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Yoshii et al.

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(54) **LIQUID EJECTION HEAD AND LIQUID
EJECTION APPARATUS**

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(Continued)

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CPC **B41J 2/175** (2013.01); **B41J 2/14**
(2013.01); **B41J 2/17596** (2013.01); **B41J**
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(Continued)

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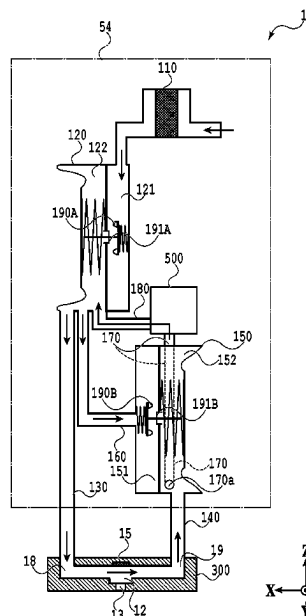
Primary Examiner — Justin Seo

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Division

(57) **ABSTRACT**

A liquid ejection head includes a pressure chamber, an upstream channel, a downstream channel, a pump, an inflow channel, and a bypass channel. The upstream channel communicates with the pressure chamber to supply the liquid to the pressure chamber. The downstream channel communicates with the pressure chamber. The pump communicates with the upstream channel and the downstream channel to cause the liquid in the downstream channel to flow into the upstream channel. The inflow channel communicates with the upstream channel to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel. The upstream channel and the downstream channel communicate with each other through the bypass channel without the pressure chamber being between the upstream channel and the downstream channel. Part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

20 Claims, 30 Drawing Sheets



- (51) **Int. Cl.**
B41J 2/18 (2006.01)
B41J 2/19 (2006.01)
- (52) **U.S. Cl.**
CPC *B41J 2/19* (2013.01); *B41J 2002/14467*
(2013.01); *B41J 2202/12* (2013.01)
- (58) **Field of Classification Search**
CPC B41J 2202/12; B41J 2/17563; B41J 29/38;
B41J 2/14145; B41J 2202/19; B41J
2202/20; B41J 2/045; B41J 2/04501;
B41J 2/14209; B41J 2/1753
See application file for complete search history.

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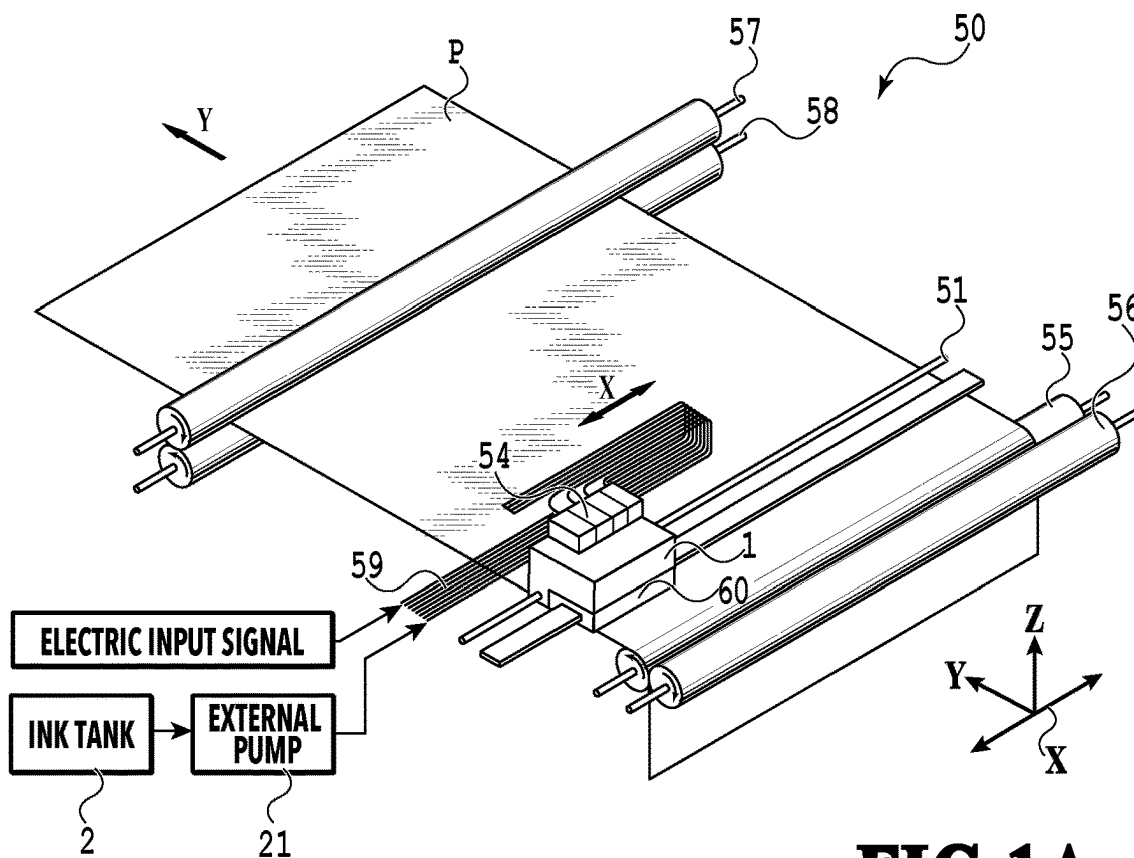


