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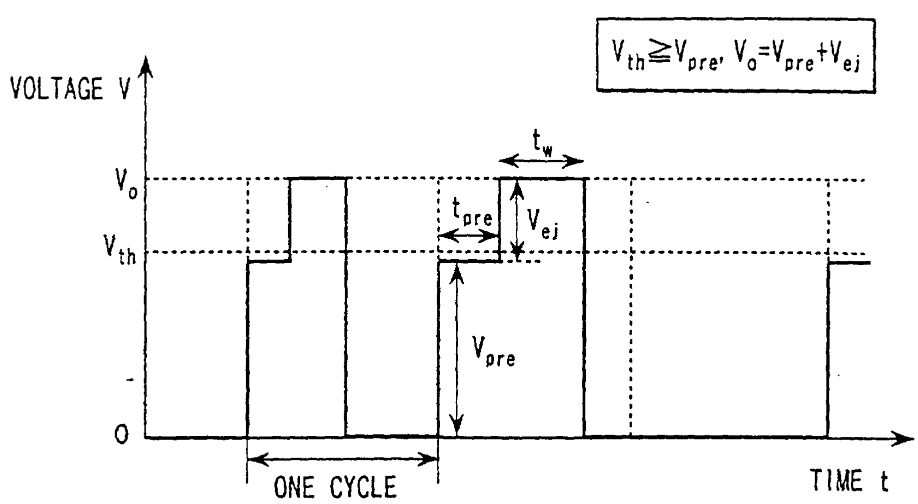
(54) **INK-JET RECORDER**

(57) The present invention has a head section for printing data by circulating the ink obtained by dispersing a color agent in a solvent through an ink channel, applying a voltage to an ejection electrode and thereby cohering the color agent, and ejecting the color agent and controls dot gradation by cohering a predetermined color agent when the color agent is cohered immediately before the ink is ejected. Thereby, it is possible to provide an ink-jet recorder from which a very reliable and minute print image is obtained.

FIG. 1



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Description

[TECHNICAL FIELD]

[0001] The present invention relates to an ink-jet recorder, particularly to an ink-jet recorder for recording data by ejecting pigment-based ink containing electrified color-agent particles onto a recording medium by an electrostatic force.

[BACKGROUND ART]

[0002] An apparatus for recording an image by ejecting liquid ink onto a recording medium in the form of small droplets and forming recording dots is practically used as an ink-jet printer. The ink-jet printer has advantages that the printer has less noises than other recording systems and it can be realized with the number of parts less than those of other recording systems because the printer directly records data on a recording medium. Therefore, the printer is watched as a normal-paper recording art. For data recording by an ink-jet printer, the following methods have been developed: a method of ejecting ink droplets by the pressure of bubbles produced due to the heat of a heating element (disclosed in Japanese Patent Publication No. 9429/1981) and a method of ejecting ink droplets by the mechanical pressure due to a volume change caused by the strain of a piezoelectric element (disclosed in Japanese Patent Publication No. 12138/1978).

[0003] In the case of the above two methods, because an ejection quantity of ink droplets to each recording dot on a recording medium is constant, a pseudo gradational expression is performed by spatially changing densities of recording dots in color-image printing. In the case of the gradational expression method, however, it is difficult to print a high-gradation color image same as a photo. To print a higher-gradation image, a gradational expression according to the so-called area modulation of changing recording-dot areas is necessary. In the case of the above two methods, however, because an ejection quantity of ink droplets is constant, the gradational expression according to the area modulation is very difficult.

[0004] As a recording method for solving the above problems, a method has been developed which applies a voltage to a plurality of electrodes arranged in parallel on a substrate and ejects ink or color-agent particles in the ink by using an electrostatic force. Specifically, Japanese Patent Laid-Open No. 4467/1981 discloses a method of ejecting ink by an electrostatic attraction, and Japanese Patent Official Announcement No. 502218/1995 discloses a method of ejecting the ink containing electrified color-agent particles by raising the concentration of the color-agent particles.

[0005] In the case of these methods, Fig. 24 shows an ink ejection timing. For example, when a bias voltage of approx. 2 kV is applied to ejected ink, pulses of approx. 500 V are superimposed on the ink ejection electrode 3 concerned. In this case, it is known that the area of a recording dot formed on a recording medium is controlled.

[DISCLOSURE OF THE INVENTION]

[0006] To apply gradation control to dots to be printed while data is printed, a method is conventionally used in which an ejection quantity of ink is controlled by modulating the width of a pulse voltage to be applied to an ink ejection electrode (pulse width modulation). In the case of this method, however, when a pulse width is small as the case of high-speed printing, a response delay occurs in the behavior of ink due to the viscosity of the ink and therefore, it is necessary to correct the response delay in the gradation control according to pulse width modulation. When occasion demands, a problem occurs that ink does not response to a pulse voltage and a dot is not printed on a position to be printed. Moreover, in the case of the conventional method, a state in which color-agent particles are cohered at the front end of an ink ejection electrode is kept by applying a DC bias voltage to the ink ejection electrode as shown in Fig. 24. In this case, however, because color-agent particles are continuously collected on the front end of the ink ejection electrode if a constant voltage is continuously applied, the color-agent particles may be easily fixed to the front end of the ink ejection electrode and thereby, ejection of ink may become unstable or a voltage for ejection may be fluctuated. As a result, a problem occurs that the reliability of an ink-jet recording head is deteriorated.

[0007] The present invention is made to solve the above problems and its object is to realize high-reliability dot gradation simpler than ever and prevent the reliability of an ink-jet recording head from deteriorating due to fixation of color-agent particles at the front end of an ink ejection electrode.

[0008] To achieve the above object, the present invention comprises a circulation section for circulating the ink obtained by impregnating a solvent with a color agent, a head section having an ink channel serving as a part of the circulation system and at least one ejection electrode for cohering the color agent in the ink channel and electrostatically flying ink, and a driving section for applying a voltage to the ejection electrode to fly the ink and controlling the voltage to be applied, wherein the driving section performs dot gradation control before ejecting the ink.

[0009] The above configuration makes it possible to previously cohere a necessary quantity of color-agent particles by using a process for cohering and flying color-agent particles and thereby, performing dot gradation control while color-agent particles are cohered immediately before ink is ejected instead of the time when the ink is ejected, easily realize dot gradation, and realize stable printing.

[0010] Moreover, it is possible to equalize color-agent-particle timings at printing positions in one line by constituting a logical circuit for controlling printing so as to synchronize with ink ejection at the rear end of a printing cycle. As a result, it is possible to suppress a shift of an impact position when the diameter of a dot to be printed depends on a printing position.

[0011] Moreover, by using a configuration of ejecting ink and thereafter applying a voltage opposite to an ink ejection voltage, color-agent particles cohered at the front end of an ejection electrode are dispersed, an ink concentration is lowered, and the color-agent particles can be prevented from fixing. Moreover, because fixation of the color-agent particles can be prevented, it is possible to provide a high-reliability ink-jet recorder.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0012] Fig. 1 is an illustration showing an embodiment of timing of a voltage applied to an ejection electrode of an ink-jet recorder of the present invention.

[0013] Fig. 2 is an illustration showing a calculation result of an electric field distribution nearby the front end of an ink ejection electrode in terms of vectors.

[0014] Fig. 3 is an illustration for explaining the threshold of the number of particles when an aggregate is ejected.

[0015] Fig. 4 is a schematic illustration showing a force working when color-agent particles are cohered.

[0016] Fig. 5 is an illustration showing the relation between the number of cohered color-agent particles on one hand and an electrostatic repulsion and a surface tension working on an aggregate on the other.

[0017] Fig. 6 is an illustration showing the relation between the threshold of the number of particles and the number of cohered particles at a voltage when an aggregate is ejected.

[0018] Fig. 7 is an illustration showing the relation between the threshold of the number of particles and the number of cohered particles at a voltage when an aggregate is ejected.

[0019] Fig. 8 is an illustration showing the relation between the threshold of the number of particles and the number of cohered particles at a voltage when an aggregate is ejected.

[0020] Fig. 9 is an illustration showing the relation between an ejection preparation time and a quantity of cohered color-agent particles in the present invention.

[0021] Fig. 10 is an illustration showing the relation between an ejection preparation time and a quantity of cohered color-agent particles in the present invention.

[0022] Fig. 11 is an illustration showing an embodiment of an ink-jet recorder comprising the present invention.

[0023] Fig. 12 an illustration showing an embodiment of an ink-jet recording head comprising the present invention.

[0024] Fig. 13 is an illustration showing an embodiment of a logic circuit for applied-voltage timing control of an ink-jet recorder comprising the present invention.

[0025] Fig. 14 is an illustration showing an embodiment of a flowchart of the logic circuit in Fig. 13.

[0026] Fig. 15 is an illustration showing another embodiment of the flowchart of the logic circuit in Fig. 13.

[0027] Fig. 16 is an illustration showing an embodiment of a high-voltage circuit of an ink-jet recorder comprising the present invention.

[0028] Figs. 17(a) and 17(b) are illustrations for explaining applied-voltage timing and a dot pattern when performing solid printing in the present invention.

[0029] Fig. 18 is an illustration showing another embodiment of the timing of a voltage applied to an ejection electrode of an ink-jet recorder comprising the present invention.

[0030] Fig. 19 is an illustration showing an embodiment of the logic circuit in Fig. 18.

[0031] Fig. 20 is an illustration showing another embodiment of the logic circuit in Fig. 18.

[0032] Fig. 21 is an illustration showing another embodiment of the timing of a voltage applied to an ejection electrode of an ink-jet recorder comprising the present invention.

[0033] Fig. 22 is an illustration showing an embodiment of the logic circuit in Fig. 21.

[0034] Fig. 23 is an illustration showing another embodiment of a high-voltage circuit of an ink-jet recorder comprising the present invention.

[0035] Fig. 24 is an illustration for explaining the timing of a voltage applied to an ejection electrode of a conventional ink-jet recorder.

[BEST MODE FOR CARRYING OUT THE INVENTION]

[0036] Embodiments of the present invention are specifically described below by referring to the accompanying drawings.

[0037] A color-agent-particle-flying mechanism of an ink-jet recorder is described below in detail. First, Fig. 2 is an illustration showing an electric field 17 generated at the front end of an electrode by arrow directions and their magnifications when applying a potential to an ink ejection electrode 3 in the air. When an aggregate of color-agent particles respectively having a radius R is put at the front end of the ink ejection electrode 3, the aggregate is about to fly by breaking the surface of an ink solvent in accordance with the electric field 17 nearby the front end of the ink ejection electrode 3. In this case, a flight force F_e is proportional to the electric field 17 and the electric charge of the aggregate of color-agent particles and shown by the following expression.

$$F_e = QE$$

[0038] In this case, Q denotes the electric charge E of the aggregate of color-agent particles and E denotes the electric field at the position of the aggregate. The force F_s for preventing the flight of the aggregate is a force for pulling the aggregate of color-agent particles toward the electrode by the surface tension of the ink solvent. The force F_s is proportional to the surface tension of the ink solvent and the circumference of a cohered-ball particle. That is, the expression $F_s = v \times 2\pi R$ is effectuated. In this case, v denotes the surface tension of the ink solvent and R denotes the radius of a cohered particle. The electric charge Q of the aggregate of color-agent particles is proportional to the number of color-agent particles n and an electric charge q and shown by the following expression.

$$Q = n \times q$$

[0039] Moreover, the following expression is effectuated between the volume of cohered color-agent particles and the number of color-agent particles.

$$\alpha \frac{4}{3} \pi \times R^3 = n \frac{4}{3} \pi \times R^3$$

[0040] In this case, α denotes a filling factor. When packing a maximum number of balls having a constant radius into a box, the rate of the volume occupied by the balls becomes 74% and the filling factor becomes 0.74. R denotes the radius of an aggregate, r denotes the radius of a color-agent particle, and n denotes the number of cohered color-agent particles. In accordance with the above expression, the radius R of the aggregate 71 of color-agent particles becomes a function of the number of cohered color-agent particles and is shown by the following expression.

$$R = \left(\frac{n}{\alpha}\right)^{\frac{1}{3}} \times r$$

[0041] When expressing F_e and F_s by using the above expression, the following expressions (1) are obtained.

$$\begin{cases} F_e = nqE \\ F_s = v 2\pi r \left(\frac{n}{\alpha}\right)^{\frac{1}{3}} \end{cases} \quad \text{..................... (Expressions 1)}$$

[0042] Fig. 3 is obtained by substituting physical conditions of an ink-jet recorder used, that is, the average radius r and electric charge q of color-agent particles and the surface tension of an ink solvent for the above expressions (1) and using a result of calculating the electric field 17 in accordance with an applied potential at the position of the aggregate of color-agent particles and thereby plotting the logarithm of the number of cohered color-agent particles on y-axis and both forces on x-axis. In Fig. 3, magnitudes of the force F_e for flying particles and the force F_s for preventing the particles from flying are inverted at login'. In this case, an aggregate in which n' color-agent particles 7 are cohered flies by breaking the surface of ink.

[0043] An electric field also contributes to cohesion of color-agent particles. Fig. 4 is an illustration showing the aggregate 71 of color-agent particles and the ink ejection electrode 3 by enlarging the space between the aggregate 71 and the electrode 3.

[0044] In Fig. 4, forces due to electric fields of both the ink ejection electrode 3 and the aggregate 71 work on the color-agent particle 7 nearby the aggregate 71. In this case, the force f_e due to the ink ejection electrode 3 is expressed as $f_e = qE$ in which E denotes an electric field at the position of the color-agent particle 7 and q denotes the electric charge of one color-agent particle.

[0045] Moreover, the force f_c due to the aggregate 71 is shown by the following expression.

$$f_c = \frac{1}{4\pi\varepsilon}\frac{qQ}{(R + d)^2}$$

[0046] In the above expression, Q denotes the charge of an aggregate, q denotes the change of one color-agent particle, R denotes the radius of the aggregate, d denotes the distance between the aggregate and a color-agent particle, and ε denotes the permittivity of an ink solvent. For the aggregate 71 to grow, a state must be satisfied in which the color-agent particle 7 most approaches, that is, in the case of d=0 and $f_c < f_e$ at a certain size R' of the aggregate 71. In the case of d=0 and $f_c = f_e$, the growth of the aggregate 71 stops. The number of color-agent particles 7 constituting the largest aggregate of color-agent particles when E is decided is shown as the following expression (2).

