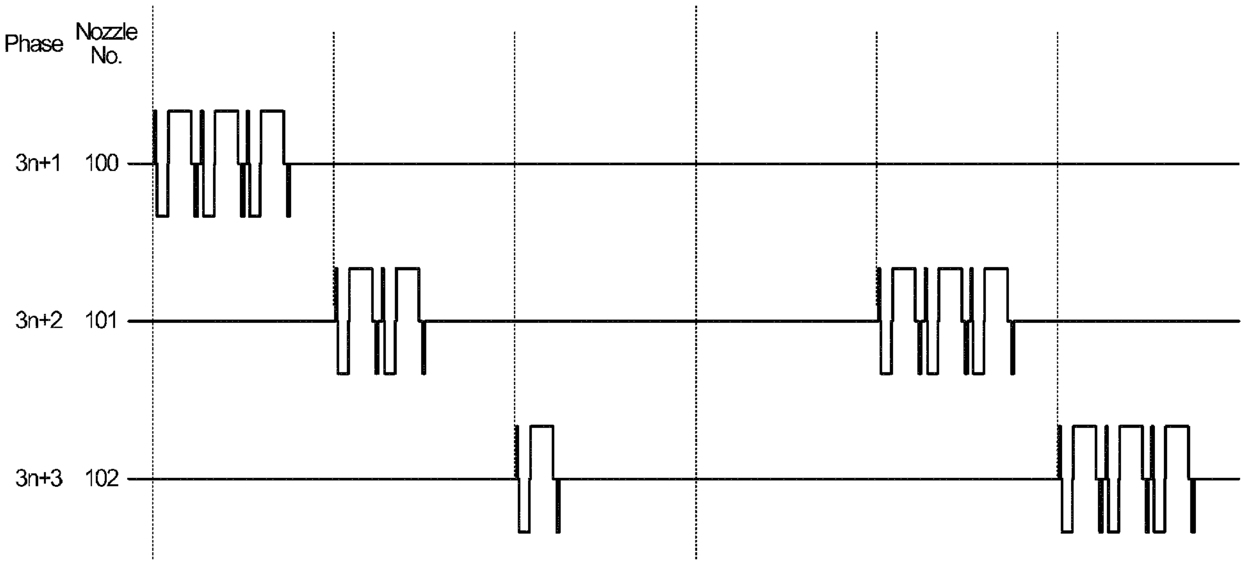


FIG. 15

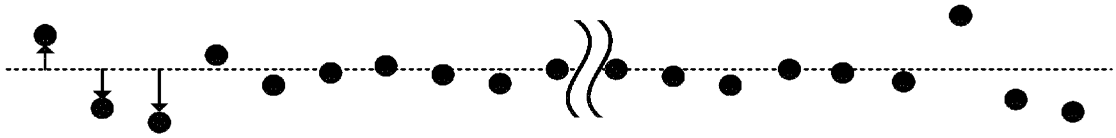


FIG. 16

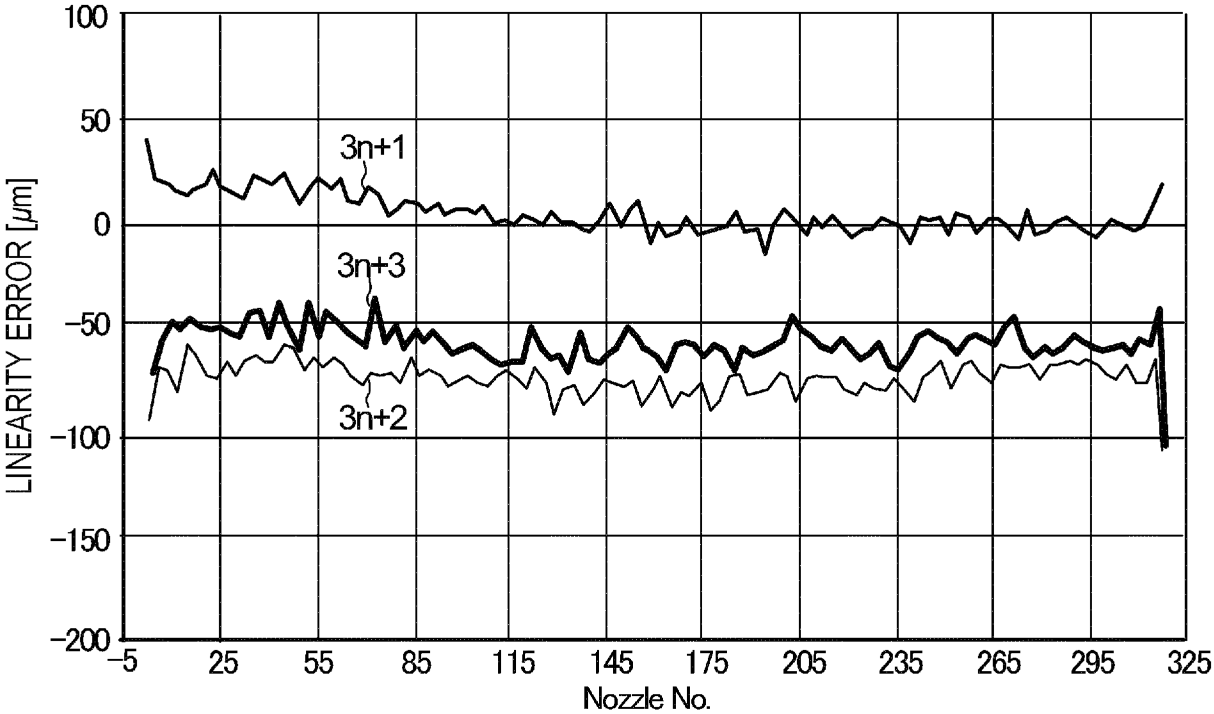

LINEARITY ERROR [μm]
100
50
0
-50
-100
-150
-200
-5
25
55
85
115
145
175
205
235
265
295
325
Nozzle No.
3n+1
3n+3
3n+2

FIG. 17

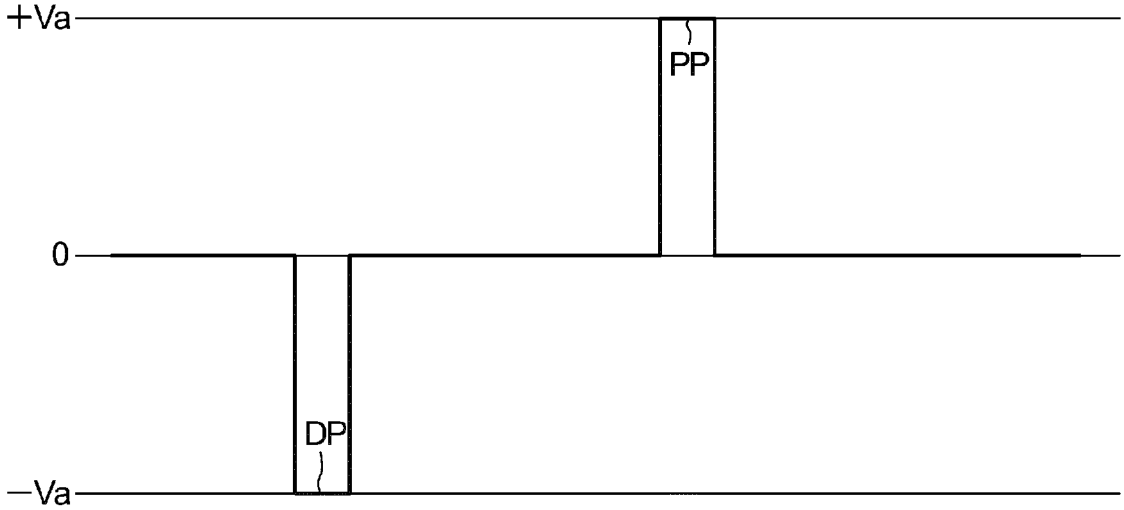


FIG. 18

Nozzle No.	1Line	2Line
#100	DISCHARGE 3 TIMES / MICRO-VIBRATION 0 TIMES	DISCHARGE 0 TIMES / MICRO-VIBRATION 3 TIMES
#101	DISCHARGE 2 TIMES / MICRO-VIBRATION 1 TIME	DISCHARGE 3 TIMES / MICRO-VIBRATION 0 TIMES
#102	DISCHARGE 1 TIME / MICRO-VIBRATION 2 TIMES	DISCHARGE 3 TIMES / MICRO-VIBRATION 0 TIMES