FIG.1A

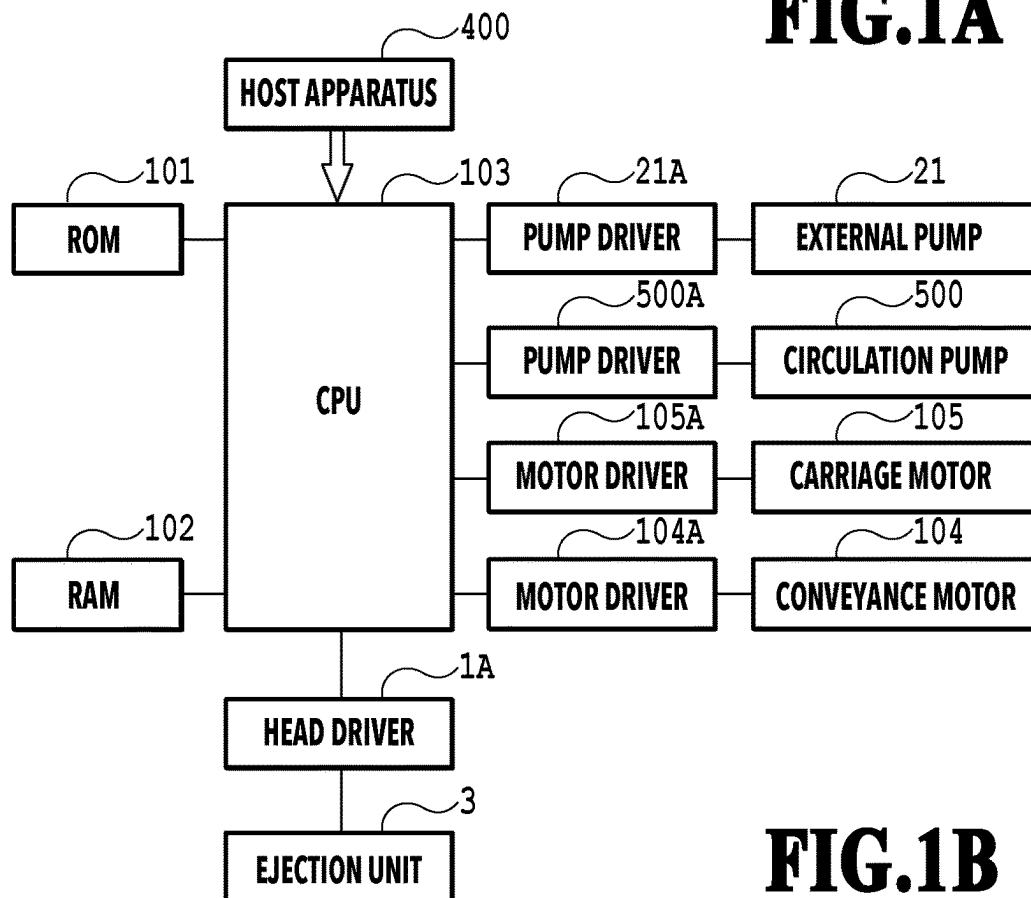


FIG.1B

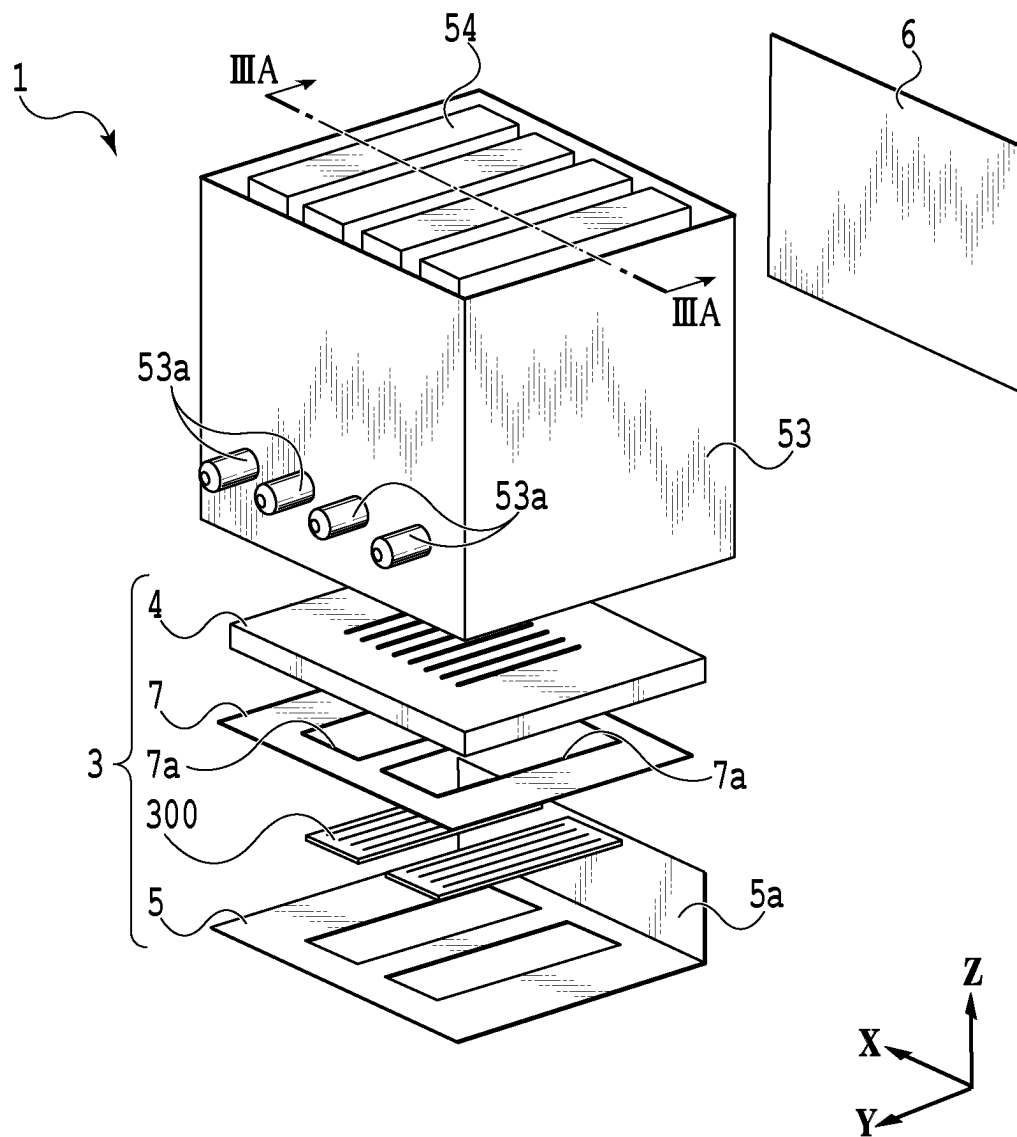


FIG.2

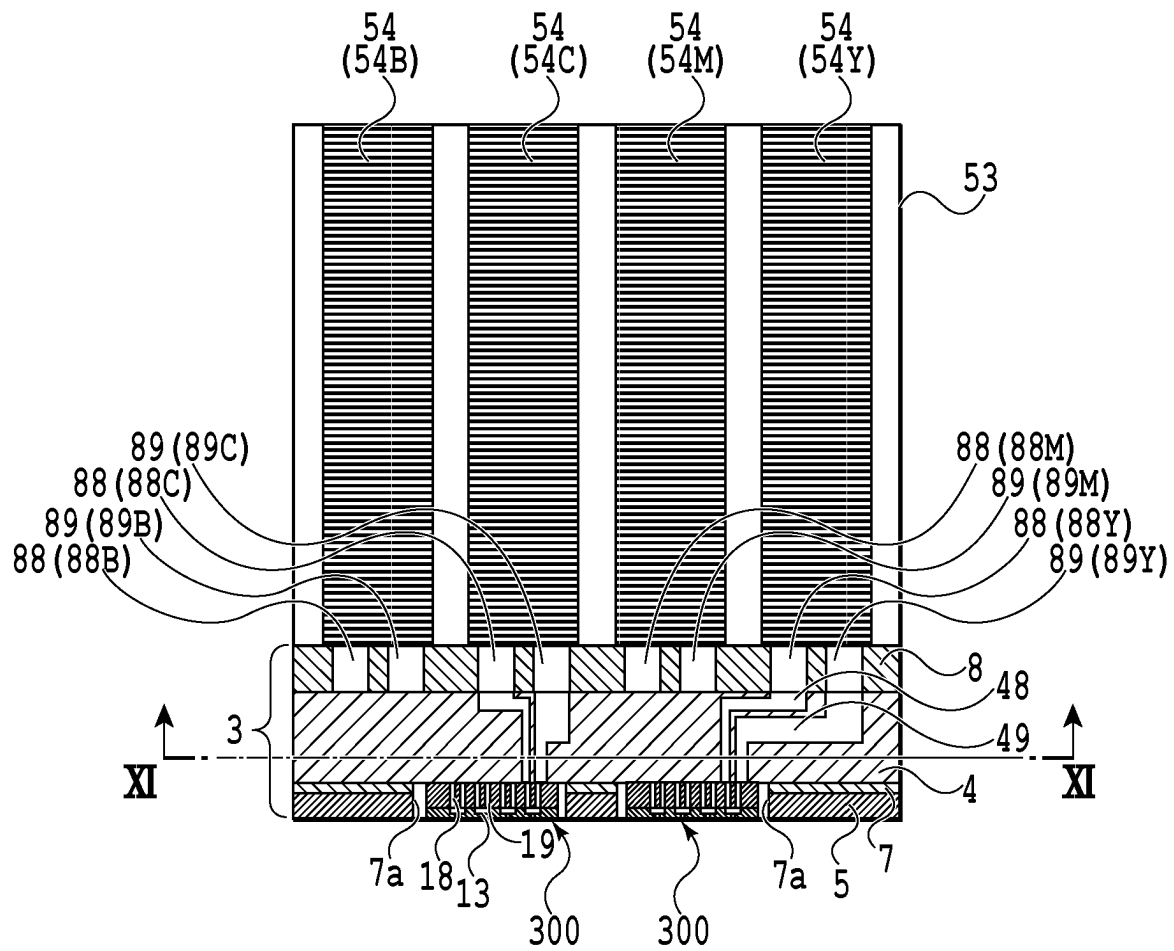


FIG. 3A

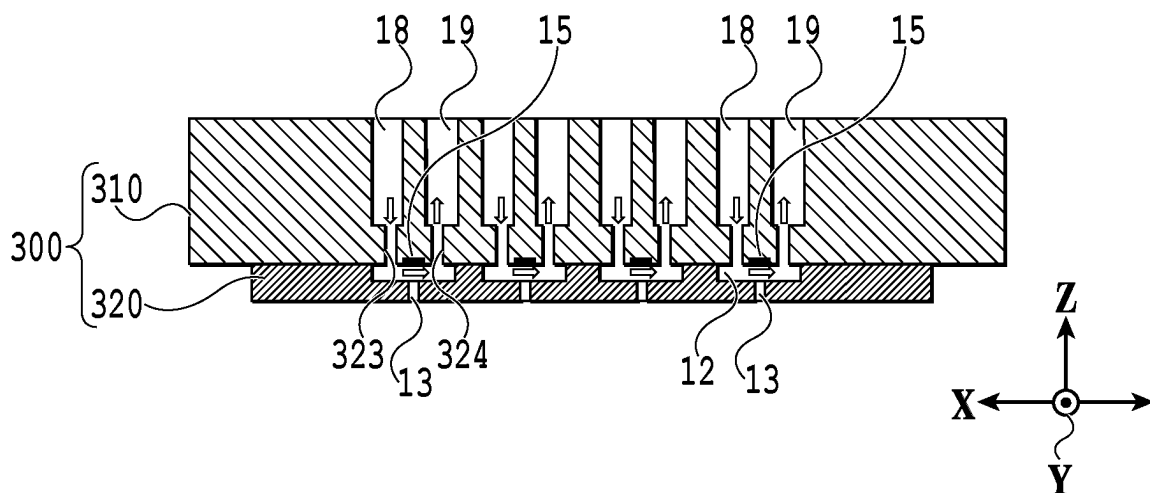
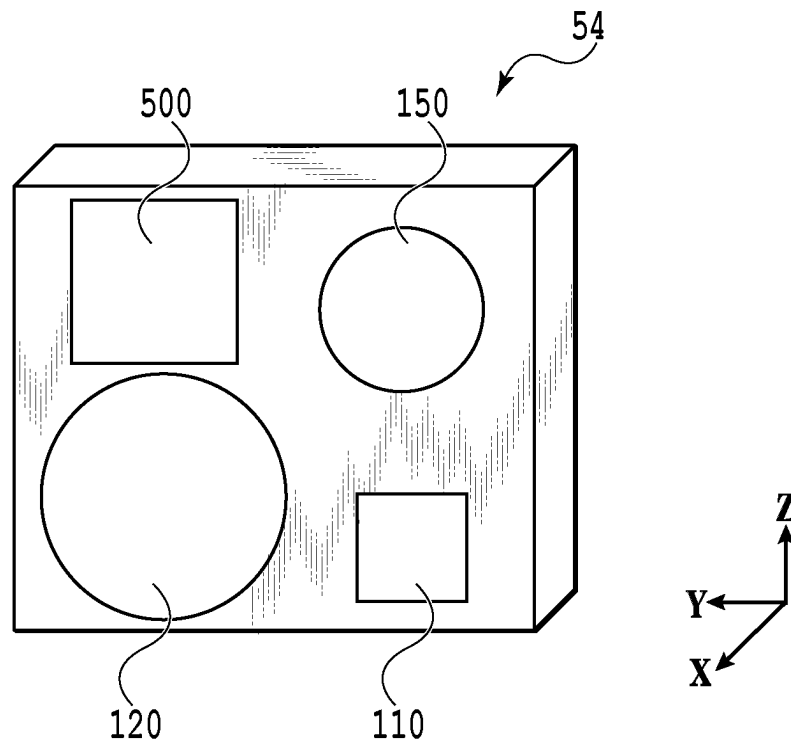