[0047] The size n of the largest aggregate is shown by the following expression (2) in accordance with the condition of $f_c = f_e \Rightarrow qE = \frac{1}{4\pi\varepsilon}\frac{qQ}{R^2}$

$$n = \frac{(4\pi\varepsilon E)^3}{\alpha r^6} \qquad \text{(Expression 2)}$$

[0048] When a potential V_1 is applied to the ink ejection electrode 3 and an electric field E_1 is generated nearby the front end of the electrode 3, the number of color-agent particles n_1 in the aggregate 71 is decided by the expression 2. Under the above condition, Fig. 5 is obtained by writing a flight condition similarly to Fig. 3 in accordance with the expression 1. Fig. 6 is obtained by indicating n_1 obtained from the expression 2 in Fig. 5. From Fig. 6, it is found that an aggregate 71 having a size n' larger than n_1 is necessary for flight though the size of the aggregate 71 of color-agent particles is only increased up to n_1 in a system. This shows that the aggregate 71 does not fly at the potential V_1 in this system. Therefore, by applying a potential V_2 higher than V_1, an electric field of $E_1 < E_2$ is obtained. In this case, Fig. 7 is obtained by drawing a graph same as that in Fig. 6. In Fig. 7, positions of n' and n_2 are inverted differently from the case of Fig. 6. This represents that the aggregate 71 can be grown up to n_2 in the system but it flies at the size of n' before grown. Moreover, when n becomes equal to nth at a certain applied potential Vth similarly to the case in Fig. 8, the potential is a threshold potential for flight and equal to the Vth in Fig. 1.

[0049] Fig. 11 shows a configuration of a printer using an ink-jet recording head 1 of the present invention. Ink 6 is attracted by a feed pump 11a from an ink tank 10 and supplied to the recording head 1 through an ink circulation path 12a. In this case, the ink 6 is supplied to the channel of the recording head 1 from the ink circulation path 12a and flows through the channel from the upper to lower sides in Fig. 11. When applying a voltage to the ink ejection electrode 3 from a pulse-voltage source 8 in the channel of the ink-jet cording head 1, electrified color-agent particles (not illustrated in Fig. 11) dispersed in the ink 6 are cohered at the front end of the ink ejection electrode 3 due to electrophoresis. When printing data is supplied to a driving circuit 9 together with a trigger for printing from the computer side (not illustrated in Fig. 11), the driving circuit 9 controls the pulse-voltage source 8 so as to apply a voltage for ejecting ink to the ink ejection electrode 3 correspondingly to the printing data. In this case, the cohered color-agent particles are ejected toward a grounded opposite electrode 16 from the front end of the ink ejection electrode 3 due to an electrostatic repulsion and data is printed on a recording medium 15 on the opposite electrode 16. The ink 6 flowing through the channel in the recording head 1 is attracted by a recovery pump 11b, returned to the ink tank 10 through an ink circulation path 12b, and reused for printing.

[0050] Fig. 12 shows an embodiment of the ink-jet recording head 1 of the present invention.

[0051] A multihead having a plurality of ink ejection electrodes 3 is constituted by laminating an insulating electrode substrate 2 on whose either side the ink ejection electrode 3 is formed through a spacer 4. A groove is formed between adjacent electrode substrates 2 by moving the front-end position of the spacer 4 backward from the electrode substrate 2 to use the groove as an ink channel 5. Moreover, the ink-jet recording head 1 is constituted by arranging the ink ejection electrodes 3 on either sides of the insulating electrode substrates 2 in parallel correspondingly to the number of dots for one line in the main scanning direction of printing. The electrode substrates 2 respectively use an insulating member such as glass or ceramics and the ink ejection electrodes 3 are formed through electroless plating or vacuum evaporation. In this case, the front end of each ink ejection electrode 3 is protruded from an end face of each electrode substrate 2 by, for example 100 μm. A guide member 31 is set to both sides of an ink ejection electrode at an interval of, for example, 100 μm. A liquid-level bridge is formed at the front end of each ink ejection electrode 3 because the electrode 3 is held by two guide members 31 so that the electrode front end is securely wet by the ink 6. As shown in Fig. 11, the pulse-voltage source 8 is for ejecting the ink 6 is brought into contact with every ink ejection electrode 3 or individually connected to some of the ink ejection electrodes 3. When a certain dot printing cycle starts, a voltage is applied to the ink ejection electrode 3 for performing printing from the pulse-voltage source 8. In this case, color-agent particles are cohered at the front end of the ink ejection electrode 3 due to an electric field at the front end of the electrode 3 in accordance with the above-described cohesion mechanism. Moreover, an electrostatic repulsion is generated between the color-agent particles cohered at the front end of the ink ejection electrode 3 and the ink ejection electrode 3 due to an electric field and the color-agent particles cohered at the front end of the ink ejection electrode 3 are about to fly toward an opposite electrode. However, an electrostatic repulsion and a surface tension in the direction opposite to the repulsion work on the surface of the ink 6 to prevent the ink from flying. Therefore, the cohered color-agent particles are not ejected as long as the voltage applied to the ink ejection electrode 3 does not exceed a certain threshold voltage Vth.

[0052] Therefore, to cohere color-agent particles, a voltage Vpre lower than the threshold voltage Vth is applied to the pulse-voltage source 8. The voltage Vpre becomes Vb in Fig. 24 in the case of the conventional method. Thereafter, color-agent particles fly toward a recording medium as the aggregate 71 when superposing an ink ejection voltage Vej by supplying a trigger signal to the pulse-voltage source 8 from the driving circuit 9 so that a voltage V_0 higher than the threshold voltage Vth is applied to the ink ejection electrode 3. When printing data with a multihead in which a plurality of ink ejection electrodes are arranged, a trigger signal is supplied to every ink ejection electrode 3 corresponding to the position of a dot to be printed in one line from the driving circuit 9. As a result, cohered color-agent particles are simultaneously independently ejected from the ink ejection electrode 3 connected to every pulse-voltage source 8 to which the trigger signal is supplied and printing is performed. In this case, the quantity of ink to be ejected is controlled by modulating the width tw of a pulse voltage to be applied to an ink ejection electrode under ejection in order to apply gradation control to a dot to be printed.

[0053] In the case of this method, however, when a pulse width is small, a response delay occurs in the behavior of ink due to its viscosity and thereby, it is difficult to perform gradation control according to pulse-width modulation. When occasion demands, ink does not respond to a pulse voltage and thereby, a dot may not be printed at a position to be printed.

[0054] Moreover, in the case of the conventional method, a DC bias voltage is applied to an ink ejection electrode to keep a state in which color-agent particles are cohered at the front end of the ink ejection electrode. In this case, however, because color-agent particles are continuously collected on the front end of an ink ejection electrode if a constant voltage is continuously applied, the probability that color-agent particles are fixed to the front end of the electrode rises and ejection of ink may become unstable or a voltage for ejection may be fluctuated.

[0055] As a result, a problem occurs that the reliability of an ink-jet recording head is deteriorated.

[0056] A printing operation procedure in the present invention is explained below by referring to Figs. 1 and 3 to describe features of the present invention. A ejection preparation voltage Vpre is applied in accordance with an operation clock when the printing cycle of each dot starts. Electrified color-agent particles dispersed in the ink 6 move toward the front end of the ink ejection electrode 3 along the flow of ink due to circulation. Then, the aggregate 71 is grown in accordance with the above-described cohesion mechanism at the front end of an ink ejection electrode. Because electric charges are accumulated in the aggregate, an electrostatic repulsion works between the aggregate and the ink ejection electrode 3 to which a voltage is applied. Therefore, when the applied voltage becomes higher than a certain threshold voltage Vth, an electrostatic repulsion working on an aggregate of color-agent particles becomes stronger than a surface tension and the aggregate flies toward a recording medium on an opposite electrode from the front end of the ink ejection electrode 3.

[0057] Therefore, after applying the ejection preparation voltage Vpre for a certain time, the aggregate of color-agent particles is ejected by superimposing an ejection voltage Vej so that a voltage applied to the ink ejection electrode 3 becomes higher than the threshold voltage Vth. In this case, by changing the time tpre for applying the ejection preparation voltage, it is possible to change the quantity of color-agent particles to be cohered at the front end of the ink ejection electrode 3. That is, it is possible to control the quantity of cohered color-agent particles required to form dots respectively having a size to be printed on a recording medium.

[0058] Fig. 9 shows the relation between the quantity of cohered color-agent particles and the ejection preparation time corresponding to printing data. The moving speed of color-agent particles when moving in ink in accordance with a circulation flow is kept constant. Therefore, the quantity of color-agent particles to be ejected correspondingly to the printing data is proportional to the ejection preparation time tpre as shown in Fig. 9. Moreover, it is permitted to control the quantity of color-agent particles to be cohered by changing the ejection preparation voltage Vpre. In this case, the relation between the quantity of cohered color-agent particles corresponding to the printing data and the ejection preparation time Vpre is shown in Fig. 10. In this case, an electric field at the front end of the ink ejection electrode 3 is proportional to the ejection preparation voltage Vpre. Therefore, according to the above cohesion mechanism, the quantity of cohered color-agent particles is proportional to the ejection preparation voltage Vpre for a certain ejection preparation time tpre. Moreover, to print a solid image, it is necessary to turn off a voltage to be applied to the ink ejection electrode 3 when dot printing is completed at the voltage V_0.

[0059] However, to prevent a gap from being formed between adjacent printing dots, it is necessary to perform printing with a dot diameter larger than a dot pitch (approx. 42 µm in the case of, for example, 600 dpi){refer to Fig. 17 (b)}. Therefore, a voltage is lowered up to the ejection preparation voltage Vpre when ejection of each dot is completed to cohere color-agent particles necessary for the next printing. This printing cycle corresponds to a cycle every line in the subscanning direction in the case of a line head. For example, when printing data in an A4-size sheet at a printing rate of one page/min, approx. 7,000 lines are printed for one min. Therefore, the time interval between lines becomes approx. 60(s)/7,000(lines) ≒8.5(ms/line). However, the ink-flow speed at the front end of an ink ejection electrode is estimated as approx. 10 cm/s as a result of observation in an experiment. Therefore, the time necessary for a color-agent particle to move to the front end of an electrode protruded by 100 µm is 1 ms and thus, it is possible enough to cohere color-agent particles in a printing cycle.

[0060] Fig. 13 is a block diagram showing a configuration of a logic circuit in the driving circuit 9 for controlling application of a voltage to the ink ejection electrode 3 for a method of controlling the quantity of cohered color-agent particles by changing the above ejection preparation time tpre. Moreover, Fig. 14 is a flowchart showing a flow of the control in the logic circuit. In Fig. 14, tcond denotes the time for applying the ejection preparation voltage Vpre, td denotes the delay time of the voltage V_0 from the ejection preparation voltage Vpre when ink is ejected, and tw denotes the time in which the voltage V_0 is applied. In Fig. 14, the ejection preparation time tpre is equal to the delay time td and the relation of tcond = td + tw is effectuated. In Fig. 13, image data is the print data at each printing position sent from a controller (not illustrated in Fig. 14). A reset signal in Fig. 14 serves as a trigger signal for the printing operation at each printing position. Moreover, a clock signal is an operation clock signal for synchronizing operations of circuits each other in printing cycles. When the image data is sent to the driving circuit 9 from the controller, a reset signal is simultaneously output from the controller to start the printing operation. First, the image data is input to data conversion tables 18a to 18c in parallel. the data conversion table 18a stores a conversion table for the width of a pulse voltage when ink is ejected, that is, the time in which the voltage V_0 is applied in Fig. 1. The image data A generated in the data conversion table 18a is input to a counter 19a. In this case, the counter 19a counts the number of clock signals corresponding to the image data A and an enabling signal A for controlling application of a pulse voltage is output when counting is carried out. The data conversion table 18b stores a conversion table for generating image data D to be input to a counter 19b. The image data D is used as the delay data for the counter 19a. When the image data D is input to the counter 19b, clock signals corresponding to the image data D are counted. When counting of clock signals is completed, a reset signal is output from the counter 19b to the counter 19a. The counter 19a receives the reset signal as a trigger and starts the operation for outputting the enabling signal A. Moreover, the data conversion table 18c stores a conversion table for deciding the time for outputting the ejection preparation voltage Vpre for cohering color-agent particles required to print dots corresponding to image data. Image data B output from the data conversion table 18c is input to the counter 19c. The counter 19c counts the number of clock signals corresponding to the image data B and continuously outputs enabling signals B for outputting the ejection preparation voltage Vpre only while the clock signals are counted.

[0061] Moreover, though enabling signals for cohesion and ejection are independently controlled in Fig. 14, it is also permitted to constitute a circuit for synchronizing the cohesion-enabling signal turn-off operation with the ejection-enabling signal turn-off operation as shown by the flowchart in Fig. 15. In this case, the cohesion data-conversion table 18c in Fig. 13 is unnecessary and thereby, it is possible to decrease the number of parts constituting a logic circuit.

[0062] Fig. 16 is an illustration showing a configuration of a high-voltage circuit for outputting a pulse voltage to the ink ejection electrode 3 by using a signal output from the logic circuit shown in Fig. 13. An SW circuit 20 is a circuit for switching a high voltage. A bias-voltage source 21 is a power supply for supplying a bias voltage for driving the SW circuit 20. A pulse-voltage source 8a is a power supply for supplying the ink ejection voltage Vej to the SW circuit 20. A pulse-voltage source 8b is a power supply for supplying the ejection preparation voltage Pre to the SW circuit 20. When a reset signal is output from a certain printing position and the printing-operation cycle starts, an enabling signal B is output through the counter 19c in Fig. 13. When the SW circuit 20 receives the enabling signal B, the input at the pulse power-supply B opens and the ejection preparation voltage Vpre is supplied to an pulse-voltage output. Then, the pulse voltage output is applied to the ink ejection electrode 3. In this case, the enabling signal A is not output for a delay time decided by the data conversion table 18b after a printing cycle starts because a delay is applied to the counter 19a shown in Fig. 13 by the counter 19b. That is, the delay time serves as the ejection preparation time tpre. Thereafter, when the counter 19a receives an output from the counter 19b as a reset signal, the enabling signal A is output.

