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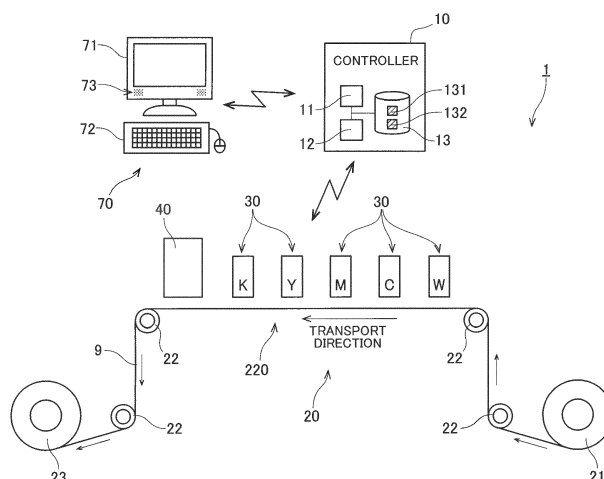
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(54) **INKJET PRINTER AND METHOD OF CHECKING LIQUID FEEDING STATE**

(57) An inkjet printer includes at least one head including a plurality of nozzles for ejecting ink toward a recording medium, a tank for supplying the ink to the head, an ink return part for feeding the ink from the head to the tank, and a pressure regulating part for performing a negative pressure reduction operation which increases the pressure in the tank when the pressure in the tank is not greater than a predetermined value. The inkjet printer further includes an operation sensing part for sensing the

number of times or frequency of the negative pressure reduction operation performed by the pressure regulating part, and an error detection part for judging whether the ink return part is operating normally or not, based on a sensing signal from the operation sensing part. Thus, whether the ink is being circulated normally or not is checked without the provision of a sensor in an ink circulation path.

Fig. 1



Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an inkjet printer and a method of checking a liquid feeding state in an inkjet printer.

Description of the Background Art

[0002] A printing apparatus having an ejection head for ejecting ink toward a recording medium has heretofore been used. A conventional printing apparatus is disclosed, for example, in Japanese Patent Application Laid-Open No. 2001-138544.

[0003] If ink is not ejected from the ejection head for a long period of time, there are cases in which the precipitation or/and agglomeration of ink components occur inside the ejection head or inside a pipe line through which the ink passes. If such precipitation or/and agglomeration of the ink components occur, there is apprehension about ejection failures of the ink from the ejection head. It is hence desirable to prevent the precipitation or/and agglomeration of the ink components in this type of printing apparatus by circulating the ink during a time period over which no printing process is performed.

[0004] If the precipitation or/and agglomeration of the ink components have already occurred inside the ejection head or inside the pipe line through which the ink passes, there are cases in which the ink cannot be circulated normally in the ink circulating process. It is hence necessary to check whether the ink is being circulated normally or not in the ink circulating process.

[0005] The printing apparatus disclosed in Japanese Patent Application Laid-Open No. 2001-138544 includes a pressure sensor provided in an ink circulation path, and checks whether the ink is being circulated normally or not with reference to the values measured with the pressure sensor. However, the provision of the pressure sensor increases the number of components in the circulation path to thereby increase the manufacturing costs of the printing apparatus. Also, it is difficult for the pressure sensor to precisely measure the pressure when the precipitation or/and agglomeration of the ink components occur around the pressure sensor.

SUMMARY OF THE INVENTION

[0006] In view of the foregoing, it is an object of the present invention to provide a technique capable of checking whether ink is being circulated normally or not without the provision of a sensor in an ink circulation path.

[0007] To solve the aforementioned problems, a first aspect of the present invention is intended for an inkjet printer comprising: at least one head including a plurality of nozzles for ejecting ink toward a recording medium; a

tank for storing the ink therein and supplying the ink to the head; an ink return part for feeding the ink from the head to the tank; a pressure regulating part for performing a negative pressure reduction operation which increases the pressure in the tank when the pressure in the tank is not greater than a predetermined value; an operation sensing part for sensing the number of times or frequency of the negative pressure reduction operation performed by the pressure regulating part; and an error detection part for judging whether the ink return part is operating normally or not, based on a sensing signal from the operation sensing part.

[0008] A second aspect of the present invention is intended for a method of checking a liquid feeding state in an inkjet printer, the inkjet printer including a head including a plurality of nozzles for ejecting ink toward a recording medium, a tank for supplying the ink to the head, and an ink return part for feeding the ink from the head to the tank, the method checking the feeding state of the ink from the head to the tank. The method comprises the steps of: a) measuring the pressure in the tank, while returning the ink from the head back to the tank, to judge whether the pressure in the tank is greater than a predetermined value or not; b) performing a negative pressure reduction operation which increases the pressure in the tank when the pressure in the tank is not greater than the predetermined value during the execution of the step a); and c) sensing the number of times or frequency of the negative pressure reduction operation during the execution of the step a) to judge whether the ink return part is operating normally or not, based on the number of times or the frequency which is sensed.

[0009] According to the first and second aspects of the present invention, whether the ink is being circulated normally or not is checked without the provision of a sensor in an ink circulation path.

[0010] These and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a diagram conceptually illustrating the configuration of a printing apparatus according to one preferred embodiment of the present invention; Fig. 2 is a bottom view of a head unit according to the one preferred embodiment of the present invention; Fig. 3 is a diagram conceptually illustrating the configuration of an ink supply system for the printing apparatus according to the one preferred embodiment of the present invention; Fig. 4 is a block diagram showing a control system for the printing apparatus according to the one pre-

ferred embodiment of the present invention;

Fig. 5 is a flow diagram showing a procedure for an ink circulating process according to the one preferred embodiment of the present invention;

Fig. 6 is a flow diagram showing a procedure for a meniscus control process according to the one preferred embodiment of the present invention; and

Figs. 7 and 8 are flow diagrams showing procedures for the ink circulating process according to modifications of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] A preferred embodiment according to the present invention will now be described with reference to the drawings. A direction in which printing paper 9 is transported is referred to as a "transport direction", and a horizontal direction orthogonal to the transport direction is referred to as a "width direction" hereinafter.

<1. Configuration of Printing Apparatus>

[0013] Fig. 1 is a diagram conceptually illustrating the configuration of a printing apparatus 1 according to one preferred embodiment of the present invention. Fig. 2 is a bottom view of a head unit 30. Fig. 3 is a diagram conceptually illustrating the configuration of an ink supply system for the printing apparatus 1.

[0014] This printing apparatus 1 is an inkjet printer which records a color image on the printing paper 9 that is an elongated strip-shaped recording medium by ejecting ink droplets from a plurality of ejection heads 32 onto the printing paper 9 while transporting the printing paper 9. As shown in Figs. 1 to 3, the printing apparatus 1 includes a transport mechanism 20, five head units 30, a UV lamp 40, five ink supply parts 50, a pressure regulating part 60, a manipulation part 70 and a controller 10.

[0015] The transport mechanism 20 is a mechanism for transporting the printing paper 9 in the transport direction that is the longitudinal direction of the printing paper 9 while holding the printing paper 9. The transport mechanism 20 according to the present preferred embodiment includes an unwinder 21, a plurality of transport rollers 22 and a winder 23.

[0016] A motor (not shown) serving as a power source is coupled to the unwinder 21, the plurality of transport rollers 22 and the winder 23. The unwinder 21, the plurality of transport rollers 22 and the winder 23 rotate when the controller 10 drives the motor. At least one or all of the transport rollers 22 may be follower rollers which are not coupled to the motor but rotate in accordance with the motion of the printing paper 9.

[0017] The transport rollers 22 constitute a transport path for the printing paper 9. Each of the transport rollers 22 rotates about a horizontal axis to guide the printing paper 9 downstream along the transport path. The printing paper 9 comes in contact with the transport rollers 22, so that tension is applied to the printing paper 9. In

this manner, the printing paper 9 is unwound from the unwinder 21, and is transported along the transport path formed by the transport rollers 22 to the winder 23. After being transported, the printing paper 9 is wound and collected on the winder 23.

[0018] The five head units 30 are arranged in spaced apart relation in the transport direction over the transport path of the printing paper 9. The five head units 30 eject ink droplets of white (W), cyan (C), magenta (M), yellow (Y) and black (K), respectively, onto the upper surface of the printing paper 9. UV inks that are ultraviolet ray curable is used in the printing apparatus 1 according to the present preferred embodiment.

[0019] The printing apparatus 1 according to the present preferred embodiment is what is called a one-pass type recording apparatus which records a desired image pattern on the printing paper 9 by ejecting ink droplets from the head units 30 while the printing paper 9 passes under the head units 30 only once. The structure of only one of the head units 30 will be described below because the five head units 30 are substantially similar in structure to each other.

[0020] As shown in Fig. 2, the head unit 30 includes a housing 31, and the plurality of ejection heads 32 mounted to the housing 31. Each of the ejection heads 32 has an exposed ejection surface at the lower surface of the housing 31. The ejection surface that is the lower surface of each of the ejection heads 32 has a plurality of nozzles 33 disposed in a two-dimensional array. The positions of the individual nozzles 33 are shifted in the width direction, and each of the nozzles 33 is assigned to a region having a width of one pixel on the printing paper 9.