FIG. 3B

**FIG. 4**

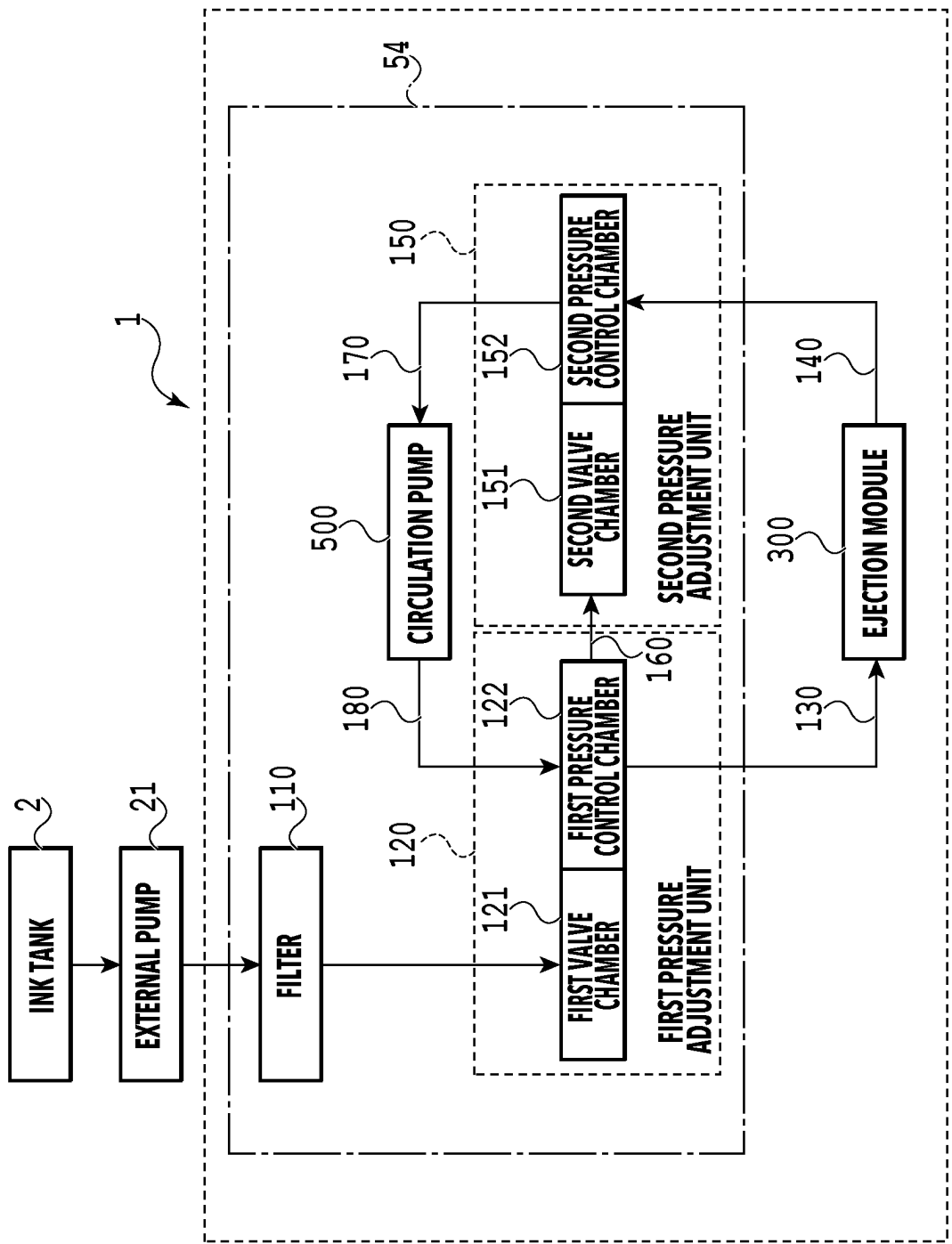


FIG. 6

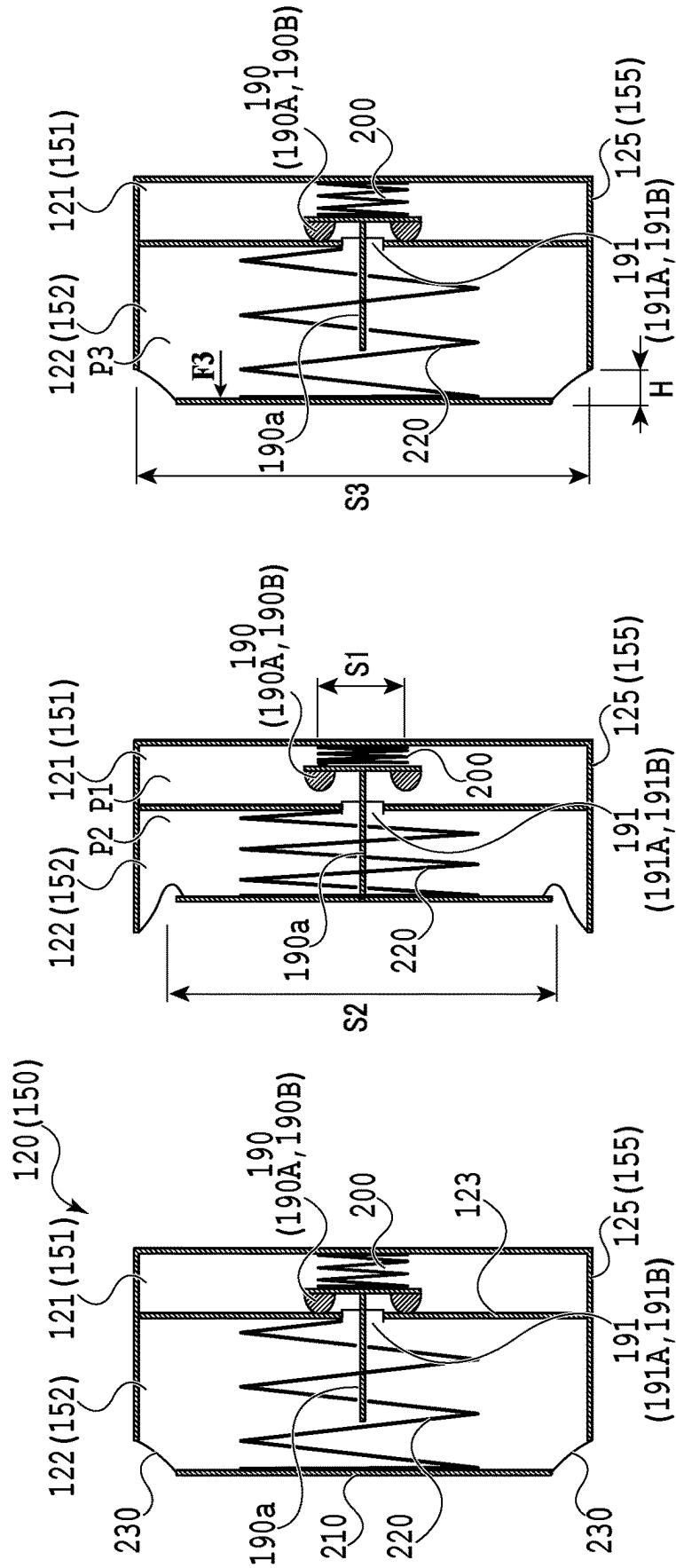


FIG. 7A

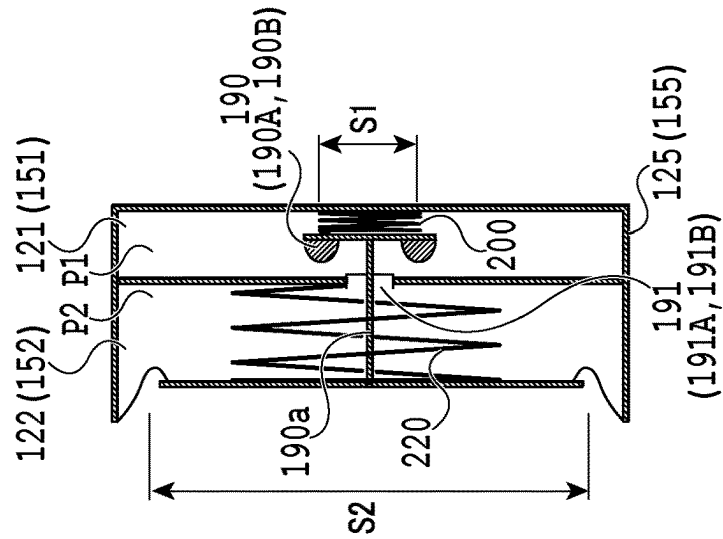


FIG. 7B