[0063] When the SW circuit 20 receives the enabling signal A, the input at the pulse-voltage source 8a opens the ink ejection voltage Vej is superimposed on a pulse voltage output. As a result, the voltage V_0 higher than the threshold voltage Vth is applied to the ink ejection electrode 3 and ink is ejected and printing is performed. Moreover, in the case of the method of changing the ejection preparation voltage Vpre, it is permitted to add a control circuit for changing a voltage to be output to the SW circuit 20 to the pulse voltage sources 8a and 8b in accordance with image data in the circuit configuration in Fig. 16.

[0064] As described above, by using this embodiment and thereby cohering only a necessary quantity of color-agent particles immediately before ejecting ink, it is possible to control dot gradation more easily than ever. Moreover, a problem that it is impossible to follow a short pulse is eliminated and stable printing can be realize compared to the case of modulating a pulse width when ink is ejected. Furthermore, by turning off a voltage after ejecting ink, color-agent particles remaining at the front end of an ink ejection electrode are removed by the flow of ink. Therefore, it is possible to prevent color-agent particles from fixing to the front end of the ink ejection electrode and improve the reliability of an ink-jet recording-head system. Moreover, by executing this embodiment in a multihead and thereby correcting the difference between cohesion quantities due to the fluctuation of shapes of ejection electrodes, it is possible to suppress the fluctuation of dot diameters to be printed.

[0065] Then, second embodiment of the present invention is described below. Fig. 18 is an illustration showing the timing for applying a voltage to an ink ejection electrode relating to the second embodiment. This embodiment also uses a method for controlling the voltage-application timing so as to cohere color-agent particles at the front end of an ink ejection electrode 3 by applying an ejection preparation voltage Vpre for an ejection preparation time tpre before applying a voltage V_0 for ejecting ink to the ink ejection electrode 3. Except a special case such as slid printing, it is overwhelmingly frequent that printing-dot diameters are different from each other in one line. In the case of a method of synchronizing the timing in which application of the ejection preparation voltage Vpre to the ink ejection electrode 3 is started with the start of the printing cycle, the ejection preparation time tpre depends on a dot diameter to be printed. Therefore, color-agent-particle ejection timings are shifted from each other between printing positions having different dot diameters in the same line. In this case, because a recording medium moves by an interval between lines from printing of a certain line up to printing of the next line, a shift of an impact position may occur between printing positions by a value corresponding to a shift of the timing of color-agent-particle ejection at each printing position. Particularly in the case of high-speed printing, the above positional shift increases and the printing quality may be deteriorated.

[0066] Therefore, in the case of this embodiment, the color-agent-particle ejection timing is adjusted by synchronizing the voltage-application timing with the completion of a printing cycle instead of starting application of a voltage to the ink ejection electrode by synchronizing the voltage application with the start of the printing cycle as the case of the first embodiment.

[0067] Fig. 19 is an illustration showing a configuration of the logic circuit for controlling the voltage application timing shown in Fig. 18. Definitions of image data, a clock signal, and a reset signal are the same as the case of Fig. 13. Moreover, a circuit indicated with NOT is an inverting circuit. When a reset signal indicating the start of a printing cycle is output from a controller (not illustrated in Fig. 19) to the logic circuit in Fig. 19, image data is input to data conversion tables 18a and 18b in parallel. In this case, the data conversion table 18a stores a conversion table for outputting the data corresponding to the time in which an ink ejection voltage Vej is not applied in a printing cycle corresponding to the image data. When image data A serving as the data corresponding to the time in which the ink ejection voltage Vej during the printing cycle is not applied from the data conversion table 18a is input to a counter 19a, the counter 19a counts the number of clock signals corresponding to the image data A. While the counting operation is performed, High-level TTL signals are output from the counter 19a. However, because an output of the counter 19a is inverted by the inverting circuit, the enabling signal A is not output. That is, the enabling signal A is not output only for the time in which the ink ejection voltage Vej is not applied in a printing cycle after the printing cycle is started. Moreover, when the counting operation of the counter 19a is completed, an output of the counter 19a changes from High-level to Low-level TTL signals and the signal is inverted by the inverting circuit. Therefore, an output for applying the ink ejection voltage Vej is output in the remaining time of the printing cycle. Moreover, the data conversion table 18b stores a conversion table for outputting the data corresponding to the time in which the ejection preparation voltage Vpre is not applied during the printing cycle correspondingly to image data. When image data B is input to the counter 19b as the data corresponding to the time in which the ejection preparation voltage Vpre is not applied during the printing cycle from the data conversion table 18b, the counter 19b counts the number of clock signals corresponding to the image data B.

[0068] While the above counting operation is performed, High-level TTL signals are output from the counter 19b. However, because outputs of the counter 19b are inverted by the inverting circuit, an enabling signal B is not output. That is, the enabling signal B is not output only for the time in which the ejection preparation voltage Vpre is not applied during the printing cycle after start of the printing cycle. Then, when the counting operation of the counter 19b is completed, an output of the counter 19b changes from High-level to Low-level TTL signals and the signal is inverted by the inverting circuit. Thus, the enabling signal B is output. Therefore, an output for applying the ejection preparation voltage Vpre is output in the remaining time of the printing cycle.

[0069] Fig. 20 shows another configuration of the logic circuit for controlling the timing for applying a voltage to the ink ejection electrode 3 in this embodiment. Differently from the case of the logic circuit in Fig. 19, the data conversion table 18a in Fig. 20 stores a conversion table for outputting the data corresponding to the time for applying the ink ejection voltage Vej during the printing cycle correspondingly to image data. Constant data values 23a and 23b respectively include the number of operation clocks in one printing cycle. An output of the data conversion table 18a and the constant data 23a are input to a difference circuit 22a and the difference between the output and the data 23a is output. That is, the number of clocks corresponding to the time in which the ink ejection voltage Vej is not applied during the printing cycle is input to the counter 19a as the image data A. The counter 19a counts the number of clocks corresponding to the image data A. While the counting operation is performed, High-level TTL signals are output from the counter 19a. However, because the signals are inverted by the inverting circuit (NOT), the enabling signal A is not output. This represents that the enabling signal A is not output only for the time in which the ink ejection voltage Vej is not applied during the printing cycle after start of the printing cycle. Moreover, the data conversion table 18b stores a conversion table for outputting the data corresponding to the time for applying the ejection preparation voltage Vpre during the printing cycle correspondingly to image data. An output of the data conversion table 18b and the constant data 23b are input to the difference circuit 22b and the difference between the output and the data 23b is output. That is, the number of clocks corresponding to the time in which the ejection preparation voltage Vpre is not applied during the printing cycle is input to the counter 19b as the image data B. The counter 19b counts the number of clocks corresponding to the image data B. While the counting operation is performed, High-level TTL signals are output from the counter 19b. However, the signals are inverted by the inverting circuit (NOT), the enabling signal B is not output. This represents that the enabling signal B is not output only for the time in which the ejection preparation voltage Vpre is not output during the printing cycle after start of the printing cycle.

[0070] In the case of this embodiment, it is possible to use a configuration same as that in Fig. 16 for the high-voltage circuit for applying a voltage to the ink ejection electrode 3 by using the logic circuit in Fig. 19 or 20. By controlling the timing of a voltage to be applied to the ink ejection electrode 3 in accordance with the configuration of the above logic circuit, it is possible to synchronize with ink ejection at the rear end of the printing cycle.

[0071] Thus, by executing this embodiment and thereby cohering only a necessary quantity of color-agent particles immediately before ejecting ink, it is possible to control dot gradation more easily than ever. Moreover, the problem that it is impossible to follow a short pulse is eliminated and more stable printing can be realized compared to the case of modulating a pulse width when ink is ejected. Furthermore, by turning off a voltage after ejecting ink, color-agent particles remaining at the front end of an ink ejection electrode are removed by the flow of ink. Therefore, it is possible to prevent color-agent particles from fixing to the front end of the ink ejection electrode and improve the reliability of an ink-jet recording-head system. Moreover, by executing this embodiment in a multihead and thereby, correcting the difference between cohesion quantities due to the fluctuation of shapes of ink ejection electrodes, it is possible to suppress the fluctuation of dot diameters to be printed. Furthermore, by constituting a logic circuit for controlling the printing operation so as to synchronize with ink ejection at the rear end of the printing cycle, it is possible to properly arrange color-agent-particle ejection timings at printing positions in one line. As a result, it is possible to suppress a shift of a dot impact position between printing positions in which diameters of dots to be printed are different from each other.

[0072] Then, third embodiment of the present invention is described below. Fig. 21 is an illustration showing the timing of a voltage to be applied to an ink ejection electrode of this embodiment. This embodiment uses a method of controlling the voltage application timing so as to cohere color-agent particles at the front end of the ink ejection electrode 3 by previously applying an ejection preparation voltage Vpre only for an ejection preparation time tpre before applying a voltage V_0 for ejecting ink to the ink ejection electrode 3 similarly to the case of the first embodiment. In the case of this embodiment, however, a voltage Vdisp lower than 0 V to lower an ink concentration by dispersing remaining color-agent particles once cohered at the front end of the ink ejection electrode 3 into an organic solvent again is applied to the ink ejection electrode 3.

[0073] Behaviors of color-agent particles in one printing cycle in this embodiment are described below. When the printing cycle starts, the ejection preparation voltage Vpre is applied to the ink ejection electrode 3, cohesion of color-agent particles in ink 6 is started toward the front end of the ink ejection electrode 3, and formation of an aggregate is started at the front end of the ink ejection electrode 3. When the ejection preparation time tpre elapses after start of the printing cycle, an ink ejection voltage Vej is superimposed on the ink ejection electrode 3 only for a time tw and the aggregate at the front end of the ink ejection electrode 3 flies toward a recording medium on an opposite electrode by overcoming the surface tension of the ink 6 by electrostatic repulsion. In this case, even after the aggregate is ejected, color-agent particles being currently cohered remain nearby the front end of the ink ejection electrode 3. Therefore, an electric field in the opposite direction to the case in which color-agent particles are cohered is generated by superimposing the ink ejection voltage Vej only for the time tw and thereafter applying the voltage Vdisp lower than 0 V. Color-agent particles are dispersed in the organic solvent by the electric field to lower the concentration of color-agent particles in the ink.

[0074] Fig. 22 is an illustration showing a configuration of a logic circuit for controlling the timing of a voltage to be applied to the ink ejection electrode 3 of this embodiment. In Fig. 22, definitions of image data, a clock signal, and a reset signal are the same as those in Fig. 13. When image data is sent to a driving circuit 9 from a controller (not illustrated), a reset signal is simultaneously output from the controller to start the printing operation. First, the image data is input to data conversion tables 18a to 18e in parallel. The data conversion table 18a stores a conversion table for the time in which the ink ejection voltage Vej is applied during the printing cycle correspondingly to the image data. Image data A generated in the data conversion table 18a is input to a counter 19a. In this case, the counter 19a counts the number of clock signals corresponding to the image data A and an enabling signal A for controlling application of a pulse voltage is output only while counting is performed. The data conversion table 18b stores a conversion table for generating image data D_1 to be input to a counter 19b. The image data D_1 is used as delay data for the counter 19a. When the image data D_1 is input to the counter 19b, clock signals corresponding to the image data D_1 are counted. When counting of the clock signals is completed, a reset signal is output to the counter 19a from the counter 19b. The counter 19a receives the reset signal as a trigger to start the operation for outputting the enabling signal A. Moreover, a data conversion table 18c stores a conversion table for deciding the time for outputting the ejection preparation voltage Vpre for cohering color-agent particles required to print dots corresponding to image data. Image data B output from the data conversion table 18c is input to a counter 19c. The counter 19c counts clock signals corresponding to the image data B and continuously outputs the enabling signal B for outputting the ejection preparation voltage Vpre while the above operation is performed. Moreover, a data conversion table 18d stores a conversion table for the time in which the voltage Vdisp for dispersing color-agent particles is applied during the printing cycle. Image data C generated in the data conversion table 18d is input to a counter 19d. In this case, the counter 19d counts the number of clock signals corresponding to the image data C and an enabling signal C for controlling application of a pulse voltage is output only while counting is performed. A data conversion table 18e stores a conversion table for generating image data D_2 to be input to the counter 19b. The image data D_2 is used as delay data for the counter 19d. When the image data D_2 is input to a counter 19e, clock signals corresponding to the image data D_2 are counted. When counting of clock signals is completed, a reset signal is output to the counter 19d from the counter 19e. The counter 19d receives the reset signal as a trigger and starts the operation for outputting the enabling signal C.

[0075] Fig. 23 is an illustration showing a configuration of a high-voltage circuit for outputting a pulse voltage to the ink ejection electrode 3 by using a signal output from the logic circuit shown in Fig. 22. In this case, definitions of an SW circuit 20, a bias-voltage source 21, and pulse-voltage sources 8a and 8b are the same as those of Fig. 16. Moreover, a pulse-voltage source 8c is a power supply for supplying a voltage for dispersing color-agent particles. When a reset signal is output at a certain printing position and the printing-operation cycle starts, he enabling signal B is output through the counter 19c in Fig. 22. When the SW circuit 20 receives the enabling signal B, the input at the pulse-voltage source 8b opens and the ejection preparation voltage Vpre is supplied to a pulse-voltage output. Then, the pulse-voltage output is applied to the ink ejection electrode 3.

[0076] In this case, because a delay is applied to the counter 19a illustrated in Fig. 22 by the counter 19b, the enabling signal A is not output only during the delay time decided by the data conversion table 18b after start of the printing cycle. That is, the delay time serves as the ejection preparation time tpre. Thereafter, when the counter 19a receives an output from the counter 19b as a reset signal, the enabling signal A is output. When the SW circuit 20 receives the enabling signal A, the input at the pulse-voltage source 8a opens and the ink ejection voltage Vej is superimposed on a pulse-voltage output.

[0077] As a result, the voltage V_0 higher than the threshold voltage Vth is applied to the ink ejection electrode 3, ink is ejected, and printing is performed. In this case, because counting operations by the counters 19a and 19b are completed, the enabling signals A and B are turned off. As a result, outputs at the pulse-voltage sources 8a and 8b are closed and supply of the ejection preparation voltage Vpre and ink ejection voltage Vej to the pulse output of the SW circuit 20 is stopped. In this case, a reset signal is simultaneously input to the counter 19d to which a delay has been applied by the counter 19e in Fig. 22, the counting operation starts, and the enabling signal C is output to the SW circuit 20.