FIG. 19

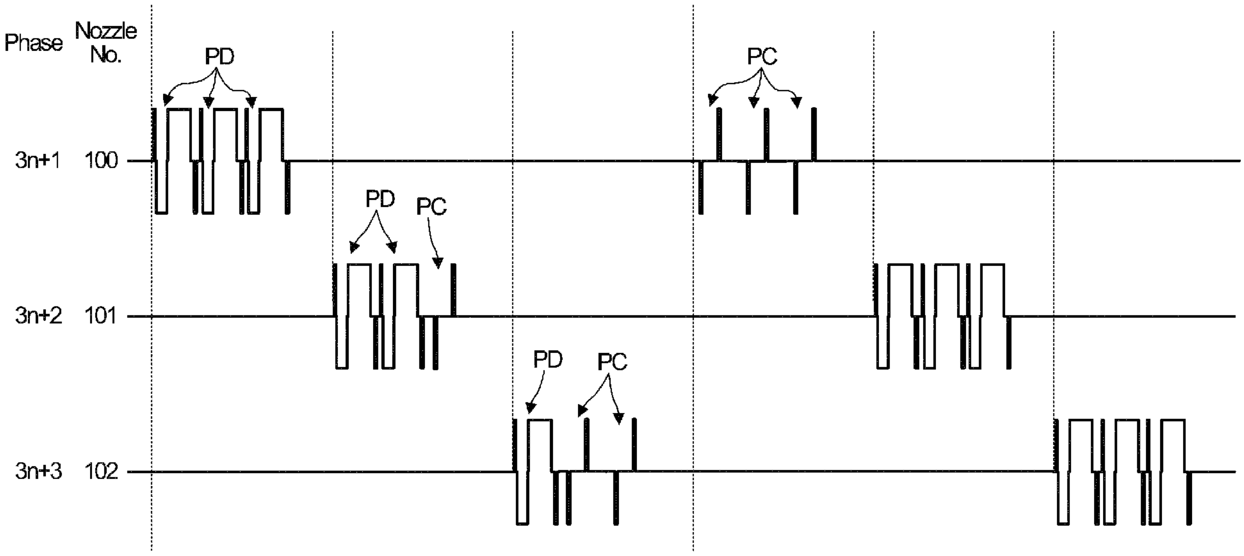


FIG. 20

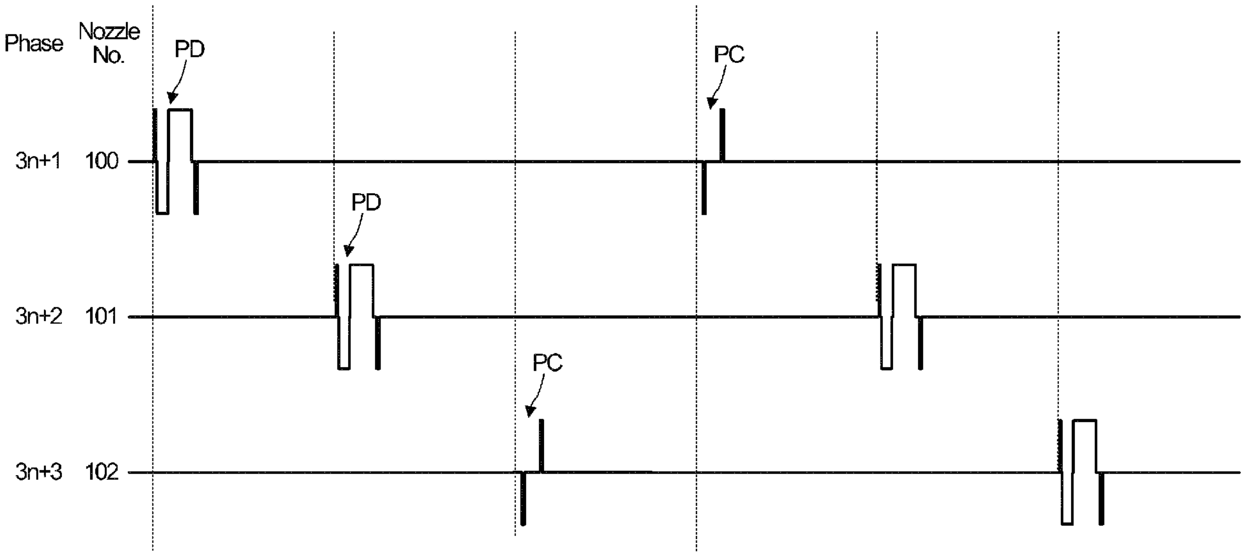


FIG. 21

	EXPANSION PULSE D1			CONTRACTION PULSE P1	EXPANSION PULSE D2		
TEST No.	FRONT	CENTER	BACK	BACK	FRONT	CENTER	BACK
00							
01	○						
02		○					
03			○				
04				○			
05					○		
06						○	
07							○
08	○			○			
09		○		○			
10			○	○			
11	○				○		
12	○					○	
13	○						○