[0021] As shown in Fig. 2, the ejection heads 32 are arranged in a staggered configuration (in obliquely alternating positions) in the width direction. Specifically, the ejection heads 32 include a first row 301 of ejection heads arranged in the width direction, and a second row 302 of ejection heads arranged in the width direction, the second row 302 being downstream of the first row 301. The ejection heads 32 in the first row 301 and the ejection heads 32 in the second row 302 are arranged alternately in the width direction. The ejection heads 32 are disposed at a high density in the width direction because of such an arrangement of the ejection heads 32 in a staggered configuration.

[0022] As shown in Fig. 3, each of the ejection heads 32 includes a casing 321, an ink reservoir chamber 322, a plurality of ink chambers 323, an ink supply port 324, an ink outlet port 325, and the plurality of nozzles 33. The ink reservoir chamber 322 and the ink chambers 323 are provided inside the casing 321.

[0023] The ink reservoir chamber 322 is primarily filled with the ink supplied from the outside of each ejection head 32 through the ink supply port 324 thereto. The ink supply port 324 and the ink outlet port 325 for providing communication between the ink reservoir chamber 322 and the outside are disposed over the ink reservoir chamber 322. The ink reservoir chamber 322 is in com-

munication with the ink chambers 323 through respective communication ports 326. Thus, when the pressure in one of the ink chambers 323 is reduced, the ink is supplied from the ink reservoir chamber 322 into the ink chamber 323.

[0024] The ink chambers 323 are filled with the ink secondarily in each ejection head 32. Although six ink chambers 323 are shown in Fig. 3 for purposes of convenience, a multiplicity of ink chambers 323 are provided for the respective nozzles 33 in actuality in each ejection head 32.

[0025] The nozzles 33 are provided on the lower ends of the respective ink chambers 323. The nozzles 33 are small apertures for providing communication between the respective ink chambers 323 and an outside space. When no ink is ejected, a liquid surface of ink forms a meniscus inside each of the nozzles 33. Each of the nozzles 33 has a lower end portion which is exposed at the lower surface of the casing 321.

[0026] A pressure generating element 327 is disposed on a wall surface of each of the ink chambers 323. The pressure generating element 327 is an in-head pressurizing mechanism for pressurizing the ink stored in each of the ink chambers 323.

[0027] Each of the ejection heads 32 according to the present preferred embodiment is an ejection head of what is called a piezoelectric type. Thus, a piezoelectric element is used for the pressure generating element 327 according to the present preferred embodiment. When an ejection signal that is an electric signal is sent from the controller 10 to the pressure generating element 327, the pressure generating element 327 is deformed to exert pressure on the ink which fills each of the ink chambers 323. When the pressure in each of the ink chambers 323 is increased, the ink in each of the ink chambers 323 is ejected in the form of droplets from each of the nozzles 33.

[0028] The heads according to the present invention are not limited to those of a piezoelectric type. For example, the heads according to the present invention may be what is called thermal ejection heads in which a heater used as the pressure generating element heats the liquid present in a pressure chamber to generate bubbles, thereby increasing the pressure in the pressure chamber.

[0029] The UV lamp 40 irradiates the upper surface of the printing paper 9 transported by the transport mechanism 20 with ultraviolet light at a location downstream from the five head units 30. The ink droplets ejected onto the printing paper 9 are cured by the irradiation with the ultraviolet light. Thus, an image is fixed on the printing paper 9.

[0030] This printing apparatus 1 includes the five ink supply parts 50 corresponding respectively to the five head units 30. The structure of only one of the ink supply parts 50 will be described below because the five ink supply parts 50 are substantially similar in structure to each other.

[0031] As shown in Fig. 3, the ink supply part 50 in-

cludes a main tank 51, a supply pump 52, a sub-tank 53, a return pump 54 and a pipe 55. The pipe 55 includes a first supply pipe 551, a second supply pipe 552, a plurality of third supply pipes 553, a plurality of first return pipes 554, and a second return pipe 555.

[0032] The main tank 51 is an ink reservoir for storing ink therein. The volume of ink storable in the main tank 51 is greater than that of ink storable in the sub-tank 53.

[0033] The first supply pipe 551 is a pipe which connects the main tank 51 and the sub-tank 53. The first supply pipe 551 has a first end connected for communication with the interior of the main tank 51 near a lower end portion of the main tank 51, and a second end connected for communication with the interior of the sub-tank 53.

[0034] A first on-off valve 556, the supply pump 52 and a filter 557 are interposed in the first supply pipe 551. The first on-off valve 556 is disposed between the main tank 51 and the supply pump 52. The filter 557 is disposed between the supply pump 52 and the sub-tank 53.

[0035] The supply pump 52 is a liquid feeding part for feeding the ink from the main tank 51 to the sub-tank 53. The supply pump 52 is interposed in the first supply pipe 551. The supply pump 52 generates a flow of ink directed from the main tank 51 toward the sub-tank 53 in the first supply pipe 551 in accordance with an operation signal from the controller 10. Thus, the ink stored in the main tank 51 is supplied through the first supply pipe 551 to the sub-tank 53.

[0036] When the first on-off valve 556 is in a closed position, the communication through the first supply pipe 551 is closed off. That is, when the first on-off valve 556 is in the closed position, the communication between the main tank 51 and the sub-tank 53 is closed off. On the other hand, when the first on-off valve 556 is in an open position, the communication through the first supply pipe 551 is ensured. The first on-off valve 556 is normally in the closed position, and is brought into the open position only when the supply pump 52 is put into operation to supply the ink from the main tank 51 to the sub-tank 53. This prevents variations in the pressure in the sub-tank 53 from exerting influence on the main tank 51.

[0037] The filter 557 removes solid components and foreign materials contained in the ink passing through the first supply pipe 551. This suppresses the contamination of solid components and foreign materials in the ink supplied to the sub-tank 53 and the ejection heads 32. The filter 557 may be disposed in a location other than between the supply pump 52 and the sub-tank 53 so long as the filter 557 is interposed in the first supply pipe 551.

[0038] The sub-tank 53 is a tank which temporarily stores the ink therein. The sub-tank 53 supplies the ink stored therein to the ejection heads 32. The sub-tank 53 includes a liquid level sensor 531. The ink is stored in a lower portion of the sub-tank 53, and an upper portion of the sub-tank 53 is filled with clean air.

[0039] The liquid level sensor 531 is a sensor for de-

tecting the liquid level of the ink stored in the sub-tank 53. The controller 10 senses the liquid level of the ink in the sub-tank 53, based on a signal from the liquid level sensor 531, to judge whether to supply the ink to the sub-tank 53 or not. For the supply of the ink from the main tank 51 to the sub-tank 53, the controller 10 brings the first on-off valve 556 into the open position, and puts the supply pump 52 into operation. For the stop of the ink supply from the main tank 51 to the sub-tank 53, the controller 10 stops the supply pump 52, and brings the first on-off valve 556 into the closed position.

[0040] The second supply pipe 552 and the third supply pipes 553 connect the sub-tank 53 and the respective ejection heads 32. That is, the sub-tank 53 is connected through the second supply pipe 552 and the third supply pipes 553 to the respective ejection heads 32.

[0041] The second supply pipe 552 has a first end connected for communication with the interior of the sub-tank 53 near the lower end portion of the sub-tank 53, and a second end connected for communication with a first end of each of the third supply pipes 553. Each of the third supply pipes 553 has a second end connected to the ink supply port 324 of a corresponding one of the ejection heads 32. Thus, the ink stored in the sub-tank 53 is supplied through the second supply pipe 552, the third supply pipes 553 and the ink supply ports 324 to the ink reservoir chambers 322 of the respective ejection heads 32.

[0042] In this manner, the sub-tank 53 is indirectly connected for communication with the ink reservoir chambers 322 and the ink chambers 323 of the ejection heads 32 through the second supply pipe 552 and the third supply pipes 553. Thus, the pressure in the ejection heads 32 is regulated by adjusting the pressure in the sub-tank 53.

[0043] The first return pipes 554 and the second return pipe 555 connect the respective ejection heads 32 and the main tank 51. Each of the first return pipes 554 has a first end connected to the ink outlet port 325 of a corresponding one of the ejection heads 32, and a second end connected to a first end of the second return pipe 555. The second return pipe 555 has a second end connected for communication with the interior of the main tank 51.

[0044] A second on-off valve 558 is interposed in each of the first return pipes 554. When the second on-off valve 558 is in a closed position, the communication through a corresponding one of the first return pipes 554 in which the second on-off valve 558 is interposed is closed off. That is, when the second on-off valve 558 is in the closed position, the communication between the ink reservoir chamber 322 of a corresponding one of the ejection heads 32 and the second return pipe 555 is closed off. On the other hand, when the second on-off valve 558 is in an open position, the communication through a corresponding one of the first return pipes 554 in which the second on-off valve 558 is interposed is ensured. That is, when the second on-off valve 558 is in the open po-

sition, the communication between the ink reservoir chamber 322 of a corresponding one of the ejection heads 32 and the second return pipe 555 is ensured.

[0045] The return pump 54 and a third on-off valve 559 are interposed in the second return pipe 555. The third on-off valve 559 is disposed between the return pump 54 and the main tank 51.

[0046] The return pump 54 is a liquid feeding part for feeding the ink from the ink reservoir chambers 322 of the respective ejection heads 32 to the main tank 51. The return pump 54 is interposed in the second return pipe 555. The return pump 54 generates a flow of ink directed from the first return pipes 554 toward the main tank 51 in the second return pipe 555 in accordance with an operation signal from the controller 10. Thus, the ink stored in the ink reservoir chambers 322 of the respective ejection heads 32 is returned to flow through the first return pipes 554 and the second return pipe 555 back to the main tank 51.