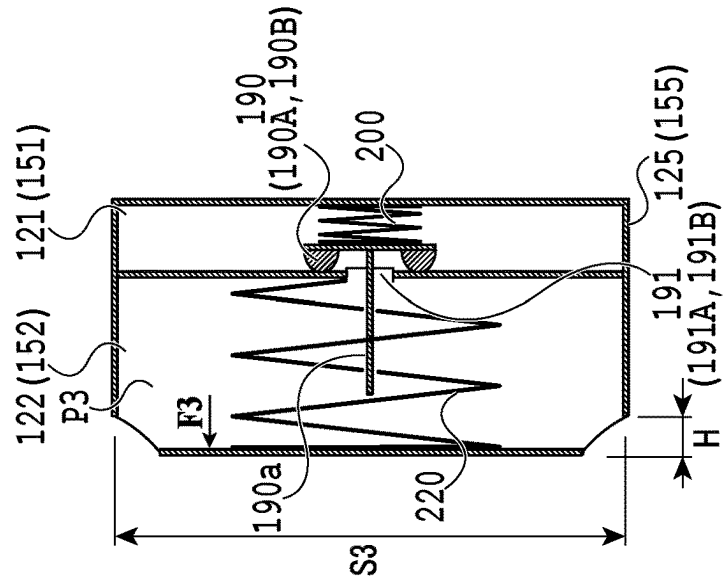


FIG. 7C

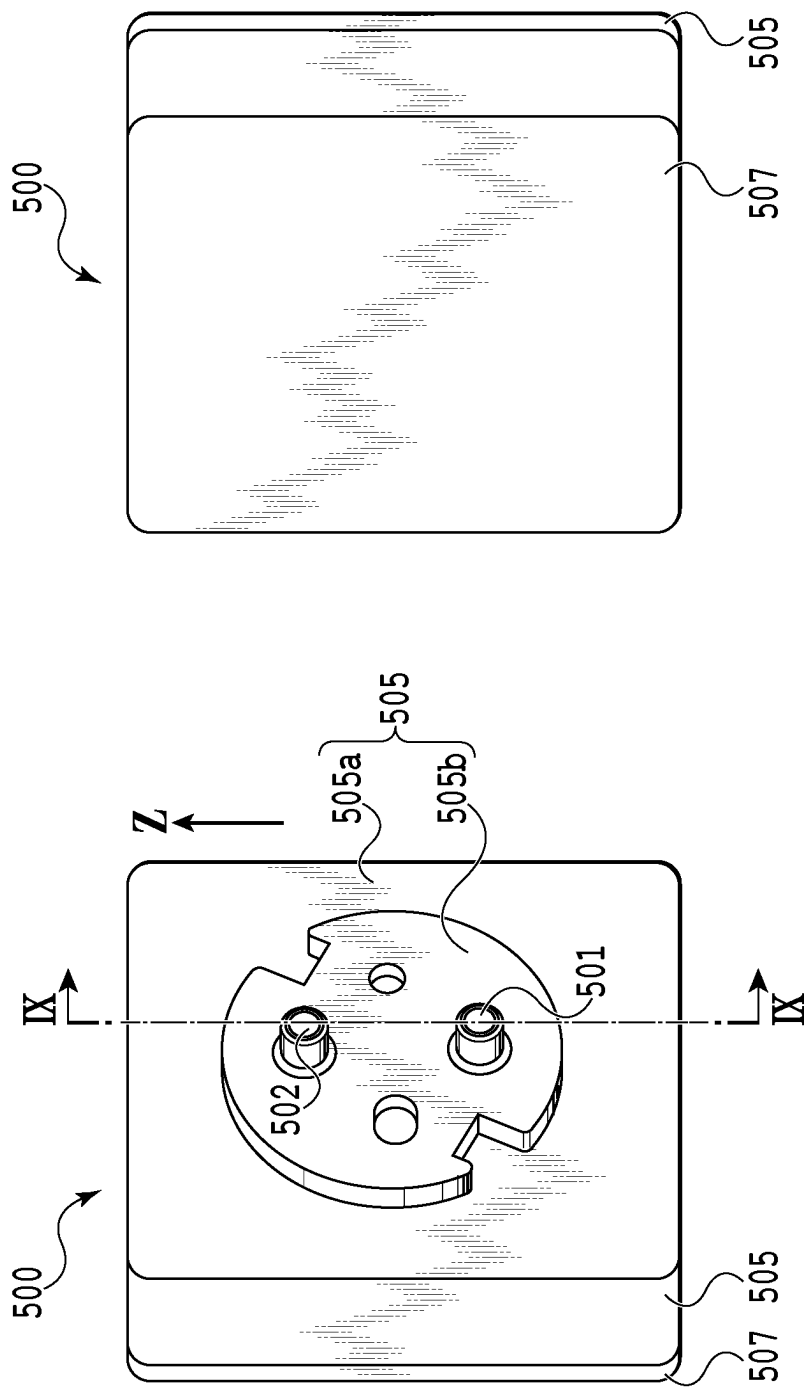


FIG. 8B

FIG. 8A

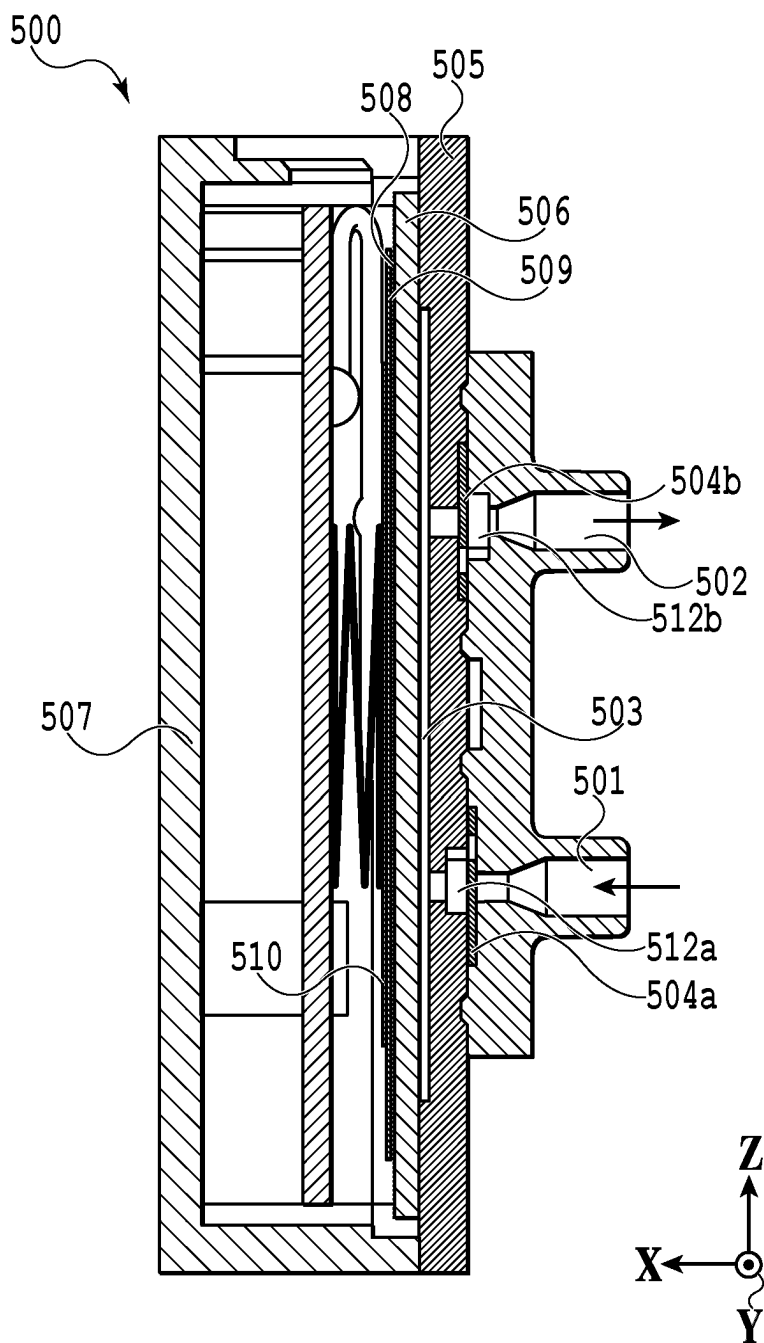
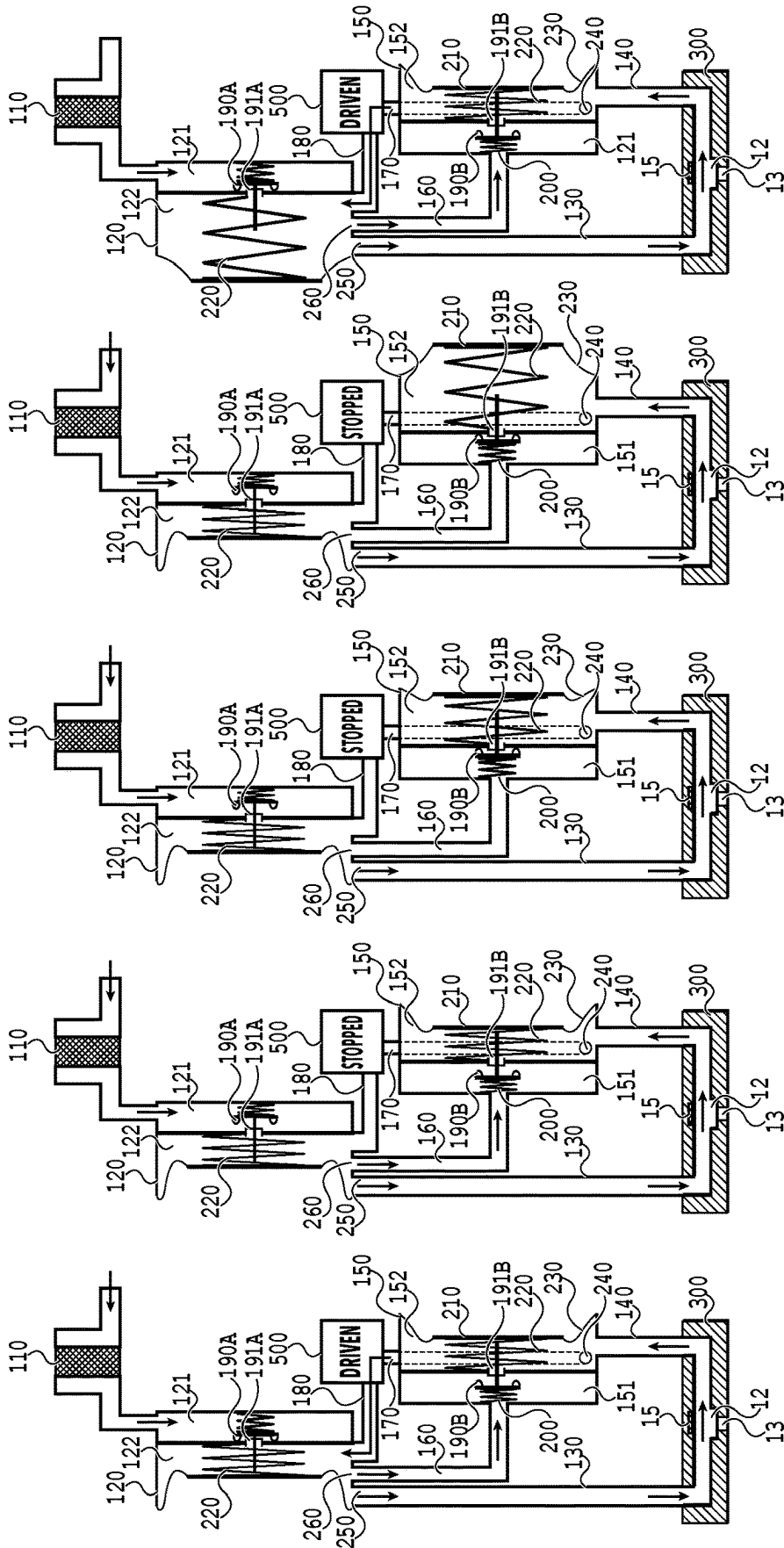