14		○			○		
15		○				○	
16		○					○
17			○		○		
18			○			○	
19			○				○
20				○	○		
21				○		○	
22				○			○
23	○			○	○		
24	○			○		○	
25	○			○			○
26		○		○	○		
27		○		○		○	
28		○		○			○
29			○	○	○		
30			○	○		○	
31			○	○			○

FIG. 22

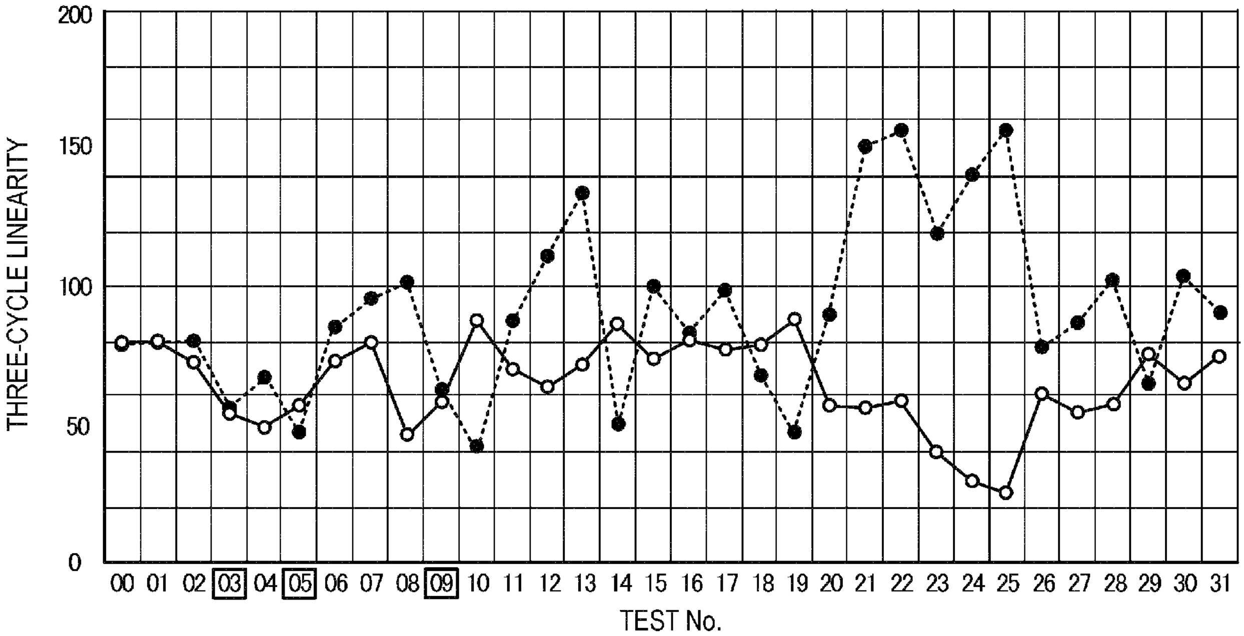

THREE-CYCLE LINEARITY
200
150
100
50
0
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
TEST No.