[0047] When the third on-off valve 559 is in a closed position, the communication through the second return pipe 555 is closed off. That is, when the third on-off valve 559 is in the closed position, the communication between the first return pipes 554 and the main tank 51 is closed off. On the other hand, when the third on-off valve 559 is in an open position, the communication through the second return pipe 555 is ensured. The third on-off valve 559 is normally in the closed position, and is brought into the open position only when the return pump 54 is put into operation to return the ink from the ejection heads 32 back to the main tank 51.

[0048] As mentioned above, the provision of the second on-off valve 558 in each of the first return pipes 554 allows the individual ejection heads 32 to return the ink. For the return of the ink from predetermined ones of the ejection heads 32 back to the main tank 51, the second on-off valves 558 corresponding to the predetermined ones of the ejection heads 32 and the third on-off valve 559 are brought into the open position whereas the remainder of the second on-off valves 558 are in the closed position, and the return pump 54 is put into operation.

[0049] The main tank 51, the supply pump 52, the return pump 54, the first supply pipe 551, the first return pipes 554, the second return pipe 555, the first on-off valve 556, the second on-off valves 558 and the third on-off valve 559 constitute an ink return part 500 for feeding the ink from the ejection heads 32 to the sub-tank 53 in this manner.

[0050] The pressure regulating part 60 controls the pressure in the sub-tank 53 and in the ejection heads 32. The pressure regulating part 60 includes a first main pipe 61, a buffer tank 62, a second main pipe 63, an open-to-atmosphere part 64, an exhaust part 65 and a pressure sensor 66. The open-to-atmosphere part 64 includes an open-to-atmosphere pipe 641 and an open-to-atmosphere control valve 642. The exhaust part 65 includes an exhaust pipe 651, an exhaust pump 652 and an exhaust control valve 653.

[0051] The first main pipe 61 has a first end connected for communication with the interior of the sub-tank 53 at the top of the sub-tank 53. The liquid level of the ink in the sub-tank 53 is near the liquid level sensor 531. Thus, the first end of the first main pipe 61 does not contact the ink in the sub-tank 53 but is disposed in a gas present in the upper portion of the sub-tank 53. The first main pipe 61 has a second end connected for communication with the interior of the buffer tank 62.

[0052] The buffer tank 62 is an enclosed tank filled with a gas. The pressure sensor 66 measures the pressure in the buffer tank 62. The interior of the sub-tank 53 and the interior of the buffer tank 62 are in communication with each other through the first main pipe 61, so that the pressure in the sub-tank 53 is approximately equal to the pressure in the buffer tank 62. For this reason, the pressure sensor 66 indirectly measures the pressure in the sub-tank 53.

[0053] The open-to-atmosphere part 64 and the exhaust part 65 may be connected to the sub-tank 53 without the buffer tank 62 connected therebetween. In such a case, the pressure sensor 66 may measure the pressure in the sub-tank 53 at the upper part of the sub-tank 53. In the case where the pressure sensor 66 directly measures the pressure in the sub-tank 53 in this manner, noise is prone to occur in the values measured with the pressure sensor 66 due to the pulsation of the supply pump 52 while the supply pump 52 is in operation. In the case where the buffer tank 62 is provided and the pressure sensor 66 measures the pressure in the buffer tank 62 as in the present preferred embodiment, the noise due to the pulsation of the supply pump 52 is reduced.

[0054] The second main pipe 63 has a first end connected for communication with the interior of the buffer tank 62, and a second end connected to a first end of the open-to-atmosphere pipe 641 and a first end of the exhaust pipe 651. That is, the open-to-atmosphere part 64 and the exhaust part 65 are connected to the second end of the second main pipe 63. Thus, the buffer tank 62 is connected to the open-to-atmosphere part 64 and the exhaust part 65.

[0055] The first end of the open-to-atmosphere pipe 641 is connected for communication with the second end of the second main pipe 63. The open-to-atmosphere pipe 641 has a second end open to the atmosphere. The open-to-atmosphere control valve 642 is interposed in the open-to-atmosphere pipe 641. The open-to-atmosphere control valve 642 performs the switching of the sub-tank 53 and the outside between a communicating state and a closed-off state. When the open-to-atmosphere control valve 642 is in an open position, the second main pipe 63 is open to the atmosphere. That is, when the open-to-atmosphere control valve 642 is in the open position, the sub-tank 53 and the buffer tank 62 are in communication with the outside and are thus open to the atmosphere. When the open-to-atmosphere control valve 642 is in a closed position, the communication between the second main pipe 63 and the outside is closed

off.

[0056] The controller 10 brings the open-to-atmosphere control valve 642 into the open position in order to reduce the pressure in the sub-tank 53 when the pressure in the sub-tank 53 is higher than atmospheric pressure. This reduces the pressure in the sub-tank 53 and in the buffer tank 62 quickly to atmospheric pressure.

[0057] The controller 10 holds the open-to-atmosphere control valve 642 in the open position for a fixed time period in order to increase the pressure in the sub-tank 53 when a desired pressure is a negative pressure lower than atmospheric pressure and the pressure in the sub-tank 53 is lower than the desired pressure. This causes the pressure in the sub-tank 53 and in the buffer tank 62 to approach atmospheric pressure and to increase.

[0058] The first end of the exhaust pipe 651 is connected for communication with the second end of the second main pipe 63. The exhaust pipe 651 has a second end connected to the exhaust pump 652. The exhaust pump 652 is a gas flow producing part for exhausting the gas from the exhaust pipe 651. The exhaust control valve 653 is interposed in the exhaust pipe 651. When the exhaust control valve 653 is in an open position, the second main pipe 63 and the exhaust pump 652 are in communication with each other. On the other hand, when the exhaust control valve 653 is in a closed position, the communication between the second main pipe 63 and the exhaust pump 652 is closed off.

[0059] Thus, when the exhaust pump 652 is driven while the exhaust control valve 653 is in the open position, the gas in the sub-tank 53 and in the buffer tank 62 is exhausted through the exhaust pipe 651. This reduces the pressure in the sub-tank 53 to a negative pressure. That is, the exhaust part 65 reduces the pressure in the sub-tank 53.

[0060] In a printing process and during a waiting time period, the pressure in the ink chambers 323 is adjusted to a pressure (referred to hereinafter as a meniscus pressure) at which a meniscus of ink is formed in each nozzle 33. In the present preferred embodiment, it is necessary that the pressure in the sub-tank 53 is set so that the pressure in the ink reservoir chambers 322 is a negative pressure because the ink chambers 323 are disposed under the ink reservoir chamber 322. When the pressure in the ink chambers 323 is higher than the meniscus pressure, the controller 10 brings the exhaust control valve 653 into the open position and drives the exhaust pump 652 to reduce the pressure in the sub-tank 53 to the meniscus pressure.

[0061] When the printing apparatus 1 performs the printing process, ink droplets are ejected from the ejection heads 32 of each of the head units 30 onto the upper surface of the printing paper 9 while the printing paper 9 is transported by the transport mechanism 20. The nozzles 33 ejecting the ink droplets in the positions opposed to substantially the full width of the upper surface of the printing paper 9 are disposed in each of the head units 30. This allows each of the head units 30 to eject the ink

droplets across substantially the full width of the upper surface of the printing paper 9.

[0062] The five head units 30 corresponding to the respective colors sequentially perform such a process of ejecting the ink droplets to form a multi-color pattern on the upper surface of the printing paper 9.

[0063] The manipulation part 70 includes a display part 71 and an input part 72. Information about the operating status and the like of the printing apparatus 1 which is inputted from the controller 10 is displayed on the display part 71. An operator may input commands from the input part 72 to the controller 10. A liquid crystal display, for example, is used for the display part 71. A keyboard and a mouse, for example, are used for the input part 72. The display part 71 includes a loudspeaker 73. The loudspeaker 73 constitutes a notifying part which uses voice or sound to provide notification of an error to an operator in accordance with an instruction from the controller 10. The display part 71 may constitute a notifying part which displays a character or an image thereon to provide notification of an error to an operator.

[0064] The display part 71 and the input part 72 in the manipulation part 70 according to the present preferred embodiment are separate devices independent of the printing apparatus 1. Alternatively, the manipulation part 70 of a touch panel type in which the display part 71 and the input part 72 are integrated together may be mounted to the body of the printing apparatus 1.

[0065] The controller 10 is a section for controlling the operations of the parts of the printing apparatus 1. As conceptually shown in Fig. 1, the controller 10 according to the present preferred embodiment is formed by a computer including an arithmetic processor 11 such as a CPU, a memory 12 such as a RAM, and a storage part 13 such as a hard disk drive. As shown in Fig. 4, the controller 10 is electrically connected to the transport mechanism 20, the pressure generating elements 327 of the five head units 30, the UV lamp 40, the supply pump 52, the liquid level sensor 531, the return pump 54, the first on-off valve 556, the second on-off valves 558, the third on-off valve 559, the open-to-atmosphere control valve 642, the exhaust pump 652, the exhaust control valve 653, the pressure sensor 66, the display part 71 and the input part 72.

[0066] The controller 10 temporarily reads a computer program 131 and data 132 which are stored in the storage part 13 onto the memory 12. The arithmetic processor 11 performs arithmetic processing based on the computer program 131 and the data 132, so that the controller 10 controls the operations of the parts of the printing apparatus 1. Thus, the printing process in the printing apparatus 1 and an ink circulating process to be described later proceed. The controller 10 may be formed by electronic circuitry.