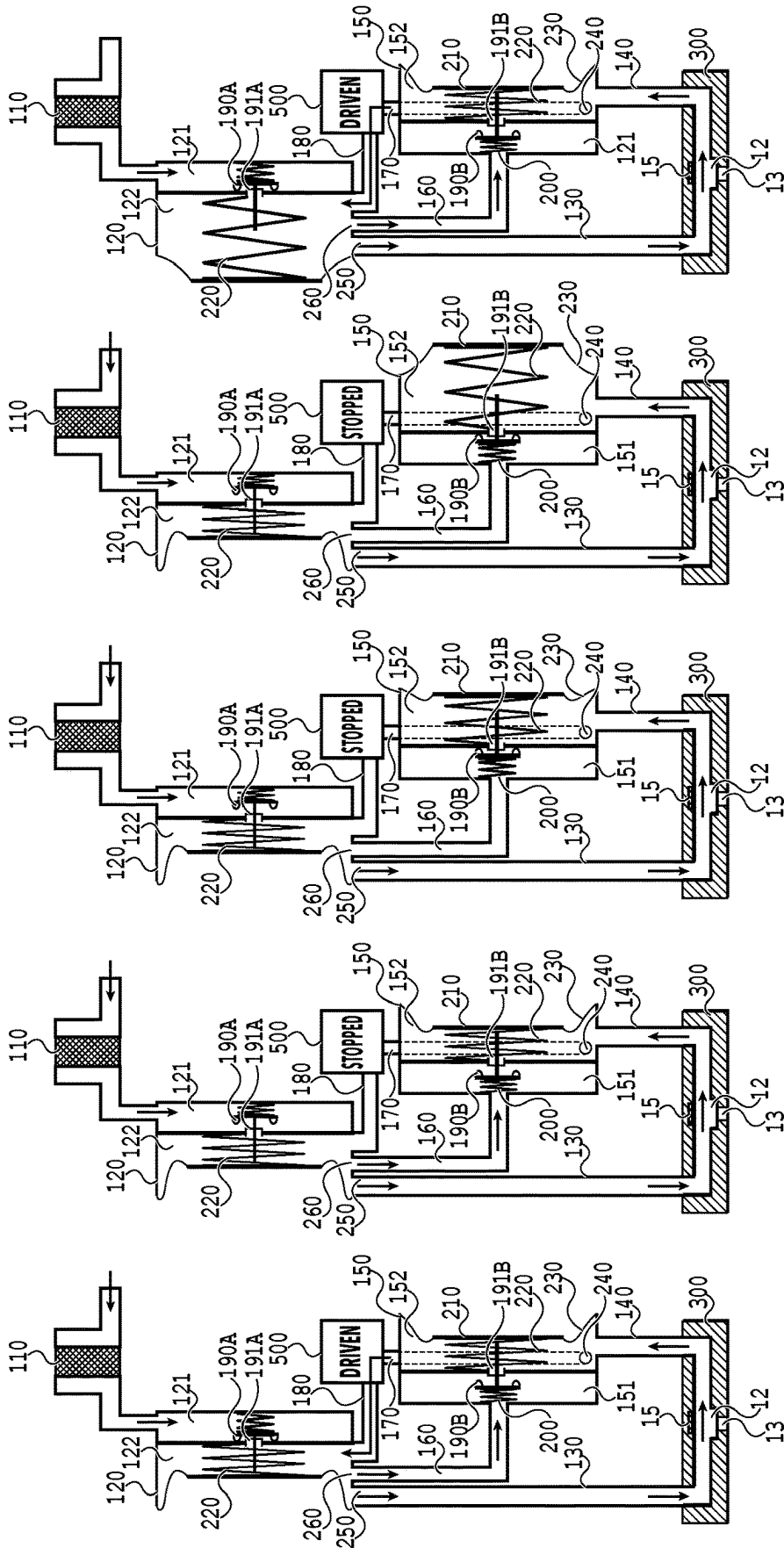
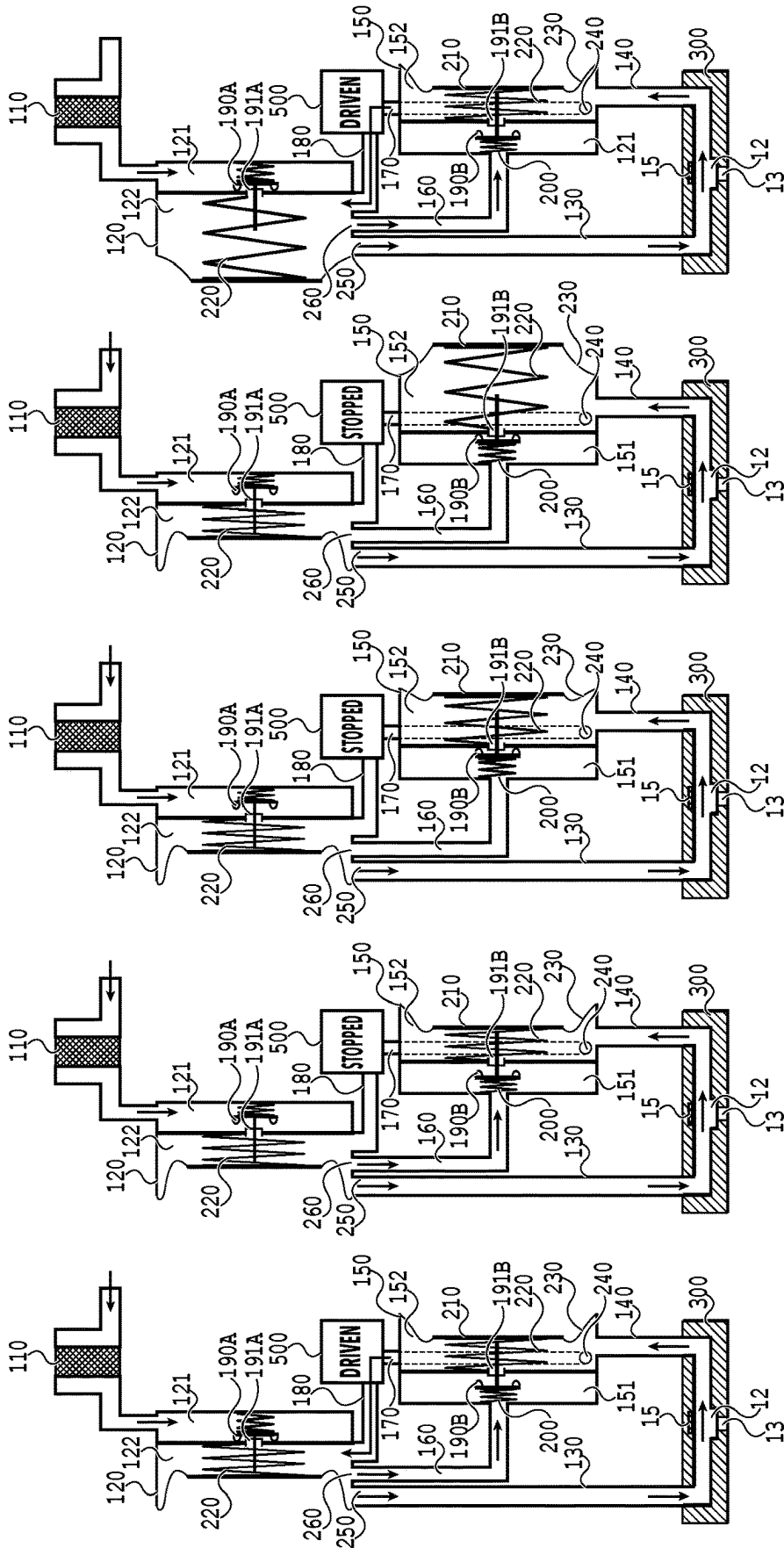
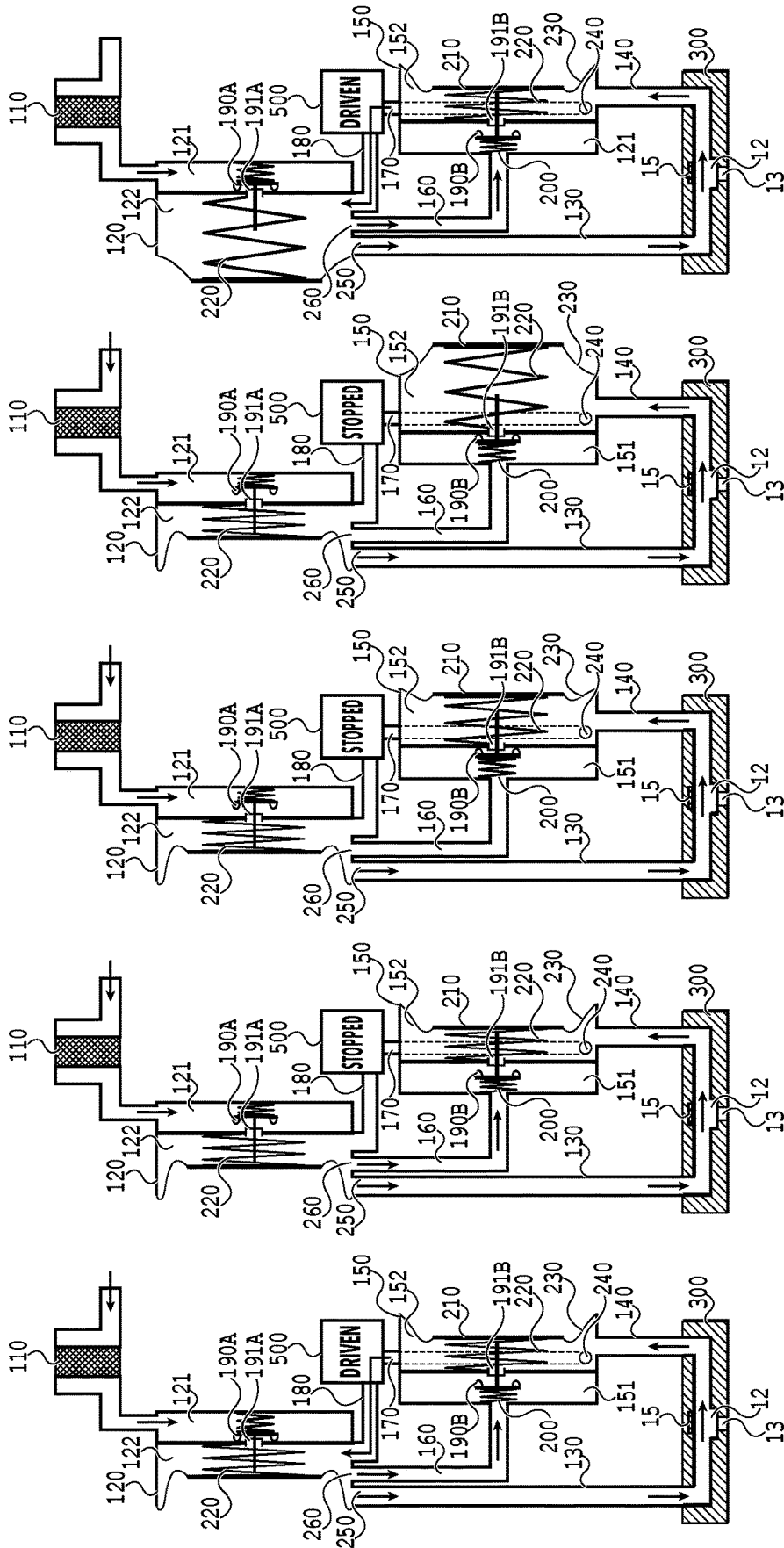
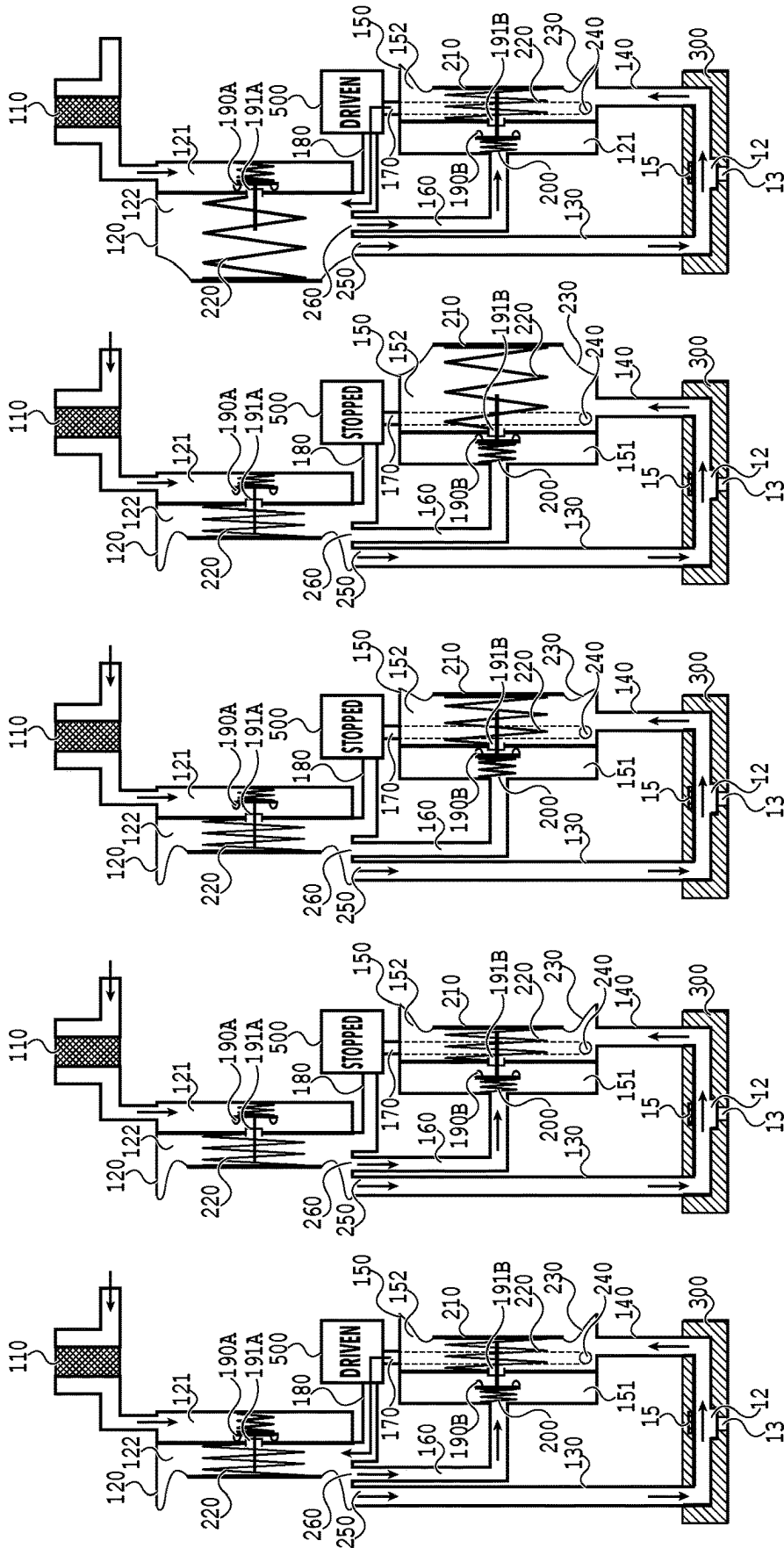