FIG. 23

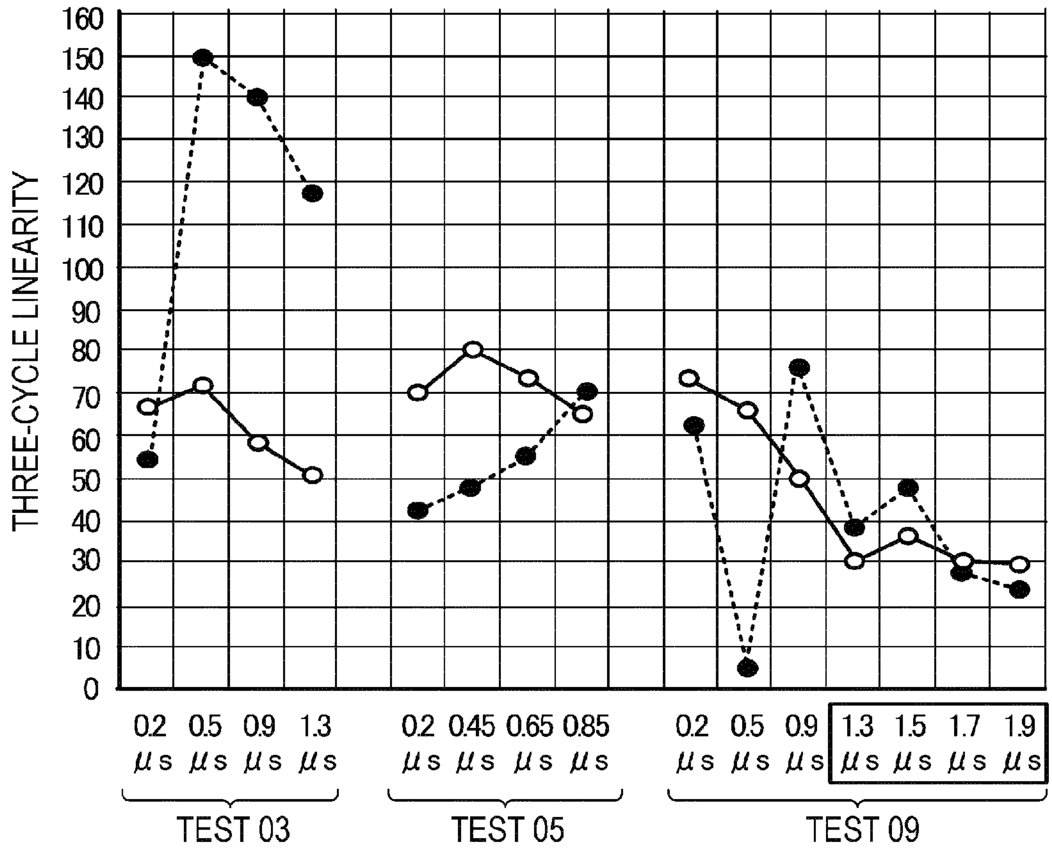

THREE-CYCLE LINEARITY
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0.2 μs
0.5 μs
0.9 μs
1.3 μs
TEST 03
0.2 μs
0.45 μs
0.65 μs
0.85 μs
TEST 05
0.2 μs
0.5 μs
0.9 μs
1.3 μs
1.5 μs
1.7 μs
1.9 μs
TEST 09