[0067] The controller 10 includes an operation sensing part 101 and an error detection part 102 which are processing parts implemented in the form of software. Specifically, the operation sensing part 101 and the error

detection part 102 are implemented by the arithmetic processor 11, the memory 12 and the storage part 13 described above. The operation sensing part 101 senses the number of times or frequency of a negative pressure reduction operation performed by the pressure regulating part 60. The error detection part 102 judges whether the ink return part 500 is operating normally or not, based on a sensing signal from the operation sensing part 101.

<2. Ink Circulating Process >

[0068] Next, the ink circulating process in the printing apparatus 1 will be described with reference to Fig. 5. Fig. 5 is a flow diagram showing a procedure for the ink circulating process according to the present preferred embodiment.

[0069] As mentioned above, the UV inks that are ultra-violet ray curable are used in the printing apparatus 1. White (W) UV ink contains titanium oxide which is a precipitable ingredient. Thus, the white (W) UV ink is more prone to precipitation and agglomeration inside the ejection heads 32 and inside pipe lines through which the ink passes than other types of inks.

[0070] For this reason, the printing apparatus 1 performs the ink circulating process on at least the head unit 30 and the ink supply part 50 for white (W) at regular time intervals during a time period over which no printing process is performed. For example, the ink circulating process for three minutes at one time is performed at time intervals of five minutes.

[0071] The term "time period over which no printing process is performed" includes not only a time period over which all of the head units 30 perform no printing process but also a time period over which the head unit 30 of interest is not used for the printing process. That is, the ink circulating process is performed on the head unit 30 and the ink supply part 50 for white (W) when the head unit 30 for white (W) is not used although the printing process is performed using other four colors.

[0072] In the ink circulating process, the controller 10 initially starts counting the number of times of the negative pressure reduction operation (Step S101), as shown in Fig. 5. Specifically, the operation sensing part 101 of the controller 10 starts sensing the number of times that the pressure regulating part 60 performs the negative pressure reduction operation. Then, the controller 10 sets a head number n to 1 (Step S102). In this printing apparatus 1, the number of heads N is 6 because one head unit 30 includes six ejection heads.

[0073] Next, the controller 10 returns the ink from the n-th ejection head 32 back to the main tank 51 (Step S103). Specifically, the controller 10 puts the return pump 54 into operation while holding the second on-off valve 558 corresponding to the n-th ejection head 32 and the third on-off valve 559 in the open position. After a lapse of a predetermined time period, the controller 10 stops the return pump 54, and brings the second on-off valve 558 and the third on-off valve 559 held in the open posi-

tion into the closed position. In the present preferred embodiment, the controller 10 performs such a return operation several times.

[0074] A circulating operation causes the ink to be ejected from the ejection heads 32. Thus, the pressure in the ejection heads 32, in the sub-tank 53 and in the buffer tank 62 is reduced when the ink is being circulated normally.

[0075] In the ink circulating process and the printing process, the controller 10 causes the pressure regulating part 60 to perform a meniscus control process. Thus, the pressure in the ejection heads 32 is controlled to be equal to the meniscus pressure. In the present preferred embodiment, the pressure regulating part 60 performs the negative pressure reduction operation and a positive pressure reduction operation, so that the pressure in the ejection heads 32 is controlled to fall within a fixed range.

[0076] Fig. 6 is a flow diagram showing a procedure for the meniscus control process according to the present preferred embodiment. In the meniscus control process, a judgment is made as to whether the pressure value measured with the pressure sensor 66 is less than a predetermined lower limit or not (Step S201), as shown in Fig. 6.

[0077] Upon judging that the pressure value measured with the pressure sensor 66 is less than the predetermined lower limit in Step S201, the controller 10 causes the pressure regulating part 60 to perform the negative pressure reduction operation (Step S202). Specifically, the controller 10 brings the open-to-atmosphere control valve 642 into the open position, and then brings the open-to-atmosphere control valve 642 into the closed position after a lapse of a predetermined time period. This causes the sub-tank 53 and the buffer tank 62 to be open to the atmosphere for the predetermined time period, thereby increasing the pressure in the ejection heads 32, in the sub-tank 53 and in the buffer tank 62. After the completion of the Step S202, the procedure returns to Step S201.

[0078] On the other hand, when the controller 10 judges that the pressure value measured with the pressure sensor 66 is not less than the predetermined lower limit in the Step S201, the procedure proceeds to Step S203. Then, a judgment is made as to whether the pressure value measured with the pressure sensor 66 is greater than a predetermined upper limit or not (Step S203).

[0079] Upon judging that the pressure value measured with the pressure sensor 66 is greater than the predetermined upper limit in Step S203, the controller 10 causes the pressure regulating part 60 to perform the positive pressure reduction operation (Step S204). Specifically, the controller 10 brings the exhaust control valve 653 into the open position, and puts the exhaust pump 652 into operation. After a lapse of a predetermined time period, the controller 10 stops the exhaust pump 652, and brings the exhaust control valve 653 into the closed position. This causes the gas in the sub-tank 53 and in the buffer tank 62 to be exhausted therefrom, thereby reducing the

pressure in the ejection heads 32, in the sub-tank 53 and in the buffer tank 62. After the completion of the Step S204, the procedure returns to Step S201.

[0080] As mentioned above, the return operation performed in Step S103 reduces the pressure in the ejection heads 32, in the sub-tank 53 and in the buffer tank 62 when the ink is being circulated normally. Thus, when the ink is being circulated normally, the controller 10 should perform the negative pressure reduction operation in association with the return operation in Step S103. The controller 10 is hence capable of judging whether the ink is being circulated normally or not by sensing the number of times of the negative pressure reduction operation between Steps S101 and S106.

[0081] Subsequent to Step S103, the controller 10 increments the head number n (Step S104). Thereafter, the controller 10 judges whether the head number n is greater than the number of heads N or not (Step S105).

[0082] When the controller 10 judges that the head number n is not greater than the number of heads N in Step S105, the procedure returns to Step S103, and the controller 10 performs the return operation on the next ejection head 32. On the other hand, when the controller 10 judges that the head number n is greater than the number of heads N in Step S105, the controller 10 considers that the return operation of all of the ejection heads 32 is completed to stop counting the number of times of the negative pressure reduction operation by means of the operation sensing part 101 (Step S106).

[0083] Thereafter, the error detection part 102 of the controller 10 judges whether the number of times of the negative pressure reduction operation between Steps S101 and S106 is included within a predetermined range or not (Step S107). In other words, the error detection part 102 judges whether the ink return part 500 is operating normally or not, based on the sensing signal from the operation sensing part 101 while the return pump 54 is in operation.

[0084] When the error detection part 102 judges that the number of times of the negative pressure reduction operation is included within the predetermined range in Step S107, the procedure proceeds to Step S108. That is, when the number of times of the negative pressure reduction operation coincides with a predetermined condition, the error detection part 102 judges that the ink return part 500 is operating normally. In this case, the controller 10 judges that the ink is being circulated normally to continue the ink circulating process. Then, the controller 10 performs the operation of supplying the ink to the sub-tank 53 (Step S108).

[0085] In Step S108, the controller 10 initially judges whether the supply of the ink to the sub-tank 53 is necessary or not, based on a sensing signal from the liquid level sensor 531. Upon judging that the supply of the ink to the sub-tank 53 is necessary, the controller 10 brings the first on-off valve 556 into the open position, and puts the supply pump 52 into operation. Then, upon judging that the liquid level of the ink in the sub-tank 53 reaches

a predetermined upper limit, based on the sensing signal from the liquid level sensor 531, the controller 10 stops the supply pump 52, and brings the first on-off valve 556 into the closed position. Thereafter, the controller 10 completes the ink circulating process. Upon judging that the supply of the ink to the sub-tank 53 is not necessary in Step S108, the controller 10 completes the ink circulating process normally.

[0086] On the other hand, when the error detection part 102 judges that the number of times of the negative pressure reduction operation is not included within the predetermined range in Step S107, the controller 10 judges that the ink is not normally being circulated. That is, when the number of times of the negative pressure reduction operation does not coincide with the predetermined condition, the error detection part 102 judges that the ink return part 500 is not normally operating. Upon sensing an error in this manner, the controller 10 causes the notifying part to make an error notification. In the present preferred embodiment, the controller 10 uses voice or sound from the loudspeaker 73 provided in the display part 71 to provide notification of an error to an operator.

[0087] As described above, the ink is returned from the ejection heads 32 through the main tank 51 back to the sub-tank 53 in the ink circulating process in this printing apparatus 1. While such ink return is performed, the pressure sensor 66 measures the pressure in the sub-tank 53 through the buffer tank 62, and the negative pressure reduction operation is performed when the pressure is not greater than the predetermined value. Then, the controller 10 senses the number of times of the negative pressure reduction operation during the circulating process to judge whether the ink return part 500 is operating normally or not, based on the sensed number of times. That is, while the ink circulating process is performed, the controller 10 senses the number of times or frequency of the negative pressure reduction operation performed by the pressure regulating part 60 as part of the meniscus control to thereby judge whether the ink is being circulated normally or not.

[0088] Thus, whether the ink is being circulated normally or not is checked without the provision of a pressure sensor in the ink circulation path. Also, whether the ink is being circulated normally or not is checked without the addition of a new part.