FIG.9



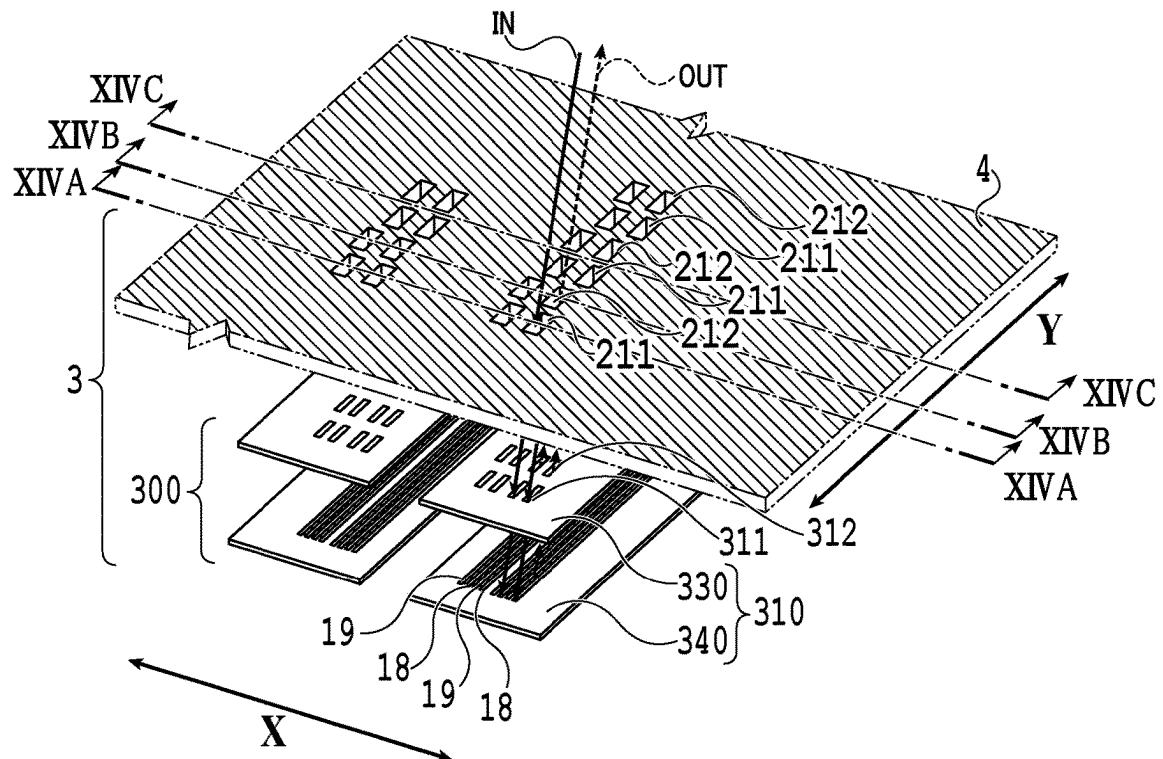


FIG.11A

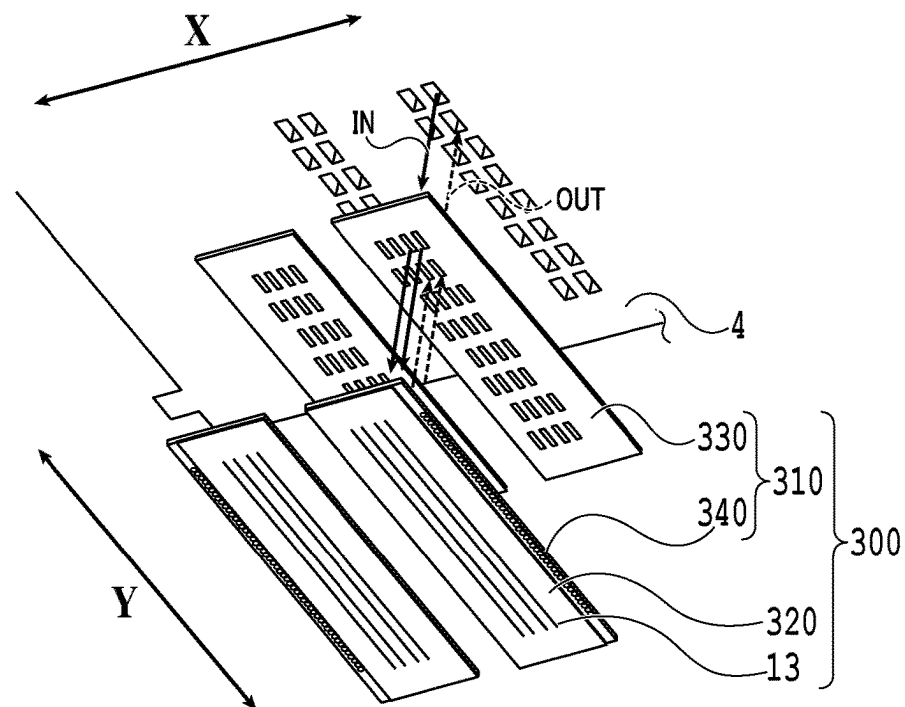


FIG.11B

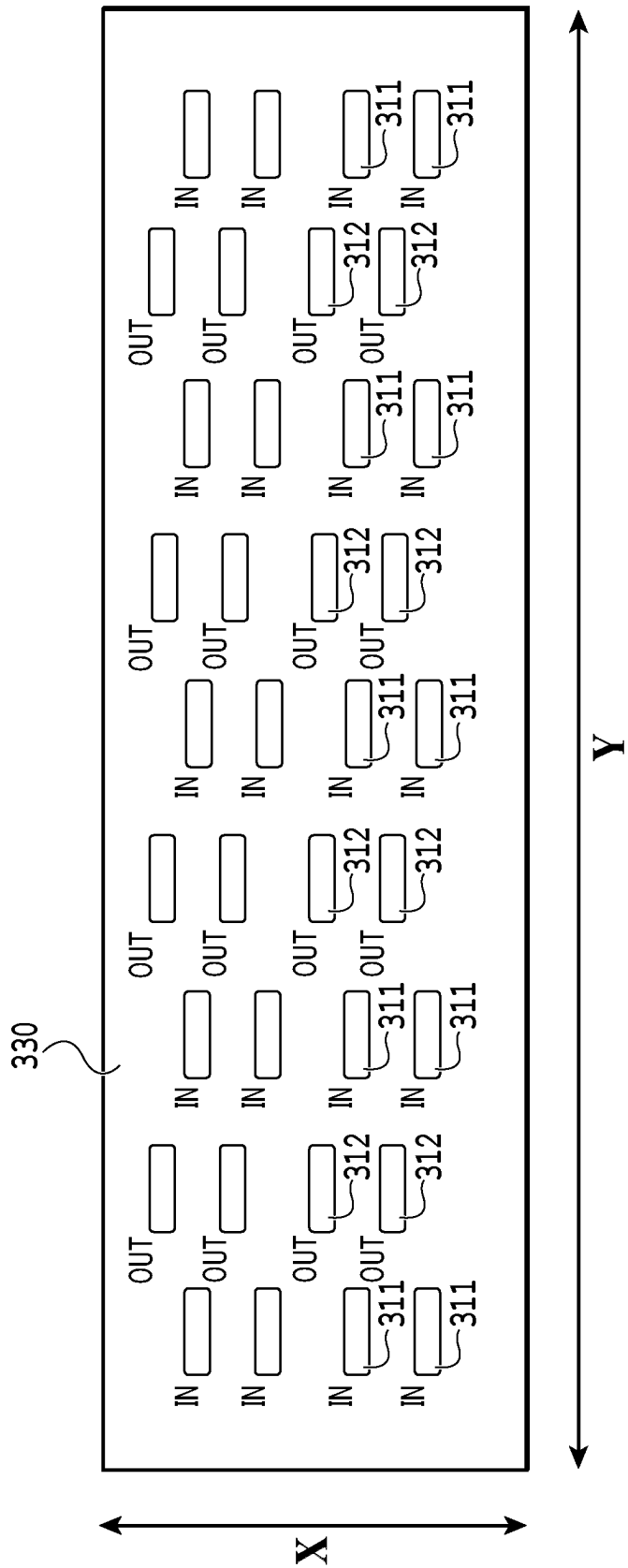


FIG.12

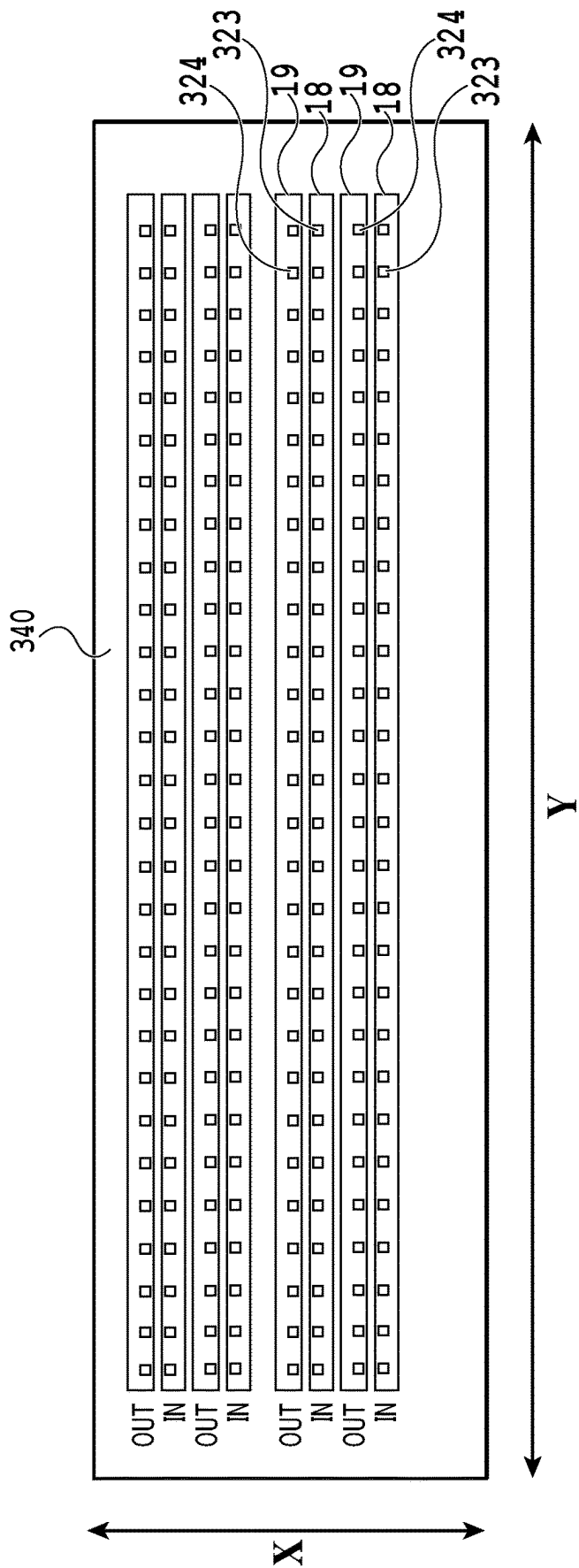


FIG.13

FIG.14C