[0078] When the SW circuit 20 receives the enabling signal C, the input at the pulse-voltage source 8c opens and the voltage Vdisp for dispersing color-agent particles is output to the pulse-voltage output of the SW circuit 20 and applied to the ink ejection electrode 3. The voltage Vdisp is continuously output while the counter 19d operates. After the operation of the counter 19d is completed, the input at the pulse-voltage source 8c is closed, supply of a voltage to the SW circuit 20 stops, and a voltage to be applied to the ink ejection electrode 3 becomes 0 V until the next printing cycle starts. The configuration of the above logic circuit makes it possible to control the timing of a voltage to be applied to the ink ejection electrode 3 of this embodiment.

[0079] Thus, by executing this embodiment and thereby, cohering necessary color-agent particles immediately before ejecting ink, it is possible to control dot gradation more easily than ever. Moreover, a problem that it is impossible to follow a short pulse is eliminated and more stable printing can be realized compared to the case of modulating a pulse width when ink is ejected. Furthermore, by applying a re-dispersing voltage after ejecting ink, color-agent particles remaining at the front end of the ink ejection electrode are removed by the flow of ink and dispersed again into an organic solvent by an electric in the opposite direction to the electric field when color-agent particles are cohered.

Therefore, it is possible to prevent color-agent particles from fixing to the front end of the ink ejection electrode and improve the reliability of an ink-jet recording-head system. Moreover, by executing this embodiment in a multihead and thereby, correcting the difference between cohesion quantities due to the fluctuation of shapes of ink ejection electrodes, it is possible to suppress the fluctuation of dot diameters to be printed.

[INDUSTRIAL APPLICABILITY]

[0080] As described above, an ink-jet recorder of the present invention is useful to record high-accuracy pictures and characters by flying ink, particularly suitable for a color ink-jet printer capable of recording very reliable and minute images.

Claims

1. An ink-jet recorder comprising:

a circulation section for circulating the ink obtained by impregnating a solvent with a color agent;
a head section having an ink channel serving as a part of the circulation system and at least one ejection electrode for cohering the color agent in the ink channel and electrostatically flying the cohered color agent; and
a driving section for applying a voltage to the ejection electrode in order to fly the ink and controlling the applied voltage; characterized in that
the driving section controls dot gradation before ejecting the ink.

2. The ink-jet recorder according to claim 1, characterized in that
the driving section has means for applying an ejection preparation voltage at which at least ink is not ejected and means for applying an ejection voltage at which ink is ejected and controls dot gradation by changing the application time of the ejection preparation voltage or the ejection preparation voltage.

3. The ink-jet recorder according to claim 1, characterized in that
the driving section controls the quantity of the cohered color agent and controls dot gradation.

4. The ink-jet recorder according to claim 1, characterized in that
the timing of a voltage to be applied to the ejection electrode is synchronized at start of the printing cycle of each dot.

5. The ink-jet recorder according to claim 1, characterized in that
the timing of a voltage to be applied to the ejection electrode is synchronized at end of the printing cycle of each dot.

6. An ink-jet recorder comprising:

a circulation section for circulating the ink obtained by adding a color agent to a solvent;
a head section having an ink channel serving as a part of the circulation system and at least one ejection electrode for cohering the color agent in the ink channel and electrostatically flying the cohered color agent; and
a driving section for applying a voltage to the ejection electrode in order to eject the ink and controlling the applied voltage; characterized in that the driving section applies a voltage opposite to an ink ejection voltage after the ink is ejected.

FIG. 1

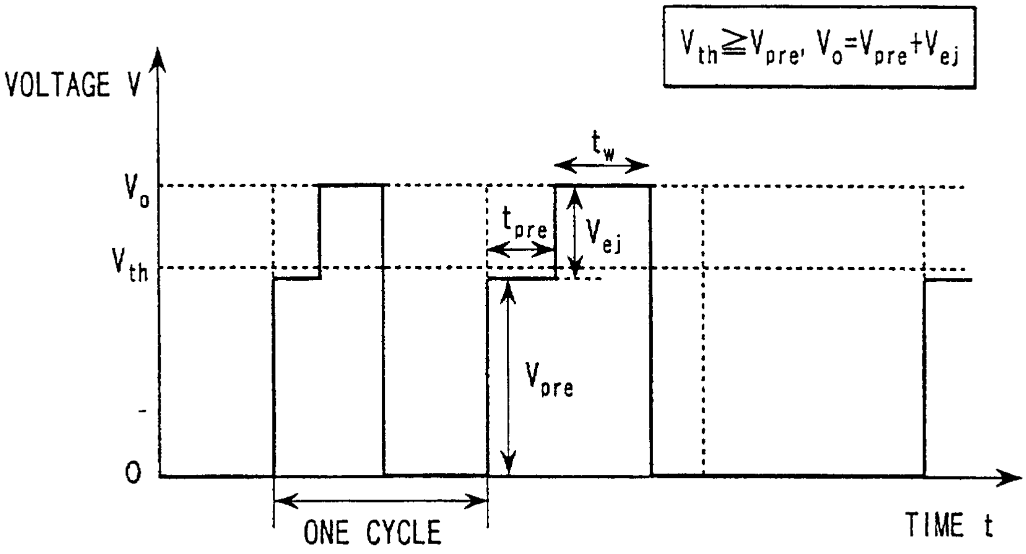

$V_{th} \geqq V_{pre}$, $V_o = V_{pre} + V_{ej}$
VOLTAGE V
t_w
V_o
t_{pre}
V_{ej}
V_{th}
V_{pre}
0
ONE CYCLE
TIME t