<3. Modifications>

[0089] While the one preferred embodiment according to the present invention has been described hereinabove, the present invention is not limited to the aforementioned preferred embodiment.

[0090] Fig. 7 is a flow diagram showing a procedure for the ink circulating process according to one modification of the present invention. In the modification of Fig. 7, the controller 10 initially sets the head number n to 1 (Step S301). Then, the operation sensing part 101 of the controller 10 starts counting the number of times of the

negative pressure reduction operation (Step S302). Next, the controller 10 returns the ink from the n-th ejection head 32 back to the main tank 51 (Step S303). Then, the controller 10 stops counting the number of times of the negative pressure reduction operation by means of the operation sensing part 101 (Step S304).

[0091] Thereafter, the error detection part 102 of the controller 10 judges whether the number of times of the negative pressure reduction operation between Steps S302 and S305 is included within a predetermined range or not (Step S305). When the error detection part 102 judges that the number of times of the negative pressure reduction operation is included within the predetermined range in Step S305, the procedure proceeds to Step S306. On the other hand, when the error detection part 102 judges that the number of times of the negative pressure reduction operation is not included within the predetermined range in Step S305, an error notification is made.

[0092] The controller 10 increments the head number n in Step S306. Subsequently, the controller 10 judges whether the head number n is greater than the number of heads N or not (Step S307). When the controller 10 judges that the head number n is not greater than the number of heads N in Step S307, the procedure returns to Step S302, and the controller 10 performs the return operation on the next ejection head 32. On the other hand, when the controller 10 judges that the head number n is greater than the number of heads N in Step S307, the procedure proceeds to Step S308, and the controller 10 performs the operation of supplying the ink to the sub-tank 53.

[0093] Each time the return operation performed on each of the ejection heads 32 is completed, the judgement may be made as to whether the number of times of the negative pressure reduction operation in the ink circulating process is included within the predetermined range or not, as in the modification of Fig. 7.

[0094] Fig. 8 is a flow diagram showing a procedure for the ink circulating process according to another modification of the present invention. In the modification of Fig. 8, the operation sensing part 101 of the controller 10 initially starts counting the number of times of the negative pressure reduction operation (Step S401). Then, the controller 10 sets the head number n to 1 (Step S402). Next, the controller 10 returns the ink from the n-th ejection head 32 back to the main tank 51 (Step S403). Subsequently, the controller 10 performs the operation of supplying the ink to the sub-tank 53 (Step S404). Thereafter, the controller 10 increments the head number n (Step S405).

[0095] After the completion of Step S405, the controller 10 judges whether the head number n is greater than the number of heads N or not (Step S406). When the controller 10 judges that the head number n is not greater than the number of heads N in Step S406, the procedure returns to Step S403, and the controller 10 performs the return operation on the next ejection head 32. On the

other hand, when the controller 10 judges that the head number n is greater than the number of heads N in Step S406, the procedure proceeds to Step S407, and the controller 10 stops counting the number of times of the negative pressure reduction operation by means of the operation sensing part 101.

[0096] Thereafter, the error detection part 102 of the controller 10 judges whether the number of times of the negative pressure reduction operation between Steps S401 and S407 is included within a predetermined range or not (Step S408). When the error detection part 102 judges that the number of times of the negative pressure reduction operation is included within the predetermined range in Step S408, the controller 10 completes the ink circulating process normally. On the other hand, when the error detection part 102 judges that the number of times of the negative pressure reduction operation is not included within the predetermined range in Step S408, an error notification is made.

[0097] Each time the return operation performed on each of the ejection heads 32 is completed, the operation of supplying the ink to the sub-tank 53 may be performed, as in the modification of Fig. 8. In particular, when a large amount of ink is returned in the return operation for each of the ejection heads 32 or when the number of ejection heads 32 is large, it is preferable that the operation of supplying the ink to the sub-tank 53 is performed at the time of completion of the return operation for one or a predetermined number of ejection heads 32.

[0098] Although the printing apparatus 1 according to the aforementioned preferred embodiment includes the five head units 30, the number of head units 30 in the printing apparatus 1 may be in the range of one to four or not less than six.

[0099] Although the UV inks that are ultraviolet ray curable are used in the printing apparatus 1 according to the aforementioned preferred embodiment, the present invention is not limited to this. For example, other types of inks such as oil-based ink and water-based ink dried by hot gases may be used in place of the UV ink. In such a case, the printing apparatus 1 need not include a UV lamp.

[0100] The printing apparatus 1 according to the aforementioned preferred embodiment prints an image on the printing paper 9 serving as a recording medium. However, the printing apparatus 1 according to the present invention may be configured to print a pattern of an image and the like on a sheet-like recording medium other than general paper (for example, a film made of resin and the like).

[0101] The components described in the aforementioned preferred embodiment and in the modifications may be consistently combined together, as appropriate.

[0102] While the invention has been described in detail, the foregoing description is in all aspects illustrative and not restrictive. It is understood that numerous other modifications and variations can be devised without departing from the scope of the invention.

Claims

1. An inkjet printer comprising:

at least one head including a plurality of nozzles for ejecting ink toward a recording medium;
a tank for storing said ink therein and supplying said ink to said head;
an ink return part for feeding said ink from said head to said tank;
a pressure regulating part for performing a negative pressure reduction operation which increases the pressure in said tank when the pressure in said tank is not greater than a predetermined value;
an operation sensing part for sensing the number of times or frequency of said negative pressure reduction operation performed by said pressure regulating part; and
an error detection part for judging whether said ink return part is operating normally or not, based on a sensing signal from said operation sensing part.

2. The inkjet printer according to claim 1, wherein:

said pressure regulating part includes
an open-to-atmosphere pipe for providing communication between said tank and the outside, and
an open-to-atmosphere valve interposed in said open-to-atmosphere pipe and for switching said tank and the outside between a communicating state and a closed-off state; and

said pressure regulating part opens said open-to-atmosphere valve to make said tank open to the atmosphere, thereby performing said negative pressure reduction operation.

3. The inkjet printer according to claim 1 or 2, wherein said error detection part judges that said ink return part is not normally operating when said number of times or said frequency does not coincide with a predetermined condition.

4. The inkjet printer according to any one of claims 1 to 3, wherein said ink return part includes:

an ink reservoir for storing said ink therein;
a return pump for feeding said ink from said head to said ink reservoir; and
a supply pump for feeding said ink from said ink reservoir to said tank.

5. The inkjet printer according to claim 4, wherein said error detection part judges whether said ink re-

turn part is operating normally or not, based on said sensing signal obtained while said return pump is in operation.

6. The inkjet printer according to any one of claims 1 to 5, wherein said at least one head includes a plurality of heads. 5

7. The inkjet printer according to any one of claims 1 to 6, further comprising a notifying part for making an error notification when said error detection part judges that said ink return part is not normally operating. 10

8. A method of checking a liquid feeding state in an inkjet printer, said inkjet printer including a head including a plurality of nozzles for ejecting ink toward a recording medium, a tank for supplying said ink to said head, and an ink return part for feeding said ink from said head to said tank, said method checking the feeding state of said ink from said head to said tank, said method comprising the steps of: 15
 - a) measuring the pressure in said tank, while returning said ink from said head back to said tank, to judge whether the pressure in said tank is greater than a predetermined value or not; 25
 - b) performing a negative pressure reduction operation which increases the pressure in said tank when the pressure in said tank is not greater than said predetermined value during the execution of said step a); and 30
 - c) sensing the number of times or frequency of said negative pressure reduction operation during the execution of said step a) to judge whether said ink return part is operating normally or not, based on said number of times or said frequency which is sensed. 35