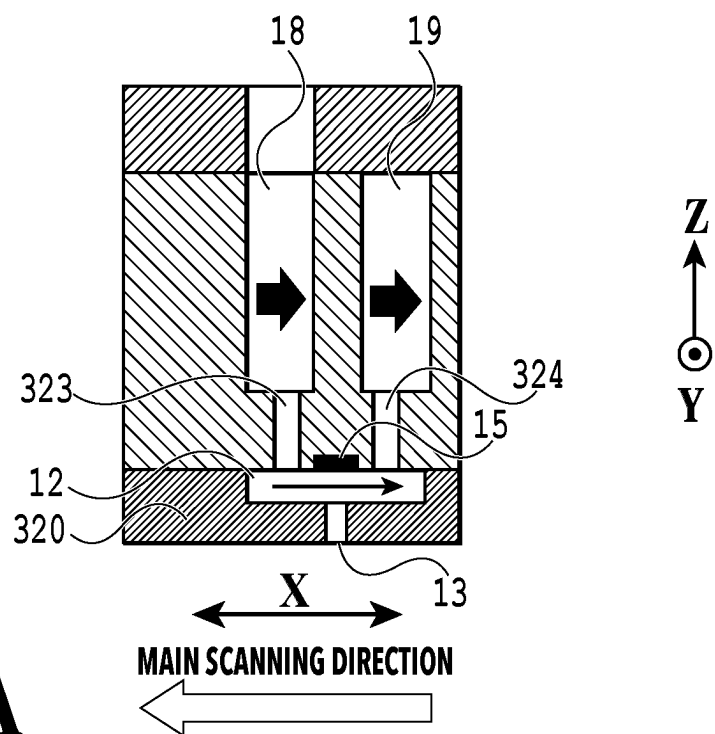


FIG.15A

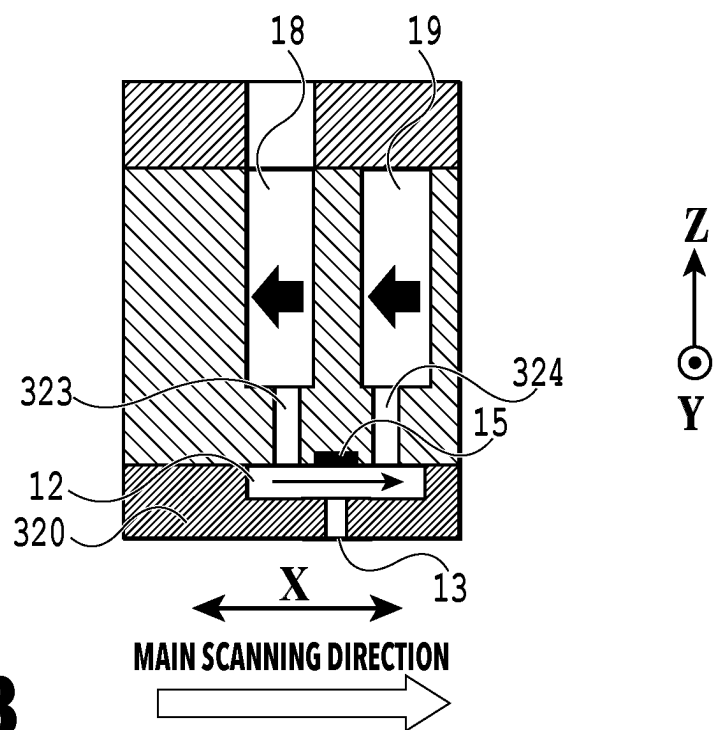


FIG.15B

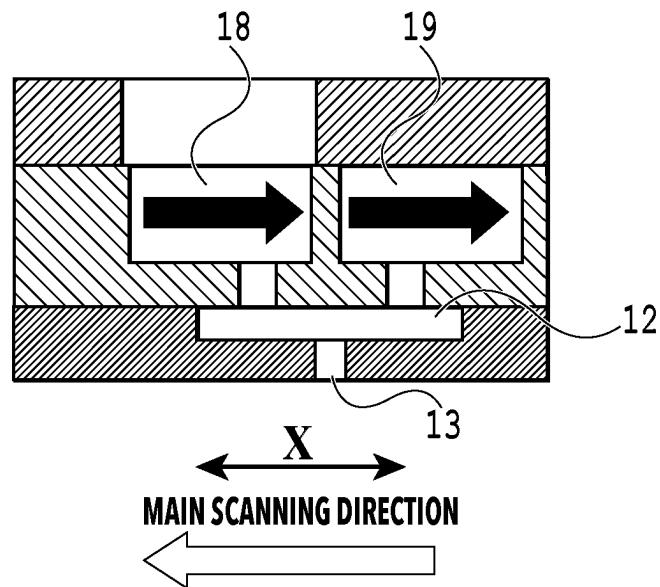


FIG.16A

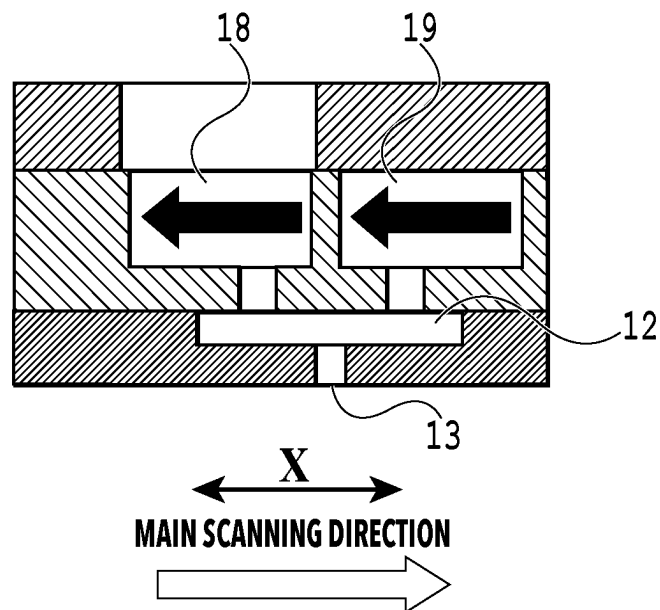


FIG.16B

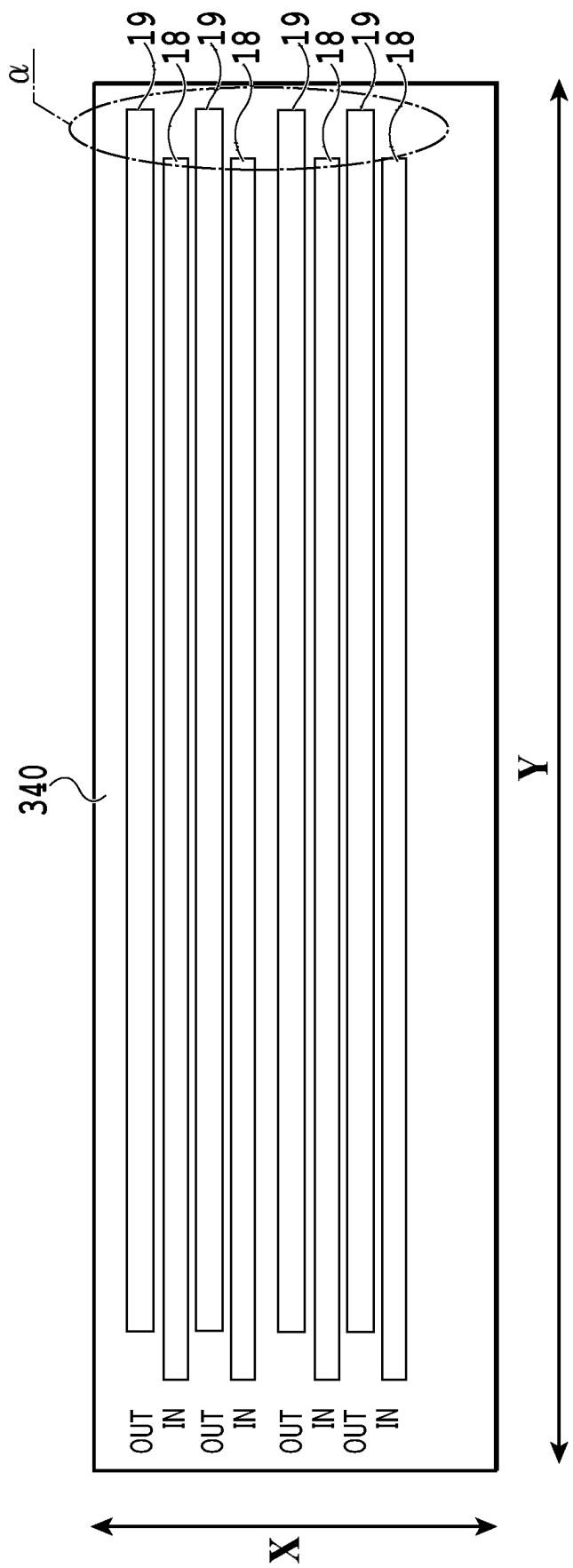