FIG. 24

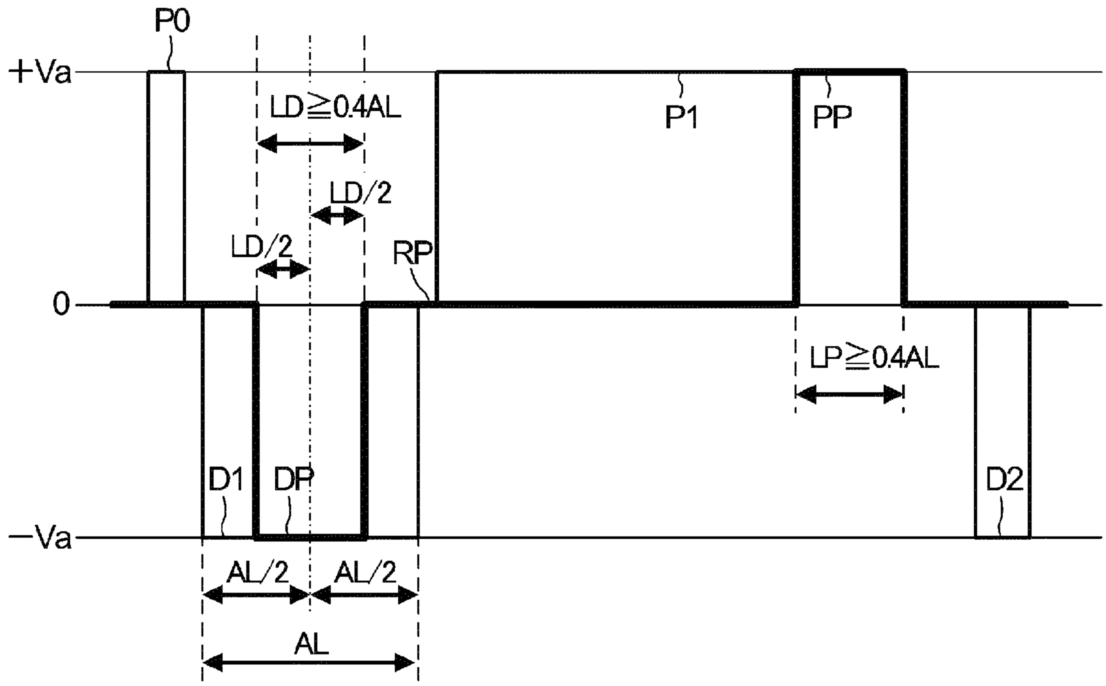

P0
+Va
0
−Va
LD≧0.4AL
LD/2
LD/2
RP
P1
PP
LP≧0.4AL
D1
DP
D2
AL/2
AL/2
AL

FIG. 25

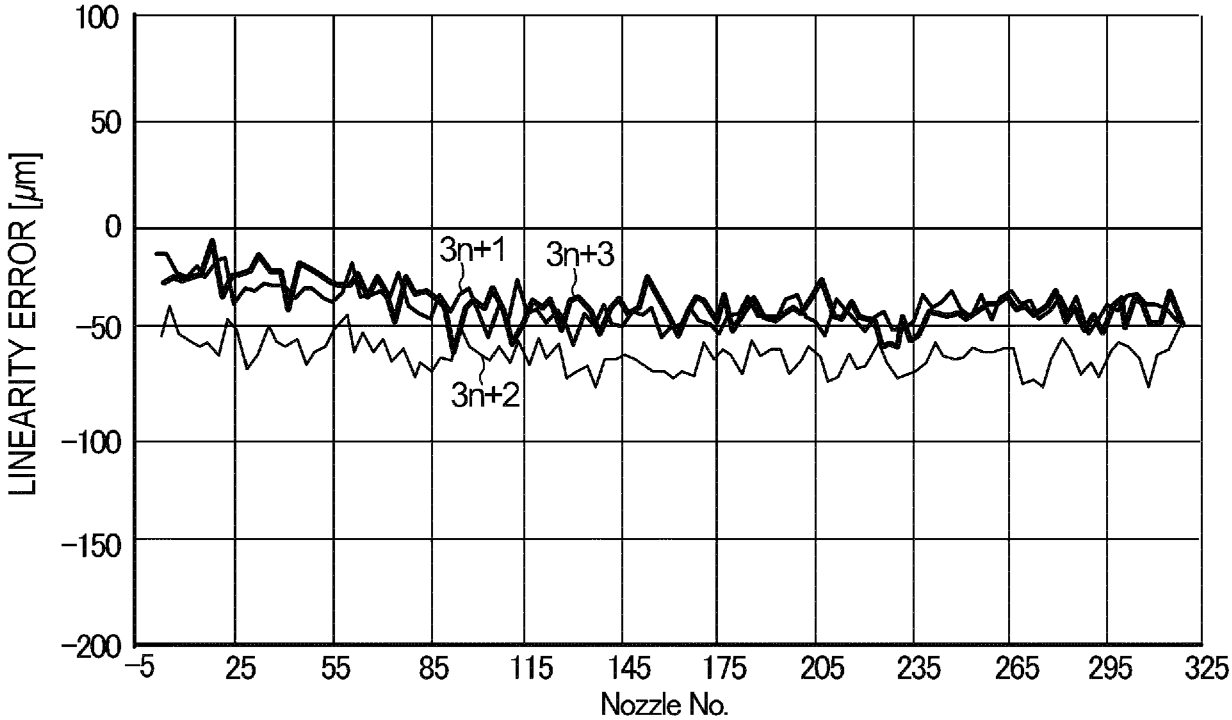
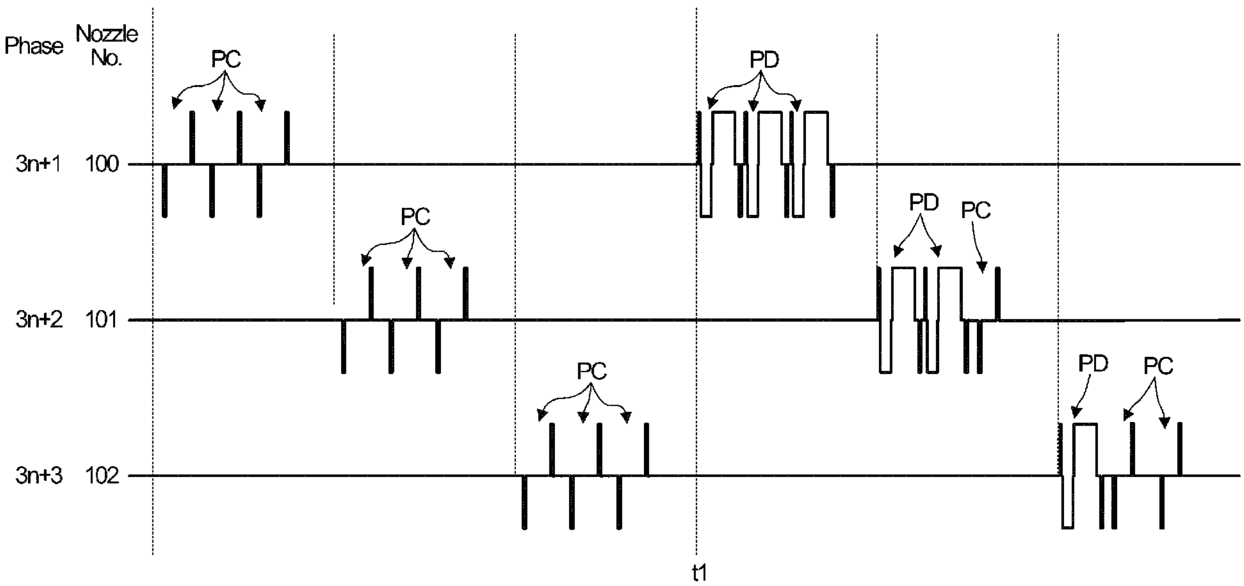

100
50
0
-50
-100
-150
-200
LINEARITY ERROR [μm]
3n+1
3n+3
3n+2
-5
25
55
85
115
145
175
205
235
265
295
325
Nozzle No.

FIG. 26



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EUROPEAN SEARCH REPORT

Application Number
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B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	10 September 2021	Bardet, Maude

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