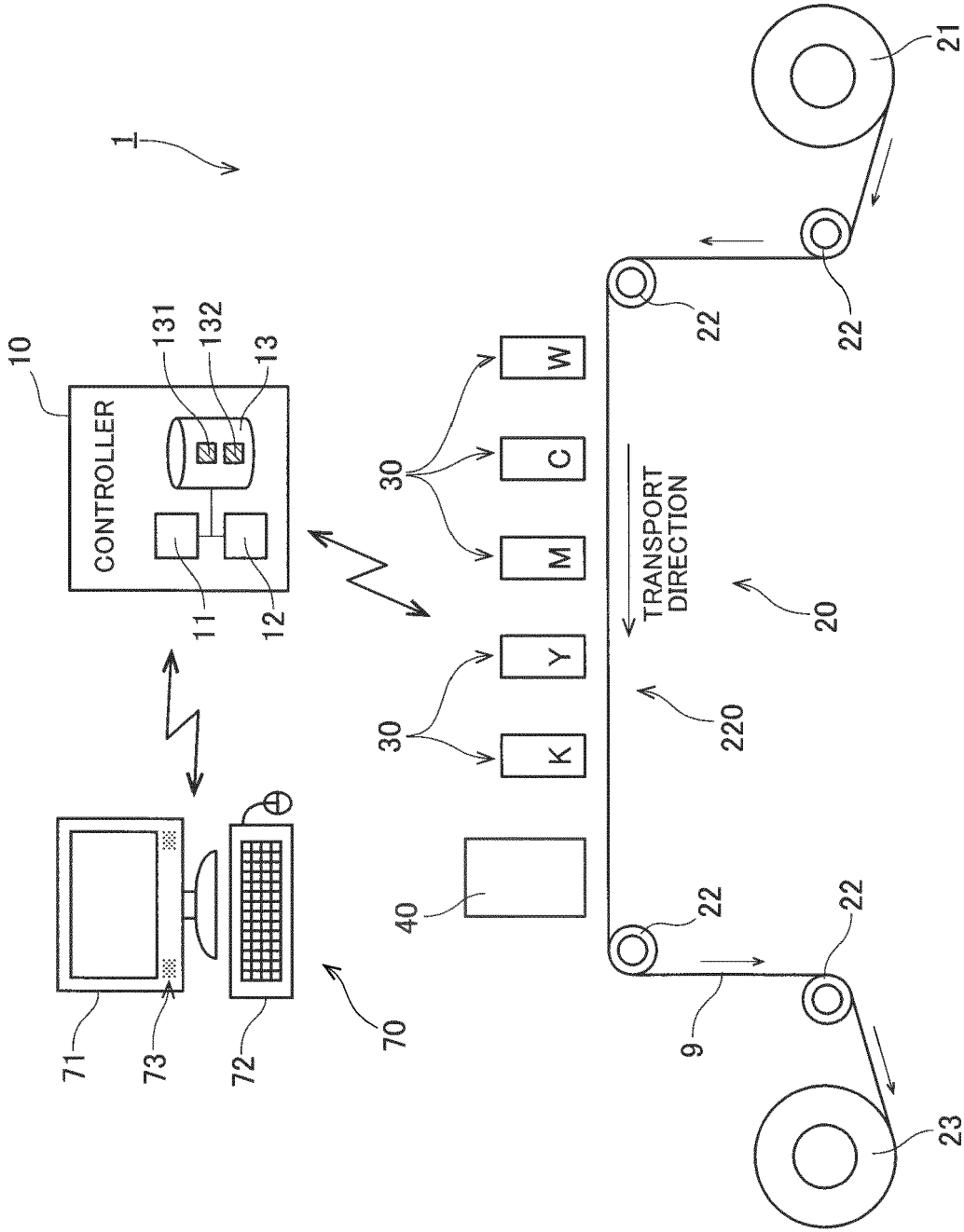
9. The method according to claim 8, wherein said negative pressure reduction operation is the process of making said tank open to the atmosphere in said step b). 40

10. The method according to claim 8 or 9, wherein it is judged that said ink return part is not normally operating when said number of times or said frequency of said negative pressure reduction operation does not coincide with a predetermined condition. 45