FIG. 2

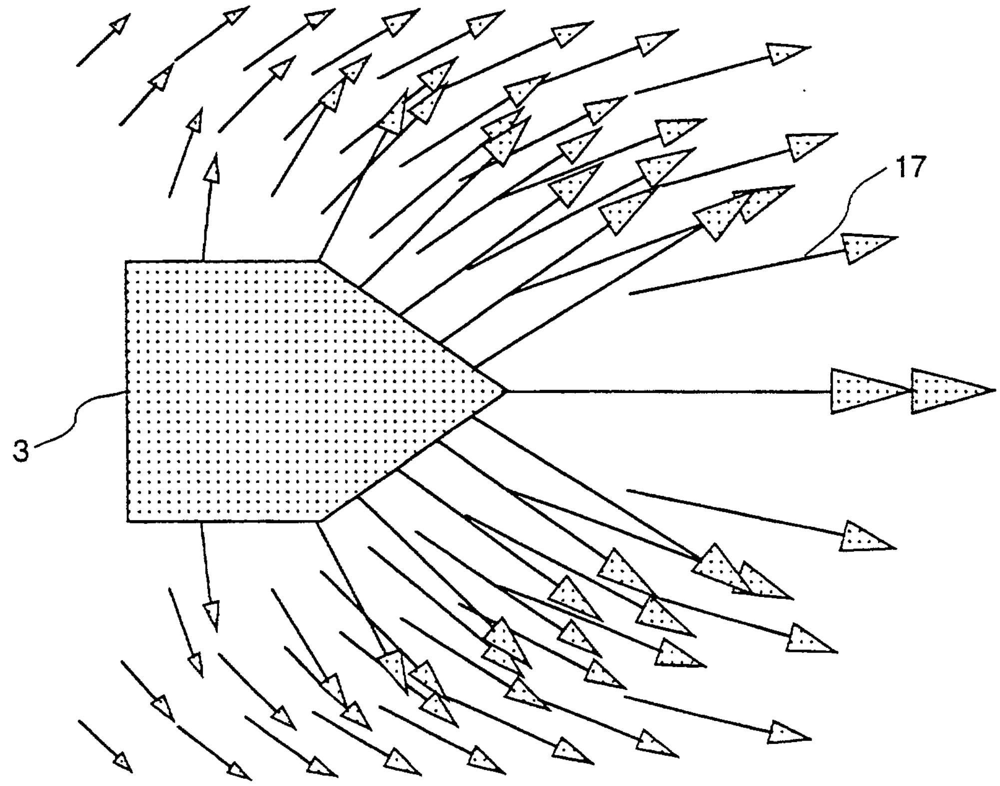

17
3

FIG. 3

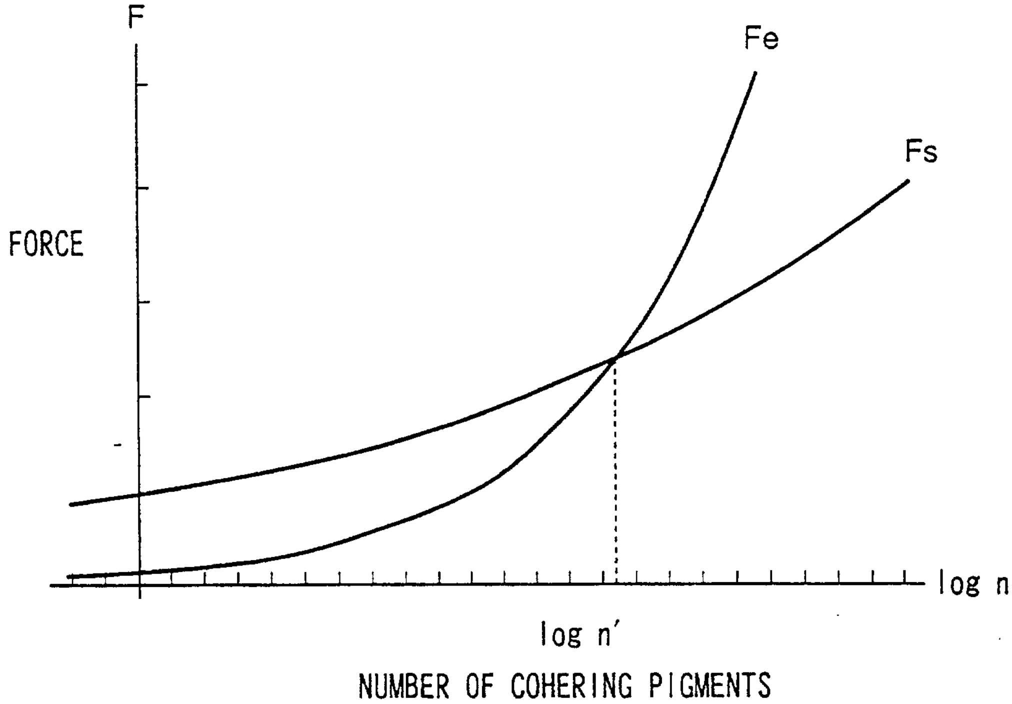

F
Fe
Fs
FORCE
log n
log n'
NUMBER OF COHERING PIGMENTS

FIG. 4

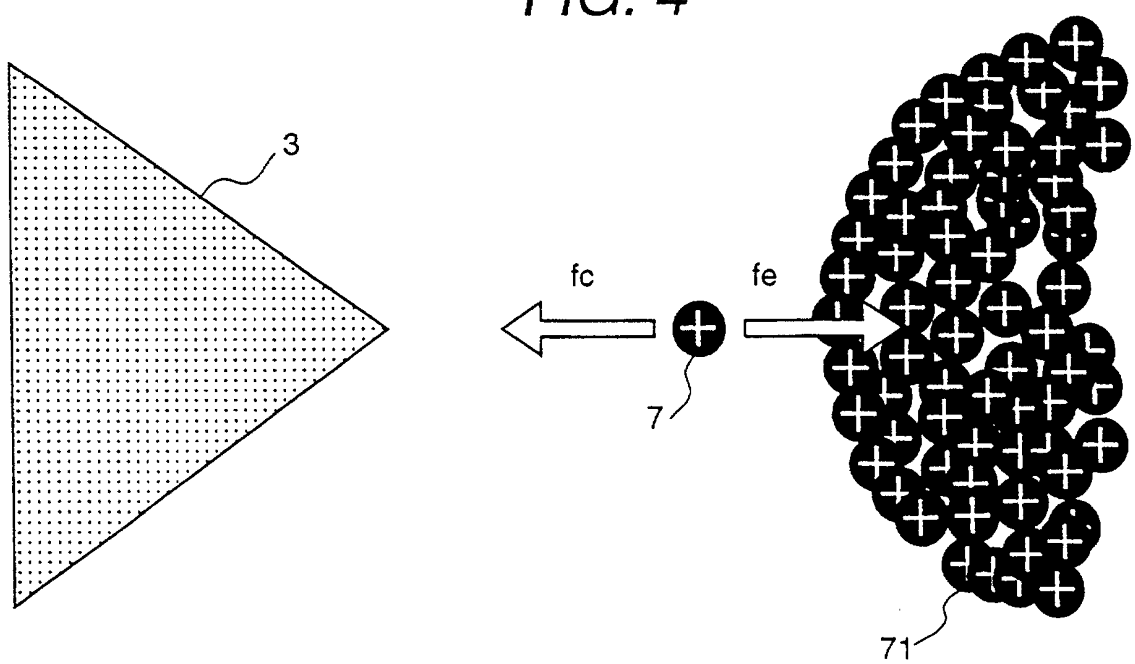

3
fc
fe
7
71

FIG. 5

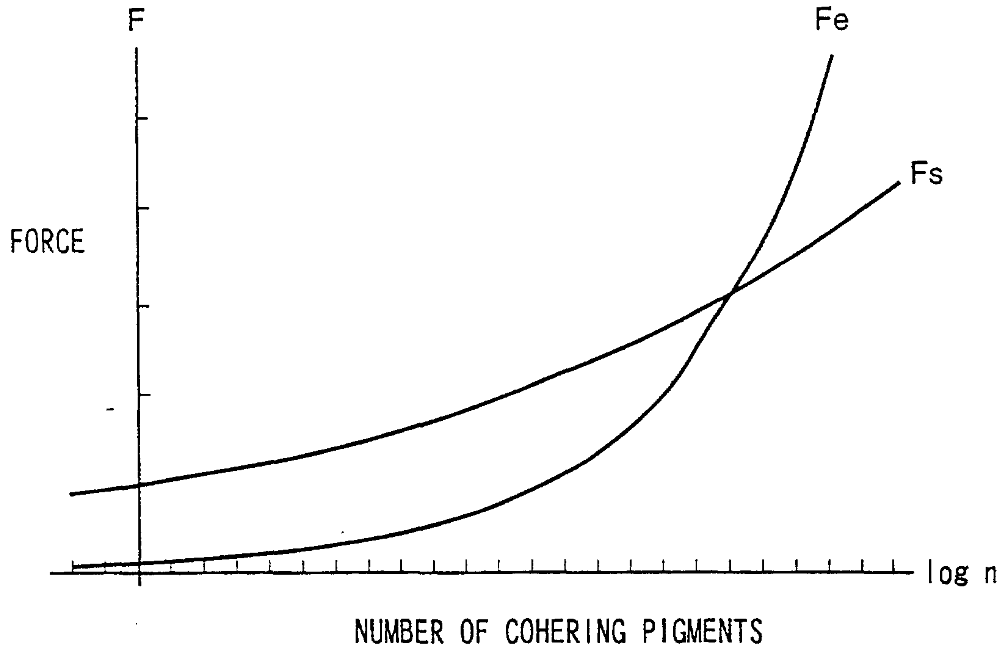

F
Fe
Fs
FORCE
log n
NUMBER OF COHERING PIGMENTS

FIG. 6

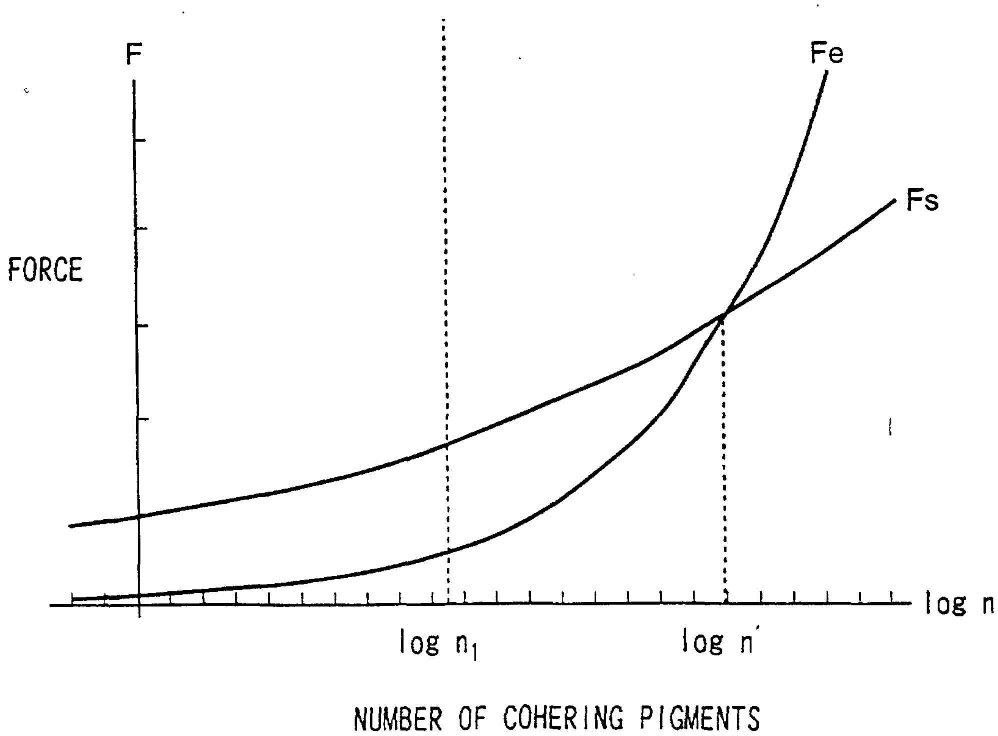

F
Fe
Fs
FORCE
log n
log n1
log n'
NUMBER OF COHERING PIGMENTS

FIG. 7

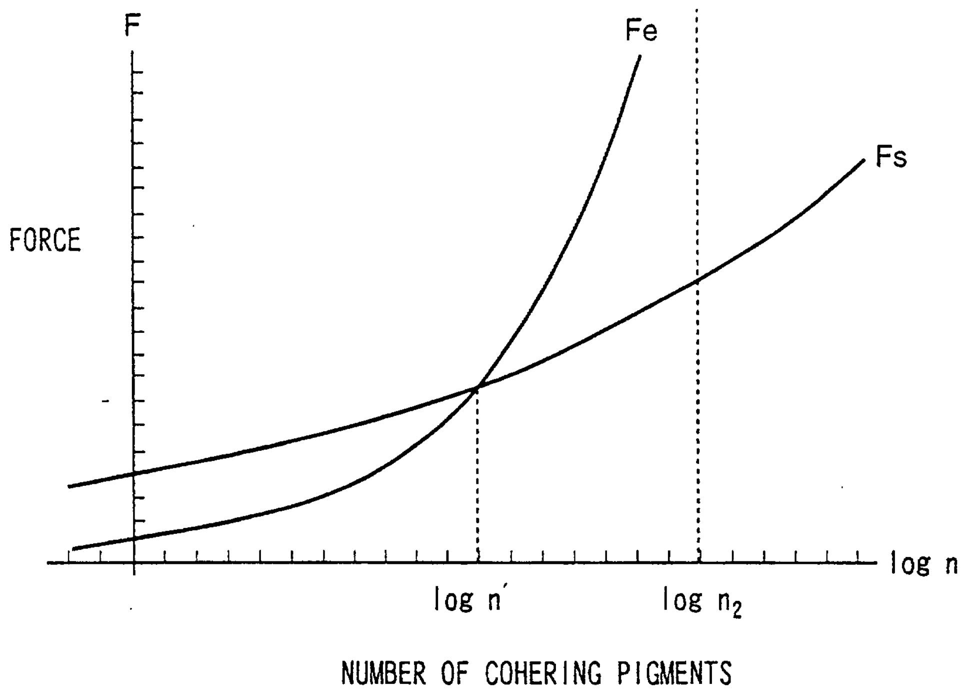

F
Fe
Fs
FORCE
log n
log n′
log n_2
NUMBER OF COHERING PIGMENTS

FIG. 8

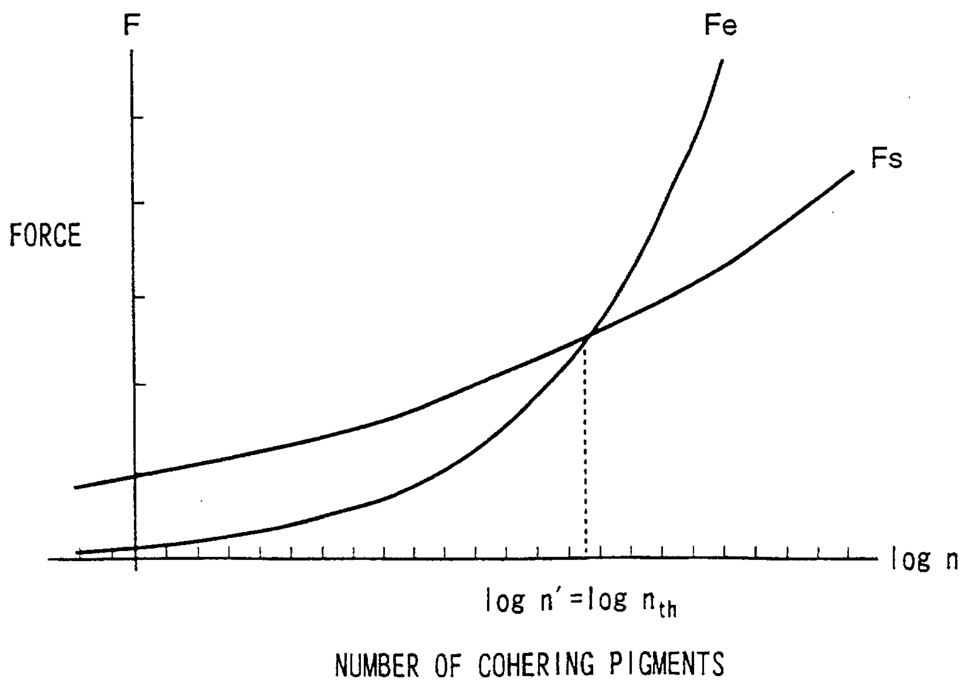

F
Fe
Fs
FORCE
log n
log n′=log n_{th}
NUMBER OF COHERING PIGMENTS

FIG. 9

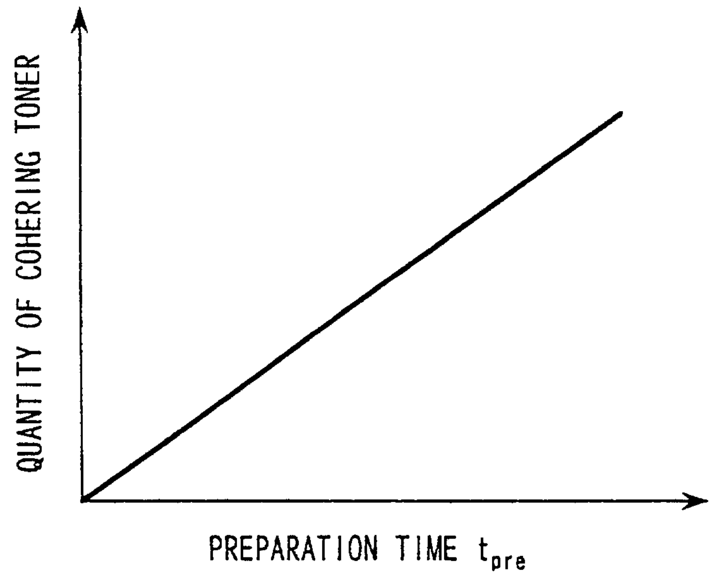

QUANTITY OF COHERING TONER
PREPARATION TIME t_{pre}

FIG. 10

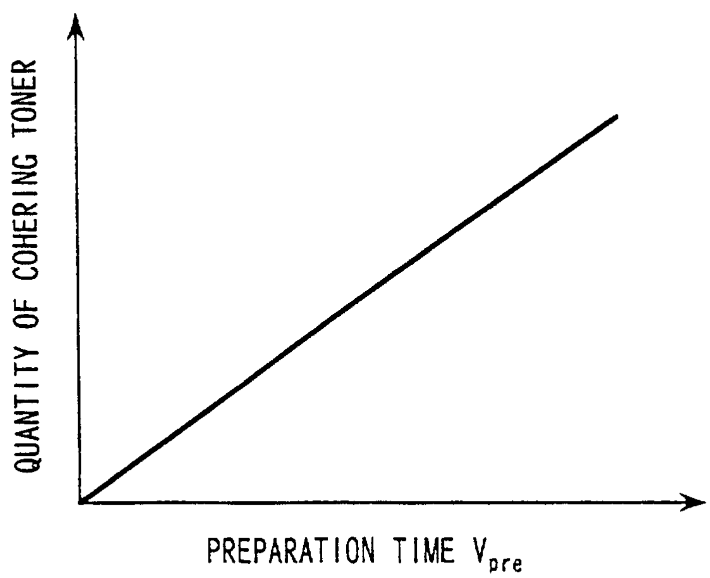

QUANTITY OF COHERING TONER
PREPARATION TIME V_{pre}

FIG. 11

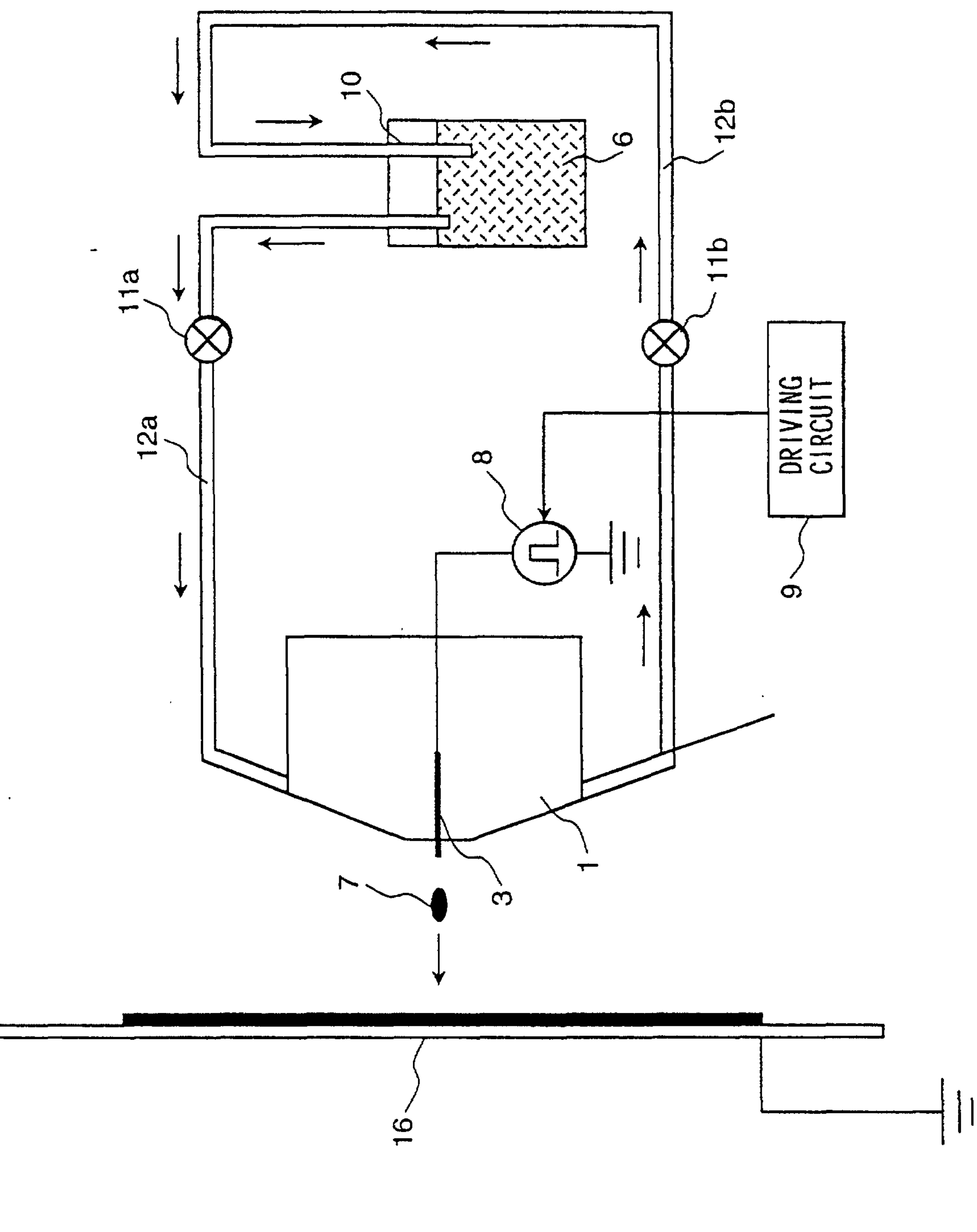


FIG. 12

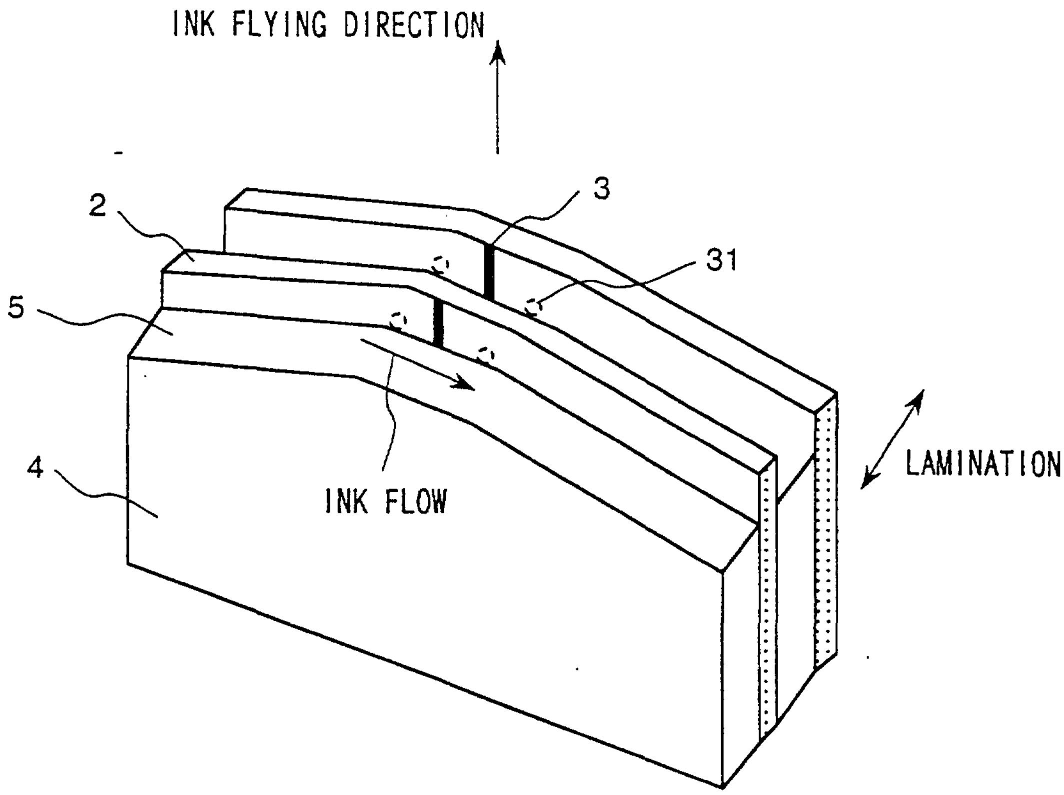


FIG. 13