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Fig. 1



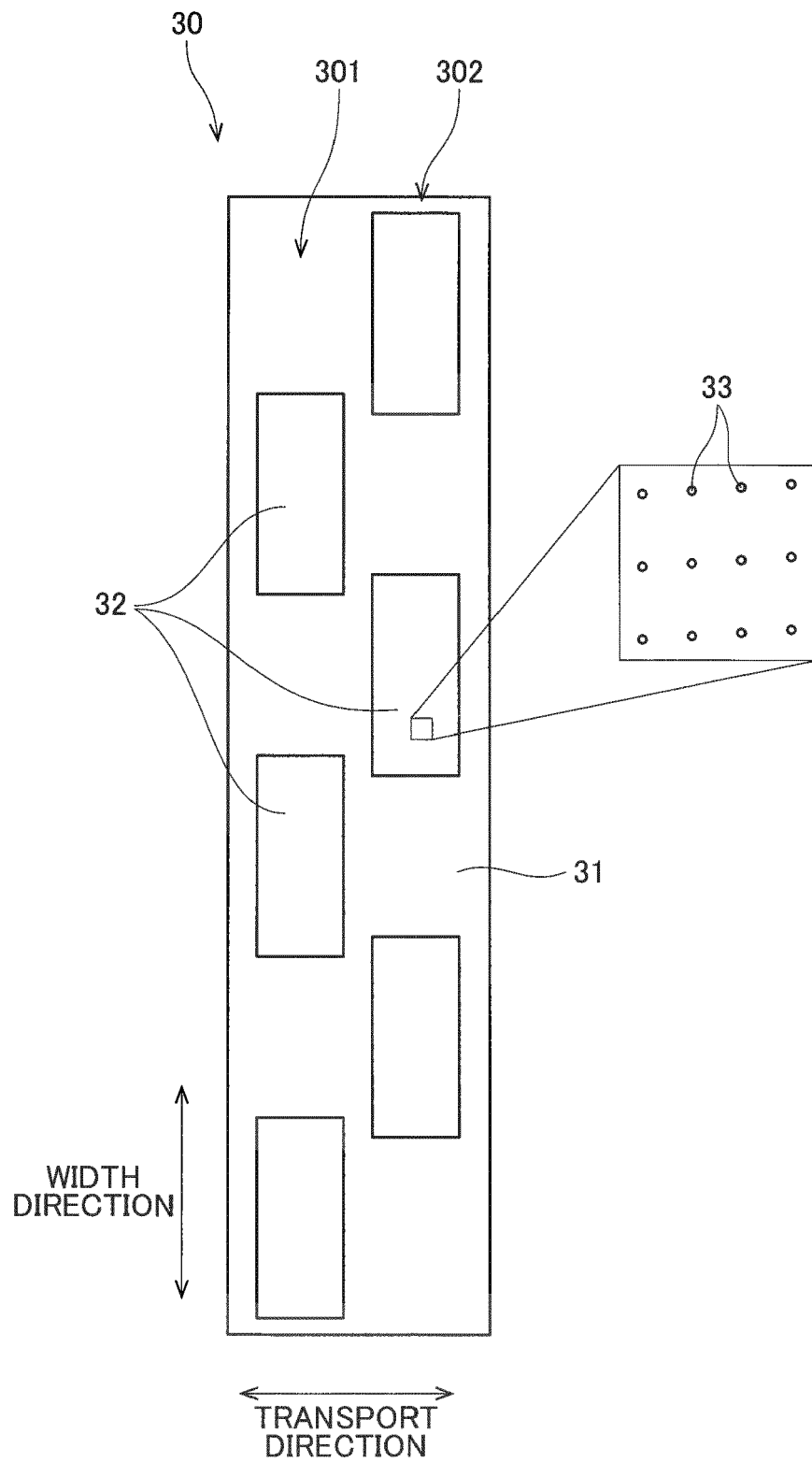


Fig. 3

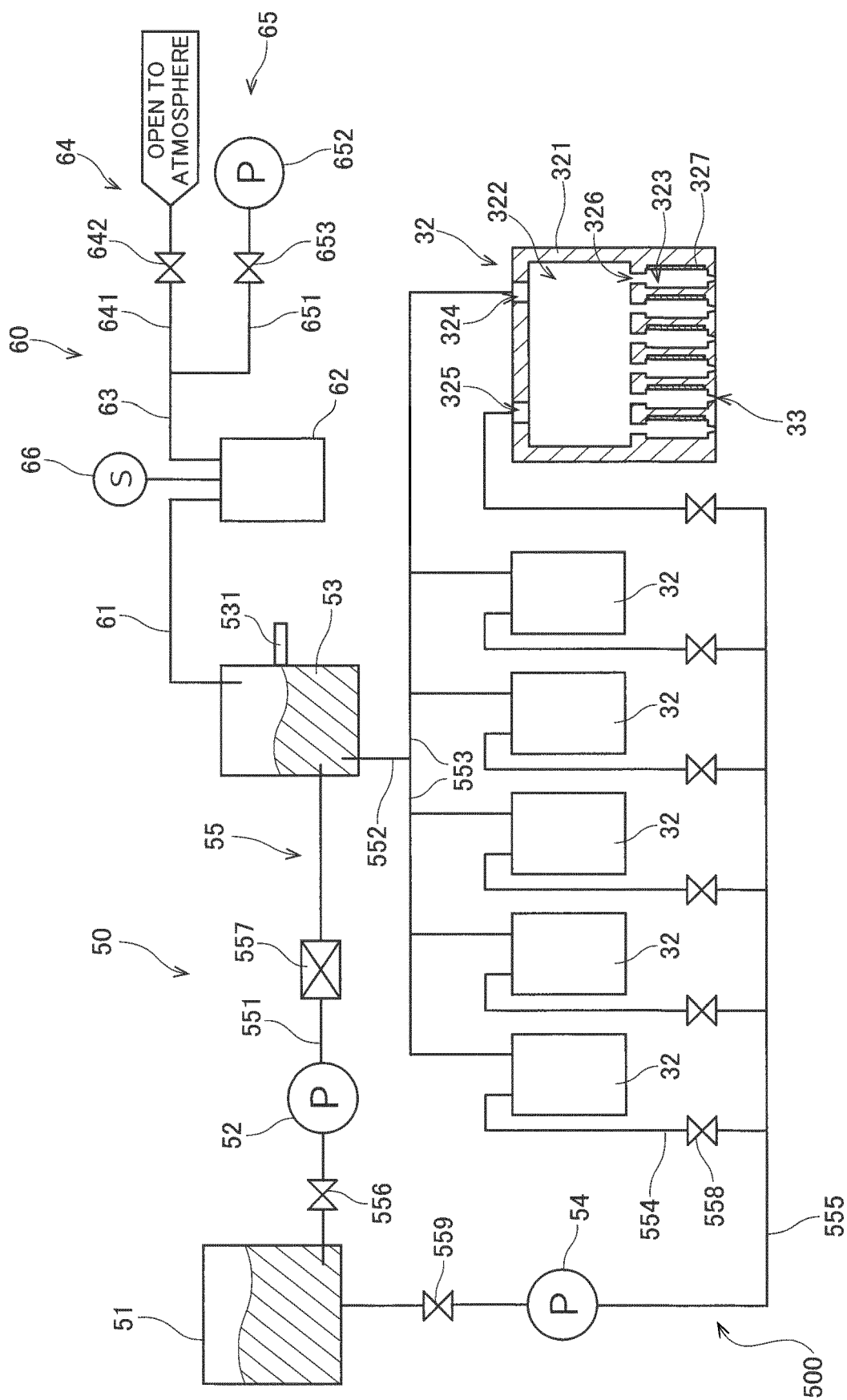


Fig. 4

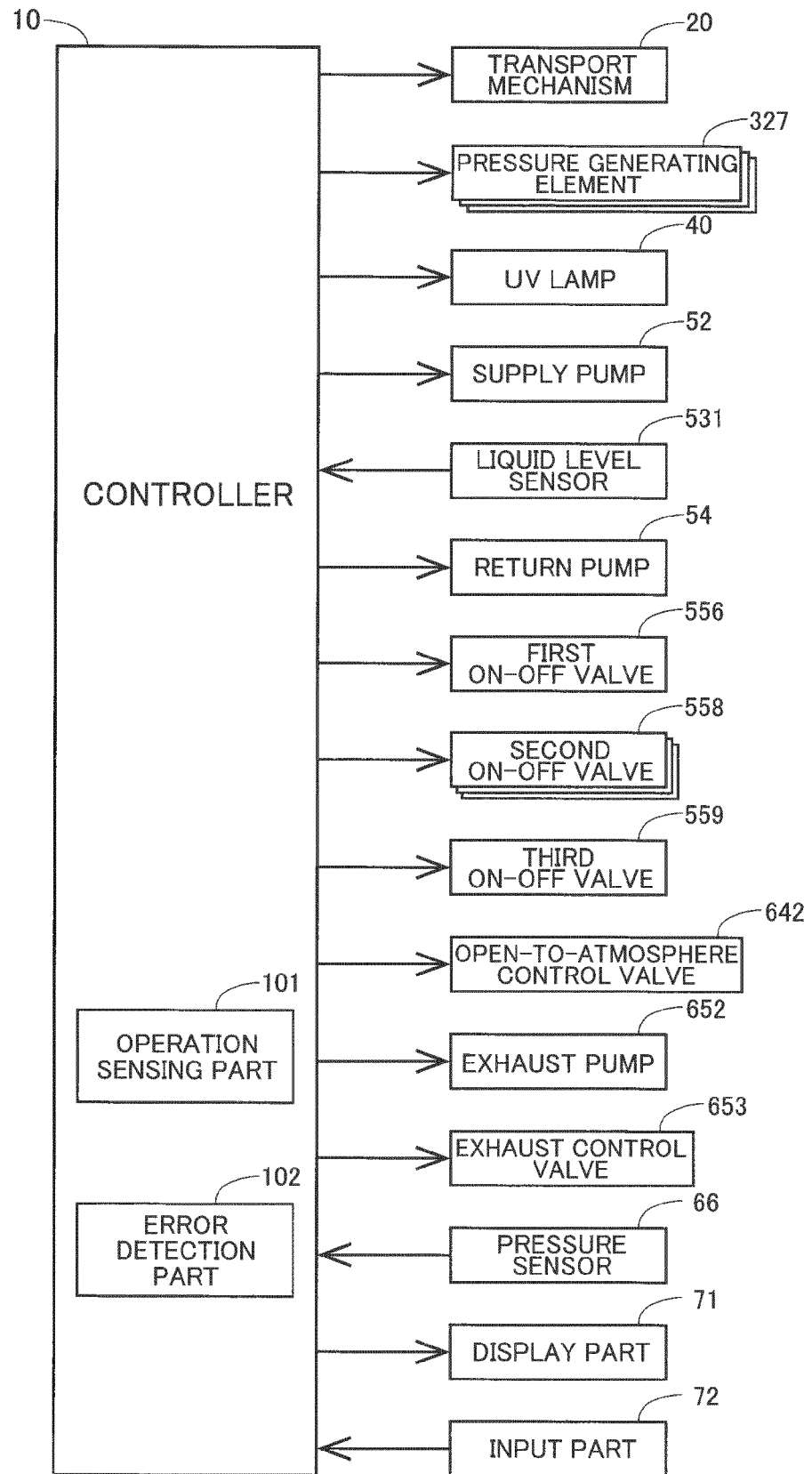


Fig. 5

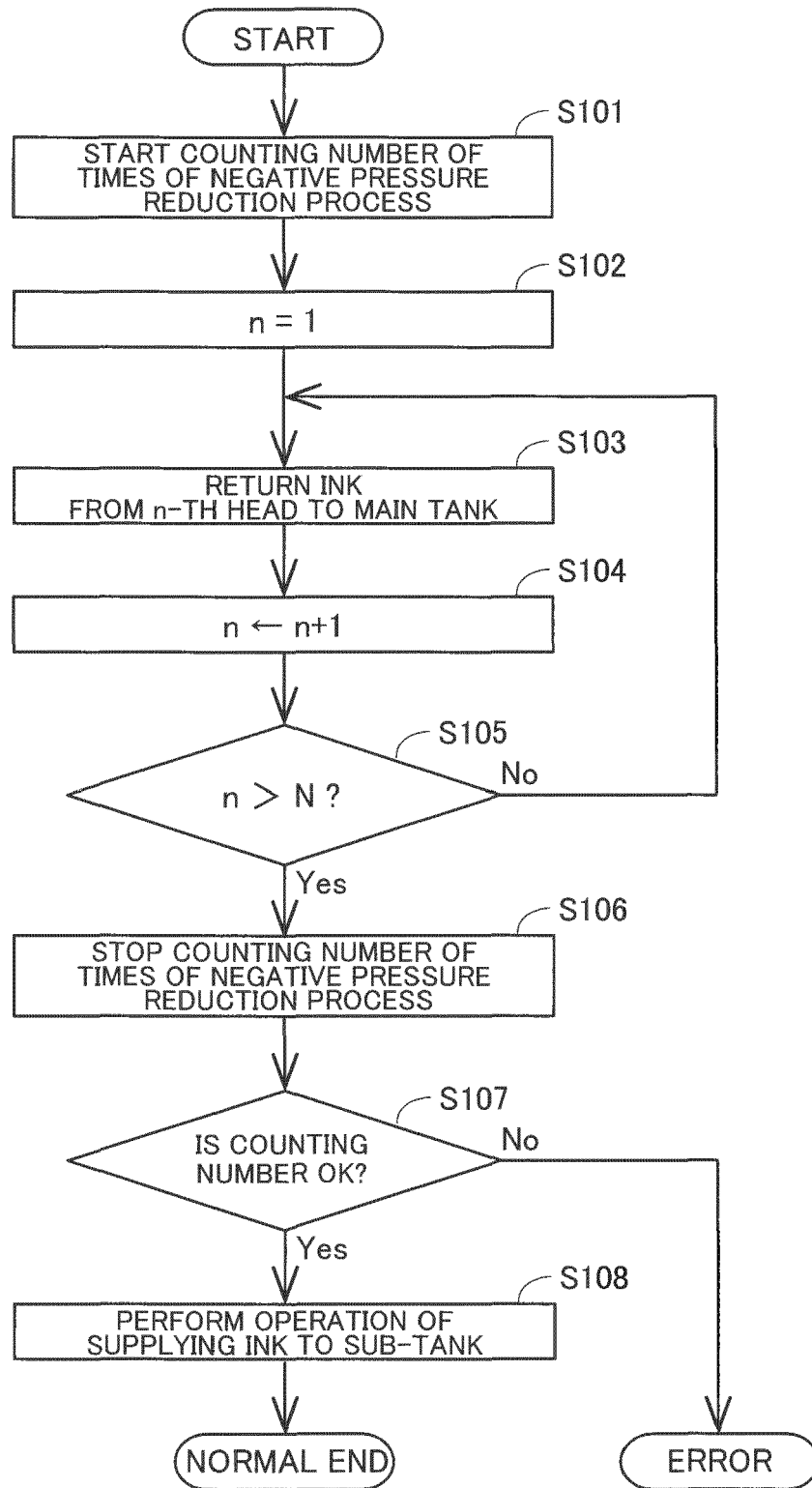


Fig. 6

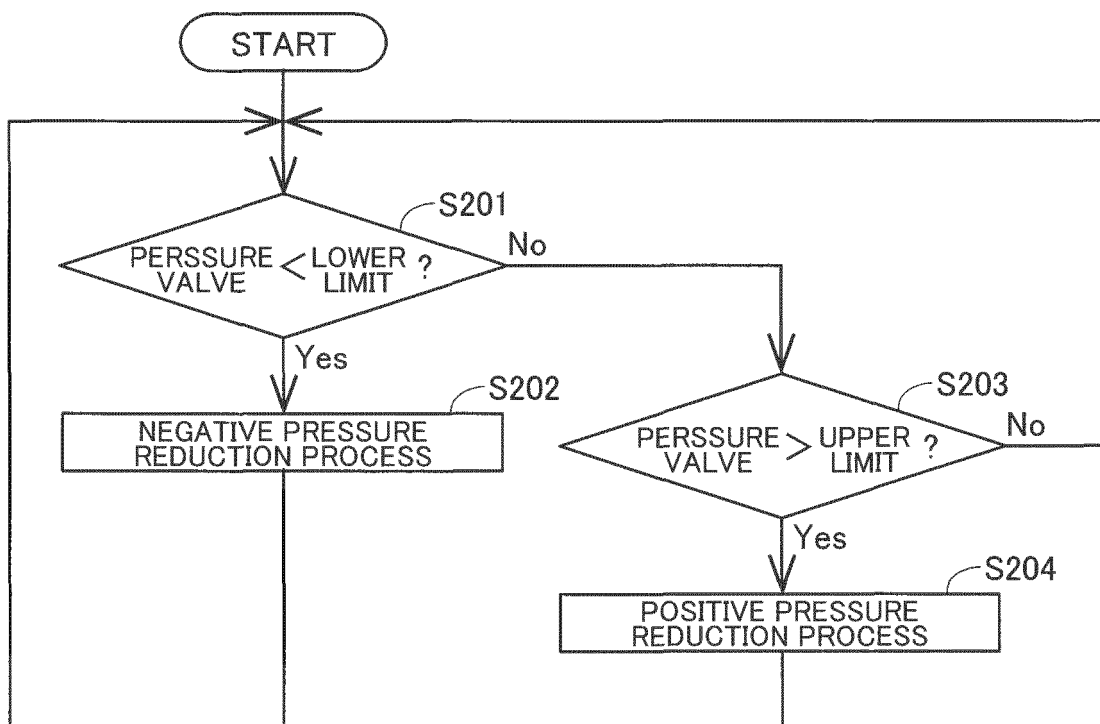


Fig. 7

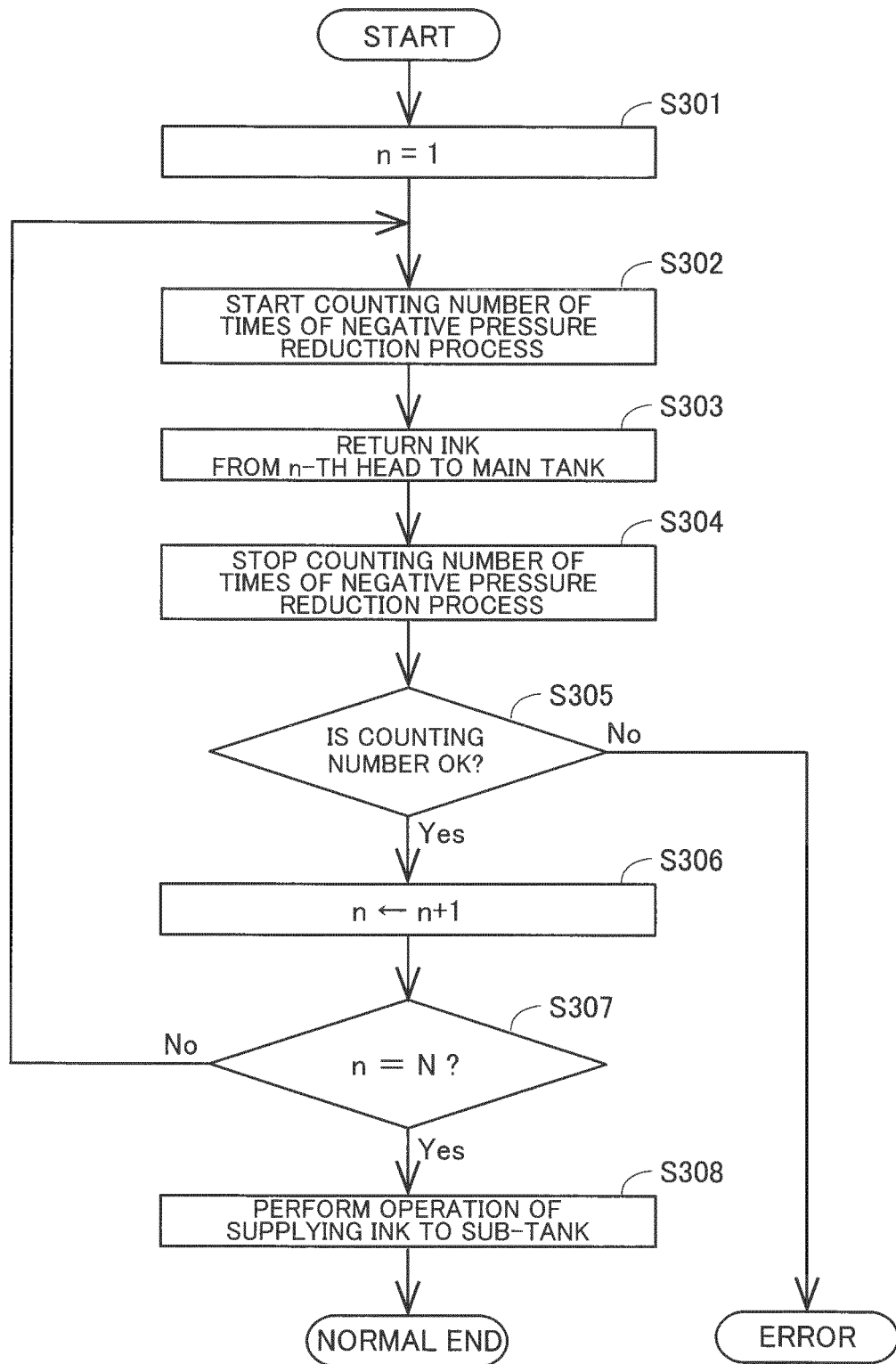
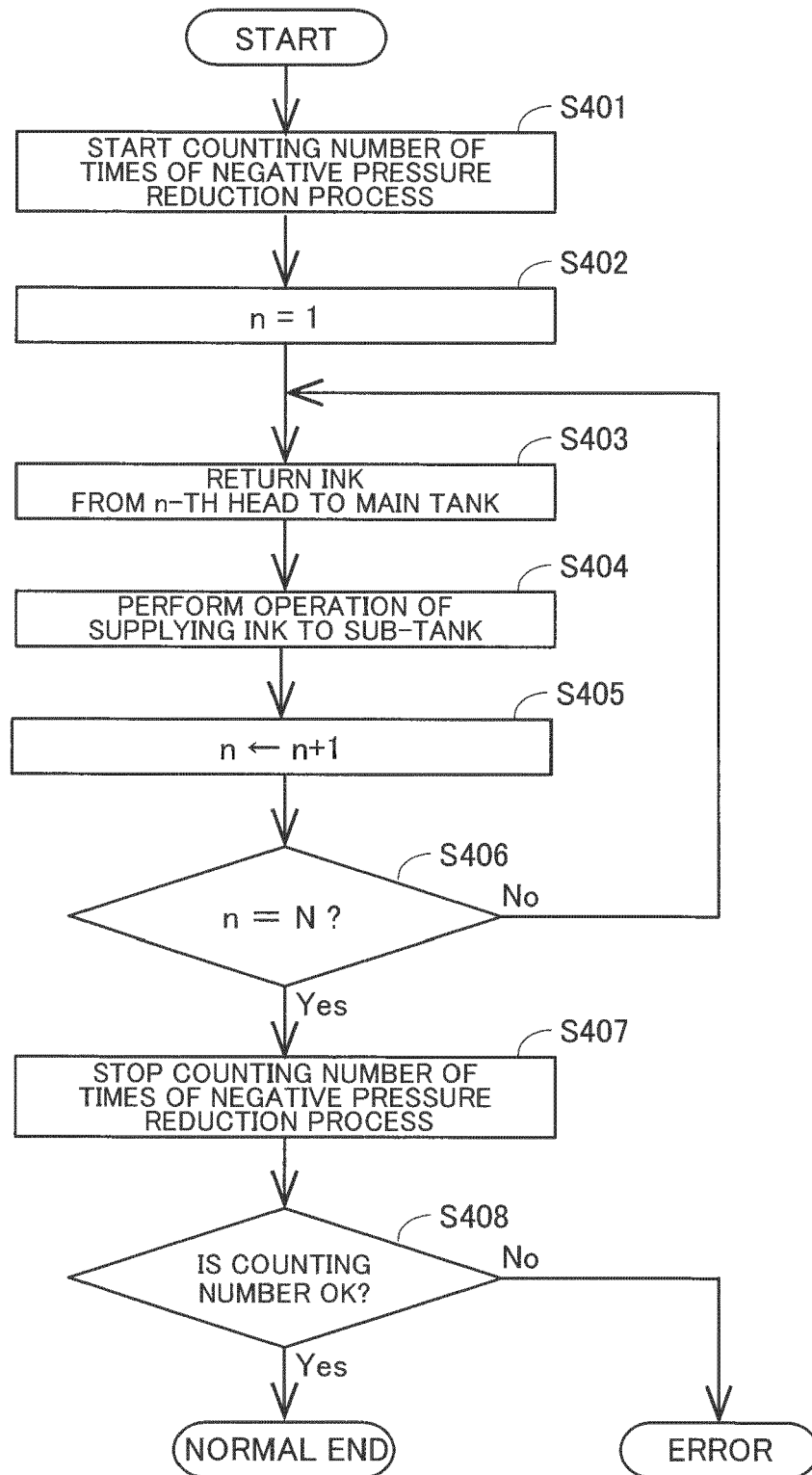


Fig. 8





EUROPEAN SEARCH REPORT

Application Number
EP 16 20 1862

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Place of search The Hague		Date of completion of the search 22 May 2017	Examiner Bitane, Rehab
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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