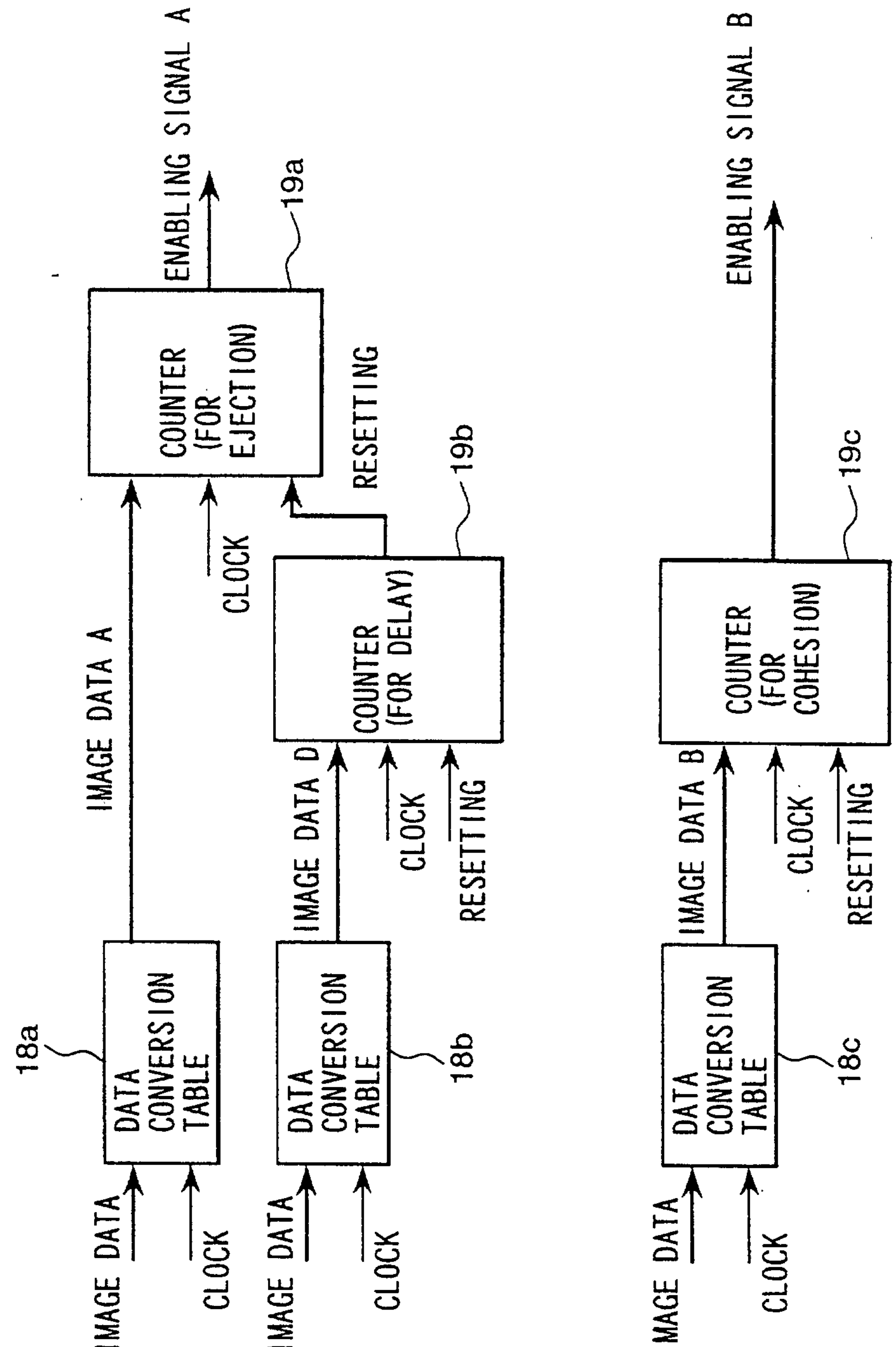


IMAGE DATA
CLOCK
DATA CONVERSION TABLE
18a
IMAGE DATA A
COUNTER (FOR EJECTION)
19a
CLOCK
ENABLING SIGNAL A
RESETTING
IMAGE DATA
CLOCK
DATA CONVERSION TABLE
18b
IMAGE DATA D
COUNTER (FOR DELAY)
19b
CLOCK
RESETTING
IMAGE DATA
CLOCK
DATA CONVERSION TABLE
18c
IMAGE DATA B
COUNTER (FOR COHESION)
19c
CLOCK
RESETTING
ENABLING SIGNAL B

FIG. 14

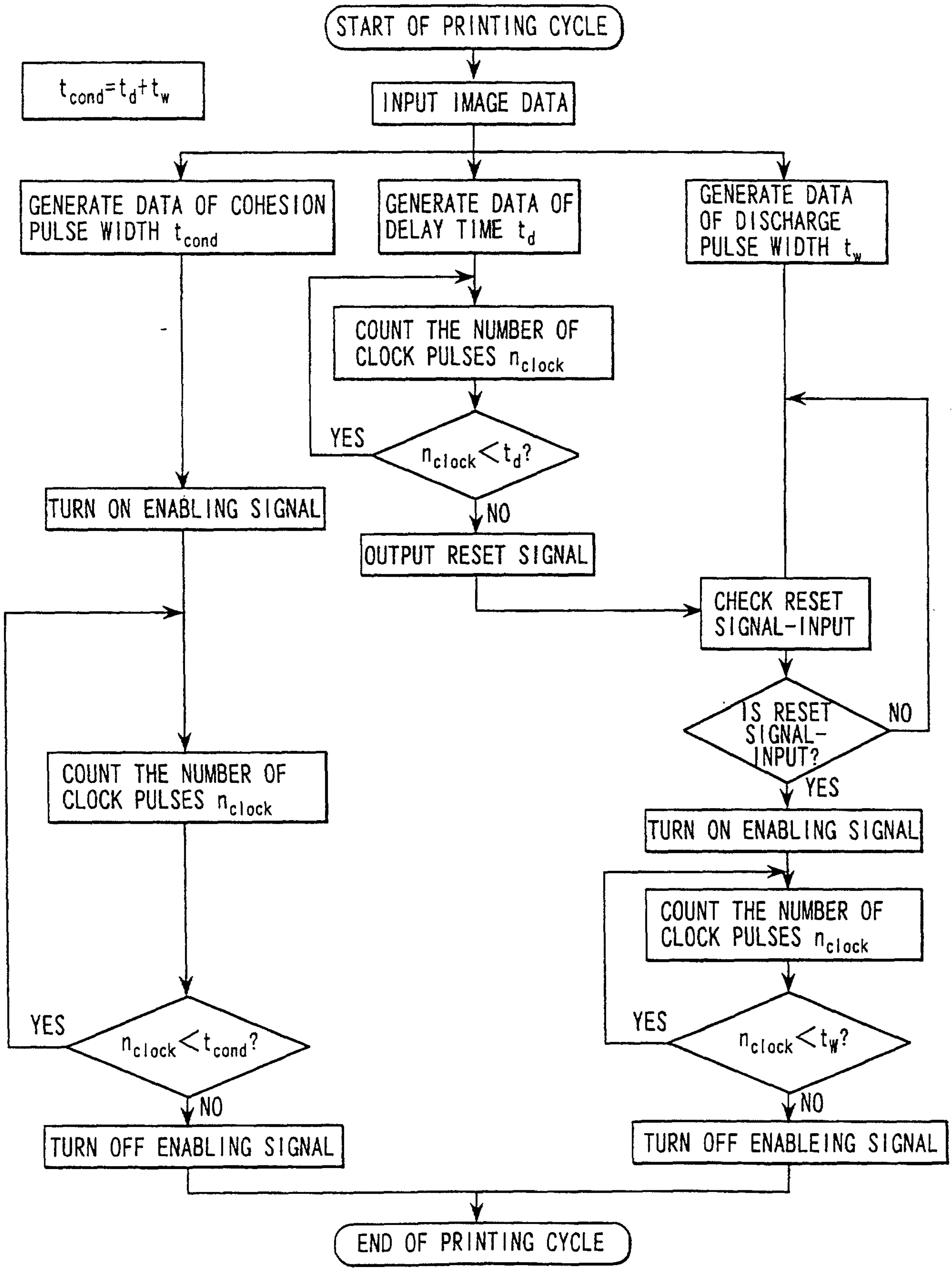

START OF PRINTING CYCLE
$t_{cond}=t_d+t_w$
INPUT IMAGE DATA
GENERATE DATA OF COHESION PULSE WIDTH t_{cond}
GENERATE DATA OF DELAY TIME t_d
GENERATE DATA OF DISCHARGE PULSE WIDTH t_w
COUNT THE NUMBER OF CLOCK PULSES n_{clock}
YES
$n_{clock}<t_d$?
NO
TURN ON ENABLING SIGNAL
OUTPUT RESET SIGNAL
CHECK RESET SIGNAL-INPUT
IS RESET SIGNAL-INPUT?
NO
YES
COUNT THE NUMBER OF CLOCK PULSES n_{clock}
TURN ON ENABLING SIGNAL
COUNT THE NUMBER OF CLOCK PULSES n_{clock}
YES
$n_{clock}<t_{cond}$?
NO
YES
$n_{clock}<t_w$?
NO
TURN OFF ENABLING SIGNAL
TURN OFF ENABLEING SIGNAL
END OF PRINTING CYCLE

FIG. 15

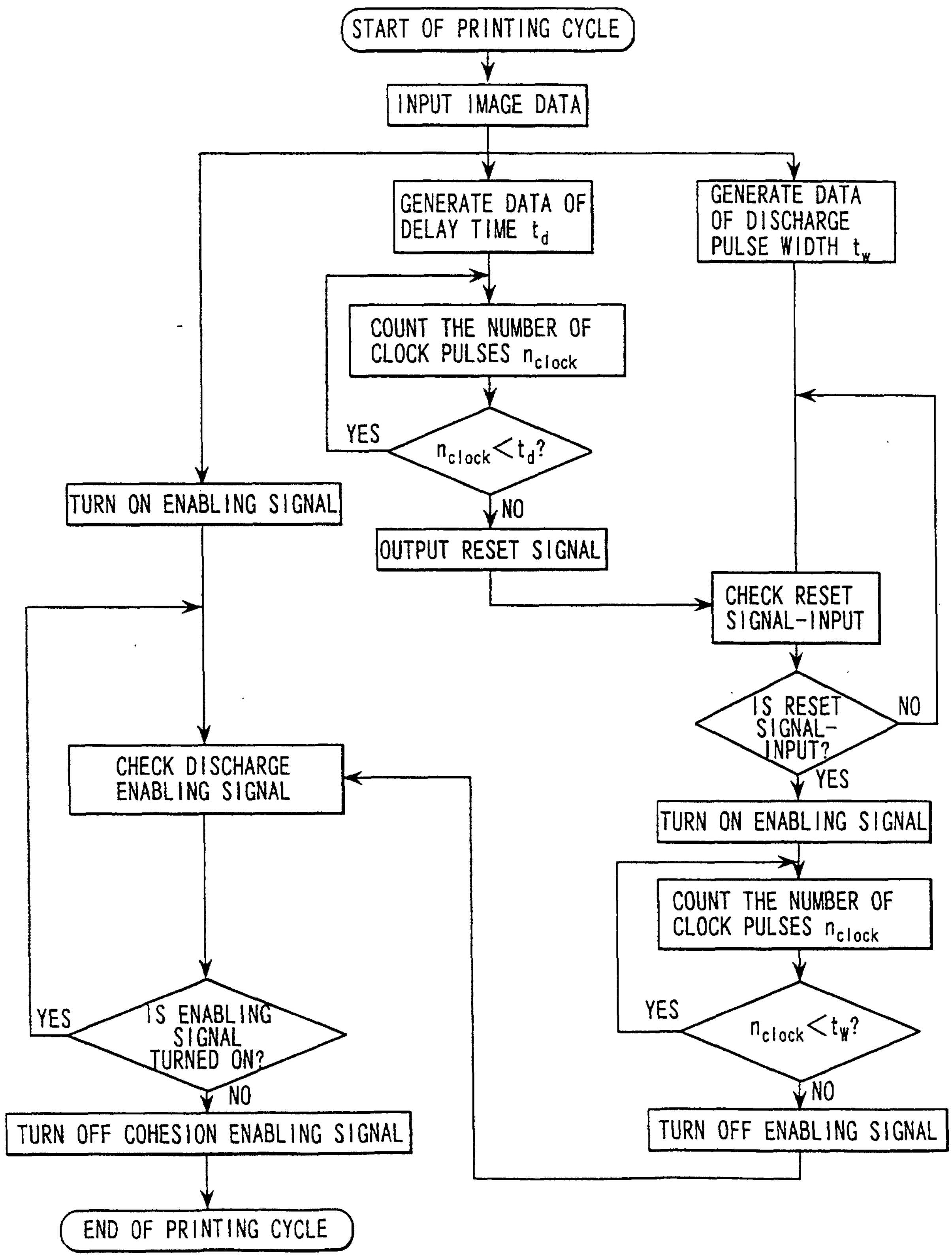

START OF PRINTING CYCLE
INPUT IMAGE DATA
GENERATE DATA OF DELAY TIME t_d
GENERATE DATA OF DISCHARGE PULSE WIDTH t_w
COUNT THE NUMBER OF CLOCK PULSES n_{clock}
YES
$n_{clock} < t_d$?
NO
TURN ON ENABLING SIGNAL
OUTPUT RESET SIGNAL
CHECK RESET SIGNAL-INPUT
IS RESET SIGNAL-INPUT?
NO
YES
CHECK DISCHARGE ENABLING SIGNAL
TURN ON ENABLING SIGNAL
COUNT THE NUMBER OF CLOCK PULSES n_{clock}
YES
IS ENABLING SIGNAL TURNED ON?
YES
$n_{clock} < t_w$?
NO
NO
TURN OFF COHESION ENABLING SIGNAL
TURN OFF ENABLING SIGNAL
END OF PRINTING CYCLE

FIG. 16

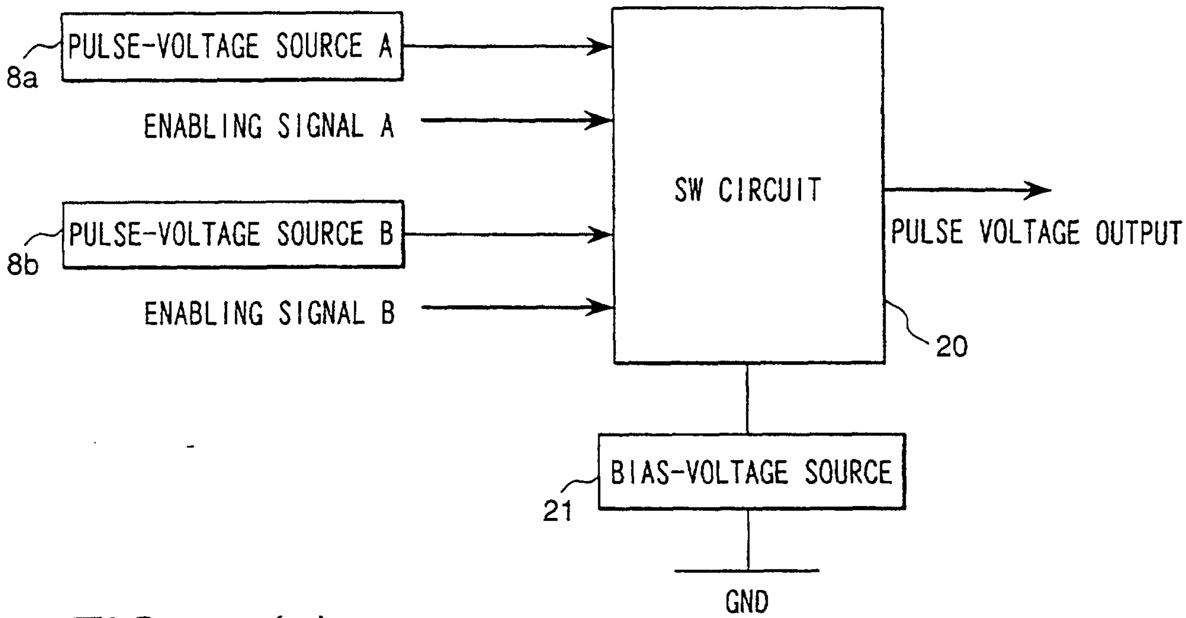


FIG. 17(a)

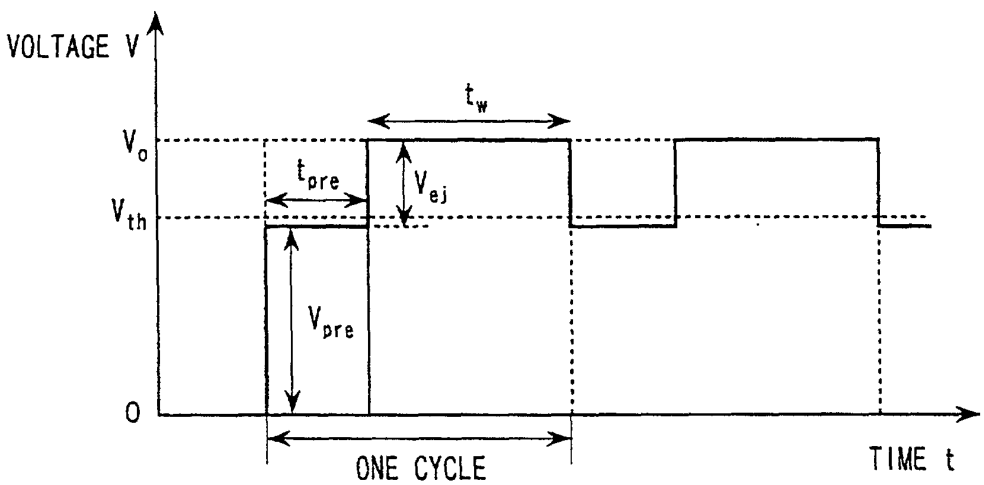


FIG. 17(b)

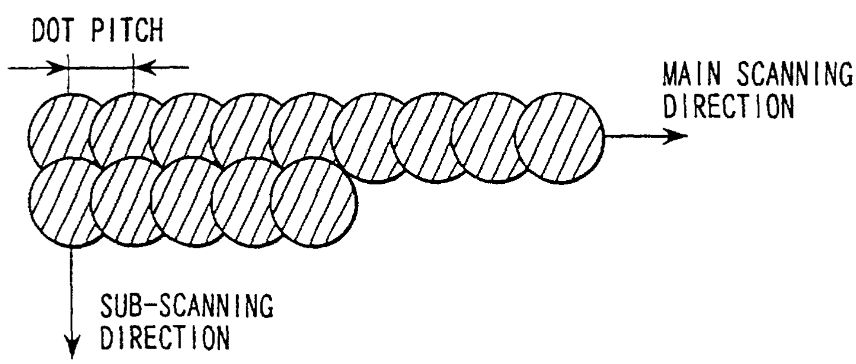


FIG. 18

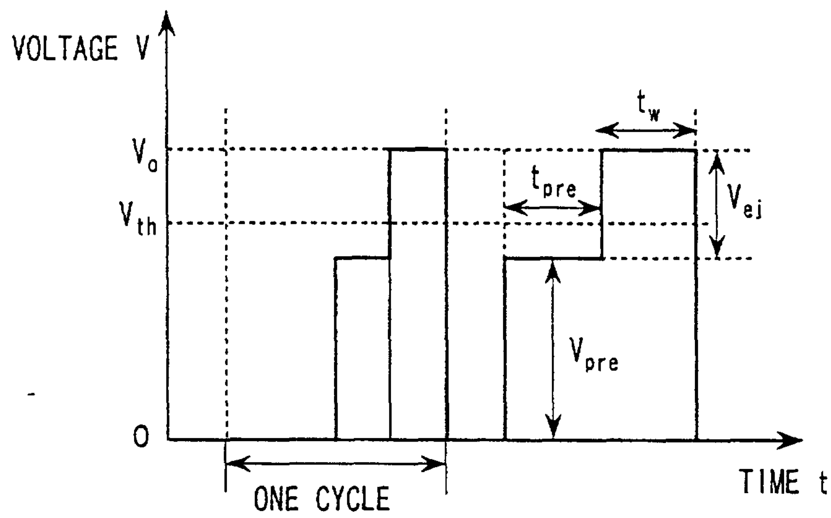

VOLTAGE V
V_o
V_{th}
0
t_w
t_{pre}
V_{ej}
V_{pre}
ONE CYCLE
TIME t

FIG. 19

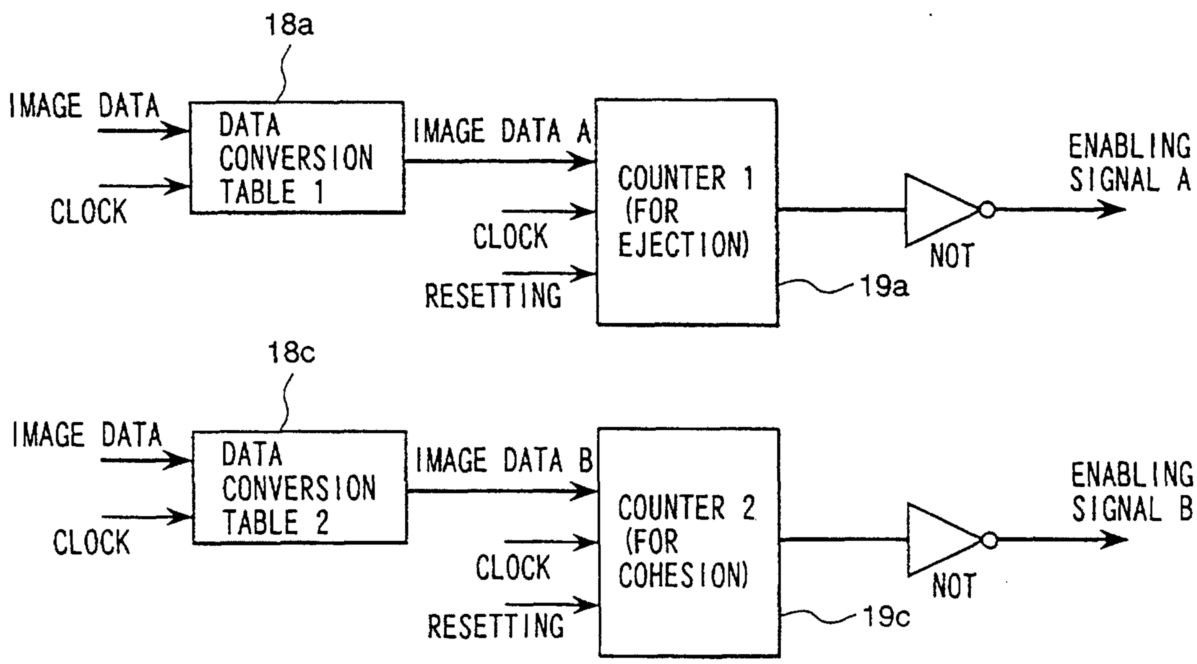

18a
IMAGE DATA
CLOCK
DATA CONVERSION TABLE 1
IMAGE DATA A
CLOCK
RESETTING
COUNTER 1 (FOR EJECTION)
19a
NOT
ENABLING SIGNAL A
18c
IMAGE DATA
CLOCK
DATA CONVERSION TABLE 2
IMAGE DATA B
CLOCK
RESETTING
COUNTER 2 (FOR COHESION)
19c
NOT
ENABLING SIGNAL B

FIG. 20

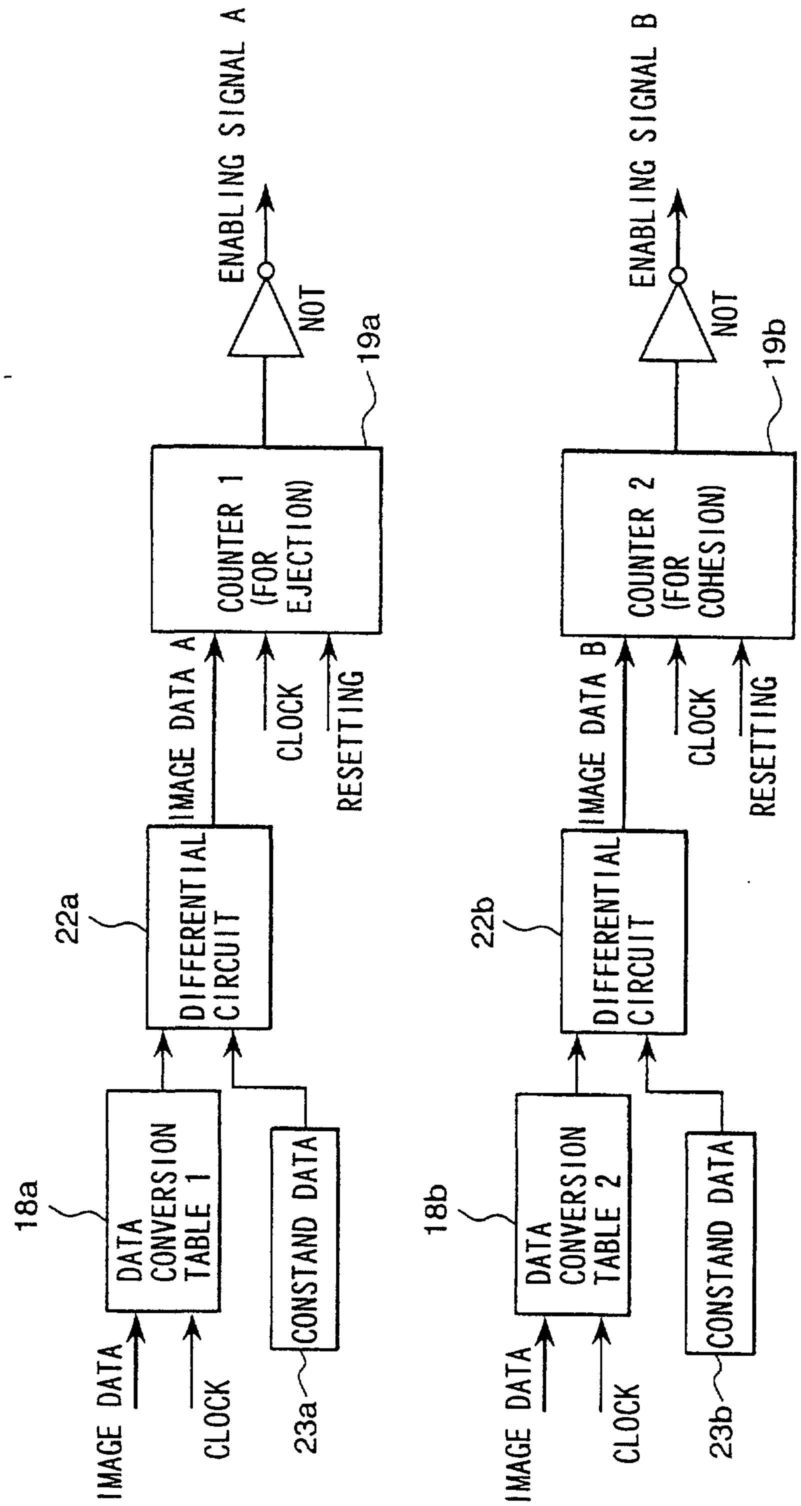


IMAGE DATA
CLOCK
18a
DATA CONVERSION TABLE 1
CONSTAND DATA
23a
22a
DIFFERENTIAL CIRCUIT
IMAGE DATA A
CLOCK
RESETTING
COUNTER 1 (FOR EJECTION)
19a
NOT
ENABLING SIGNAL A
IMAGE DATA
CLOCK
18b
DATA CONVERSION TABLE 2
CONSTAND DATA
23b
22b
DIFFERENTIAL CIRCUIT
IMAGE DATA B
CLOCK
RESETTING
COUNTER 2 (FOR COHESION)
19b
NOT
ENABLING SIGNAL B

FIG. 21

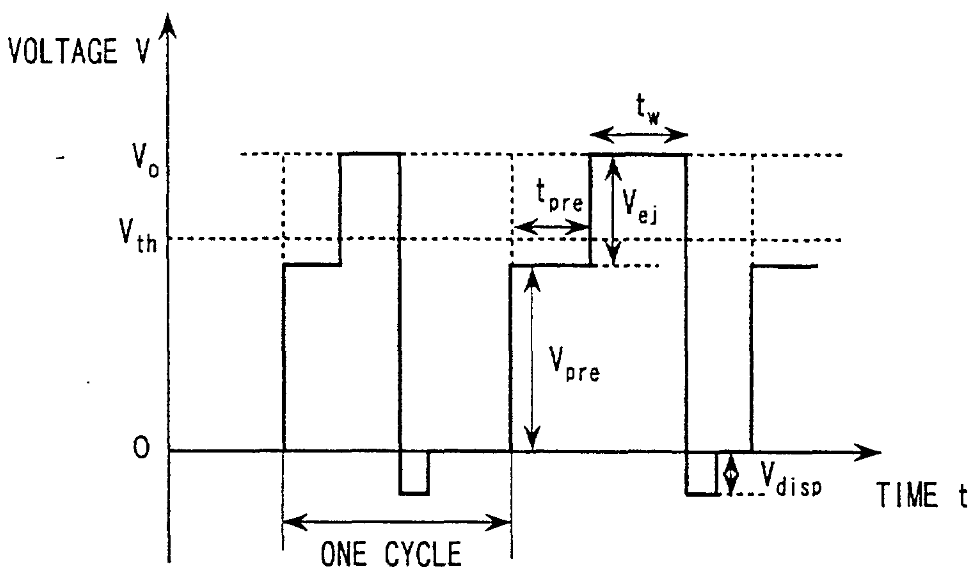


FIG. 22

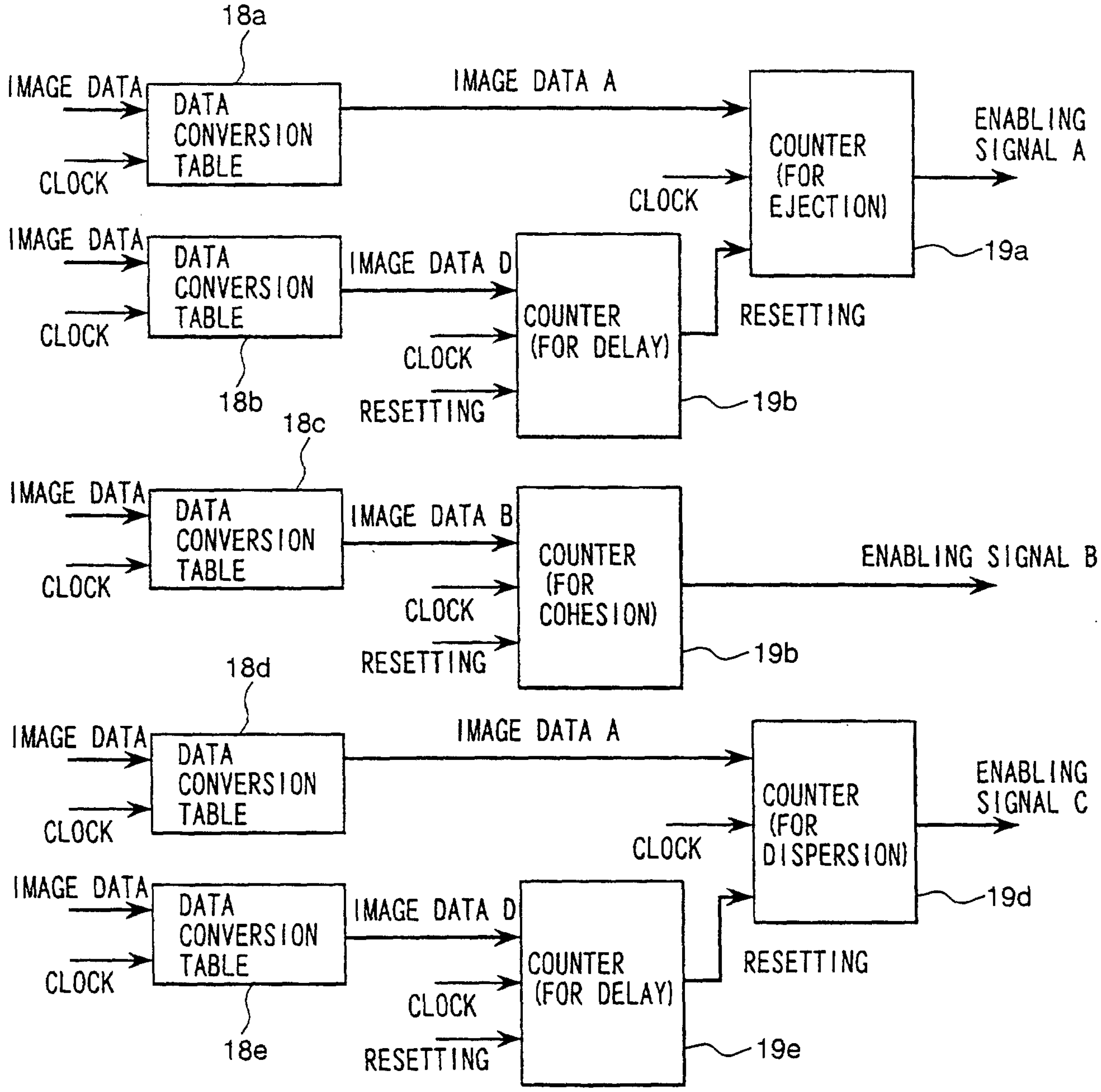

18a
IMAGE DATA
DATA CONVERSION TABLE
CLOCK
IMAGE DATA A
COUNTER (FOR EJECTION)
CLOCK
ENABLING SIGNAL A
19a
IMAGE DATA
DATA CONVERSION TABLE
CLOCK
18b
IMAGE DATA D
COUNTER (FOR DELAY)
CLOCK
RESETTING
RESETTING
19b
18c
IMAGE DATA
DATA CONVERSION TABLE
CLOCK
IMAGE DATA B
COUNTER (FOR COHESION)
CLOCK
RESETTING
ENABLING SIGNAL B
19b
18d
IMAGE DATA
DATA CONVERSION TABLE
CLOCK
IMAGE DATA A
COUNTER (FOR DISPERSION)
CLOCK
ENABLING SIGNAL C
19d
IMAGE DATA
DATA CONVERSION TABLE
CLOCK
18e
IMAGE DATA D
COUNTER (FOR DELAY)
CLOCK
RESETTING
RESETTING
19e

FIG. 23

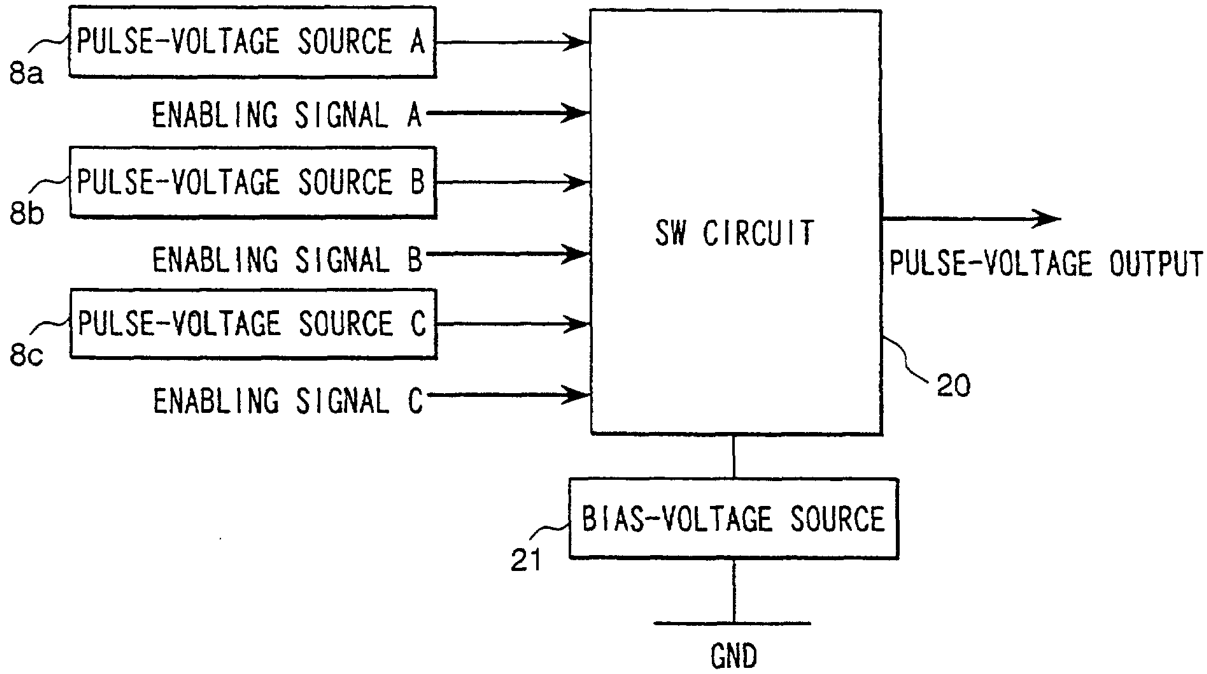
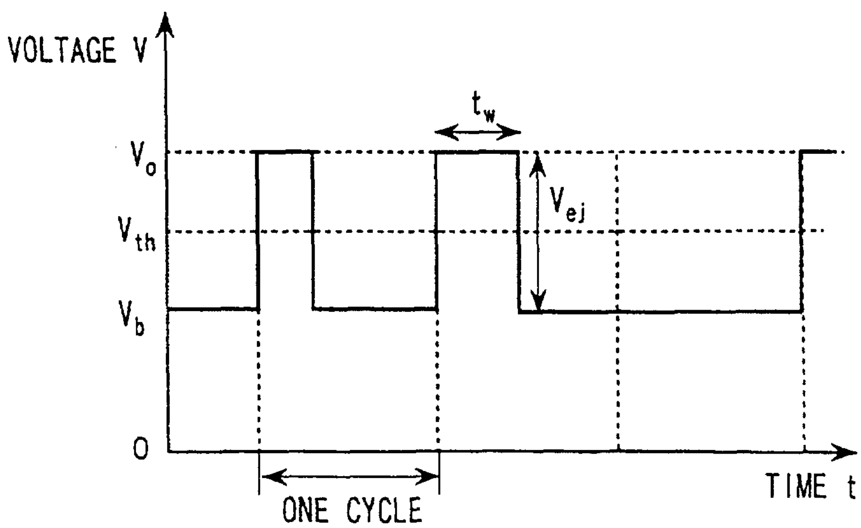

PULSE-VOLTAGE SOURCE A
8a
ENABLING SIGNAL A
PULSE-VOLTAGE SOURCE B
8b
ENABLING SIGNAL B
PULSE-VOLTAGE SOURCE C
8c
ENABLING SIGNAL C
SW CIRCUIT
PULSE-VOLTAGE OUTPUT
20
BIAS-VOLTAGE SOURCE
21
GND

FIG. 24


VOLTAGE V
t_w
V_o
V_{ej}
V_{th}
V_b
0
ONE CYCLE
TIME t

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/04870

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] B41J2/06
B41J2/205

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] B41J2/06
B41J2/205

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, 208322, B1 (Tpkyo Electric Co., Ltd.), 22 January, 1987 (22.01.87), & JP, 62-013357, A, 22 January, 1987 (22.01.87)	1~6
A	JP, 09-254392, A (Toshiba Corporation), 30 September, 1997 (30.09.97) (Family: none)	1~6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 December, 1999 (06.12.99)	14 December, 1999 (14.12.99)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)