FIG.17

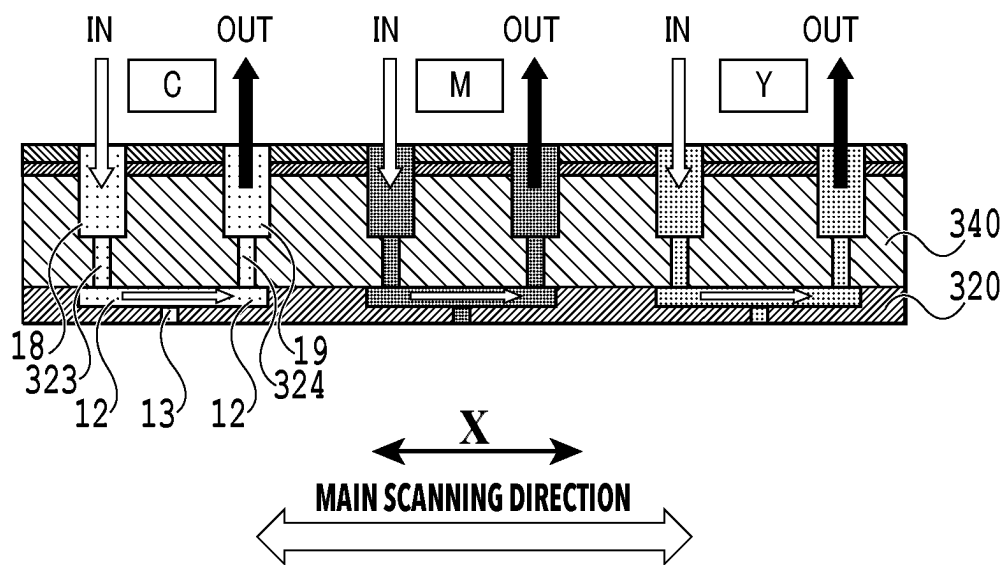


FIG.18A

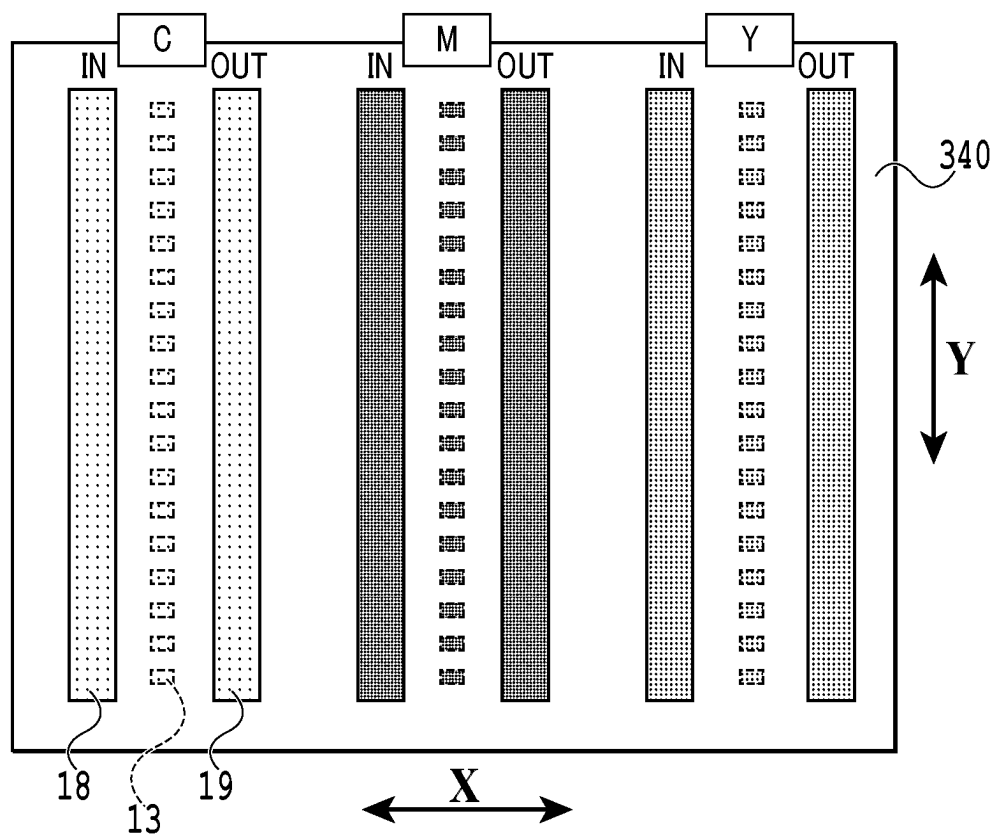


FIG.18B

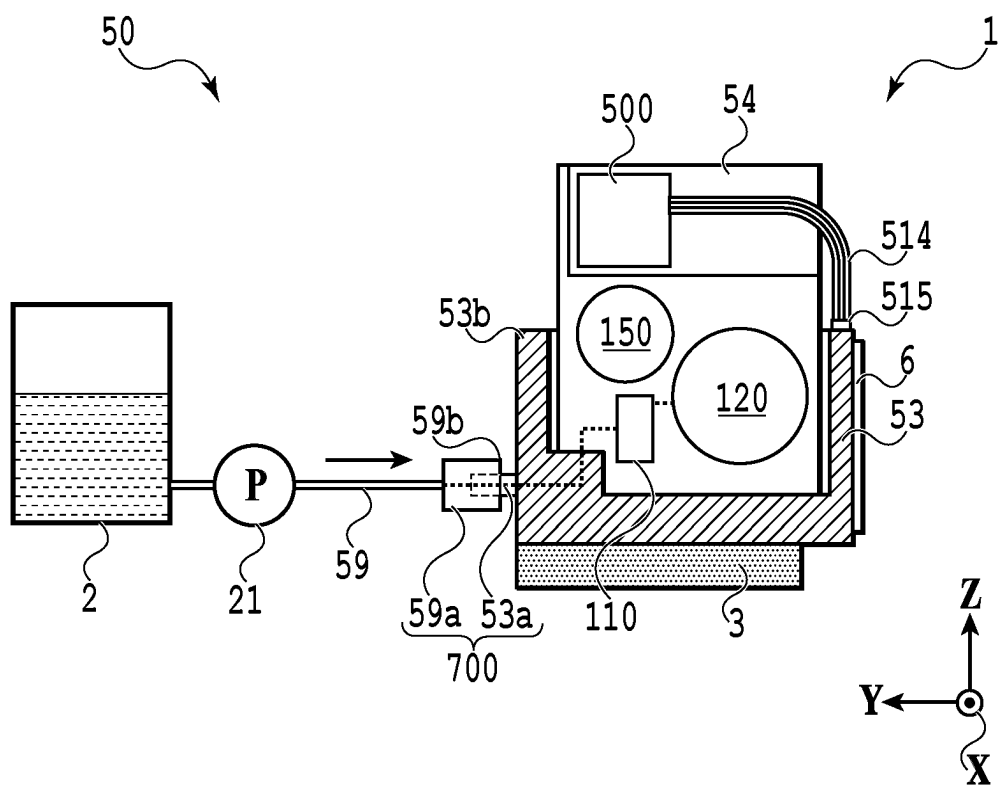


FIG.19

FIG.20A

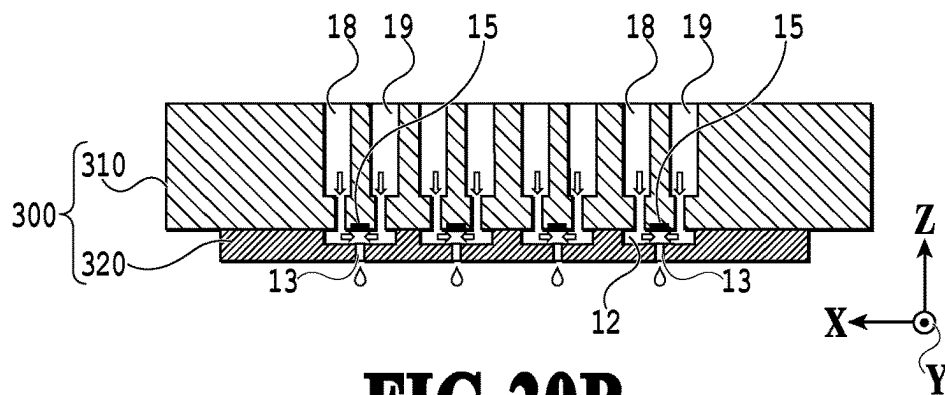
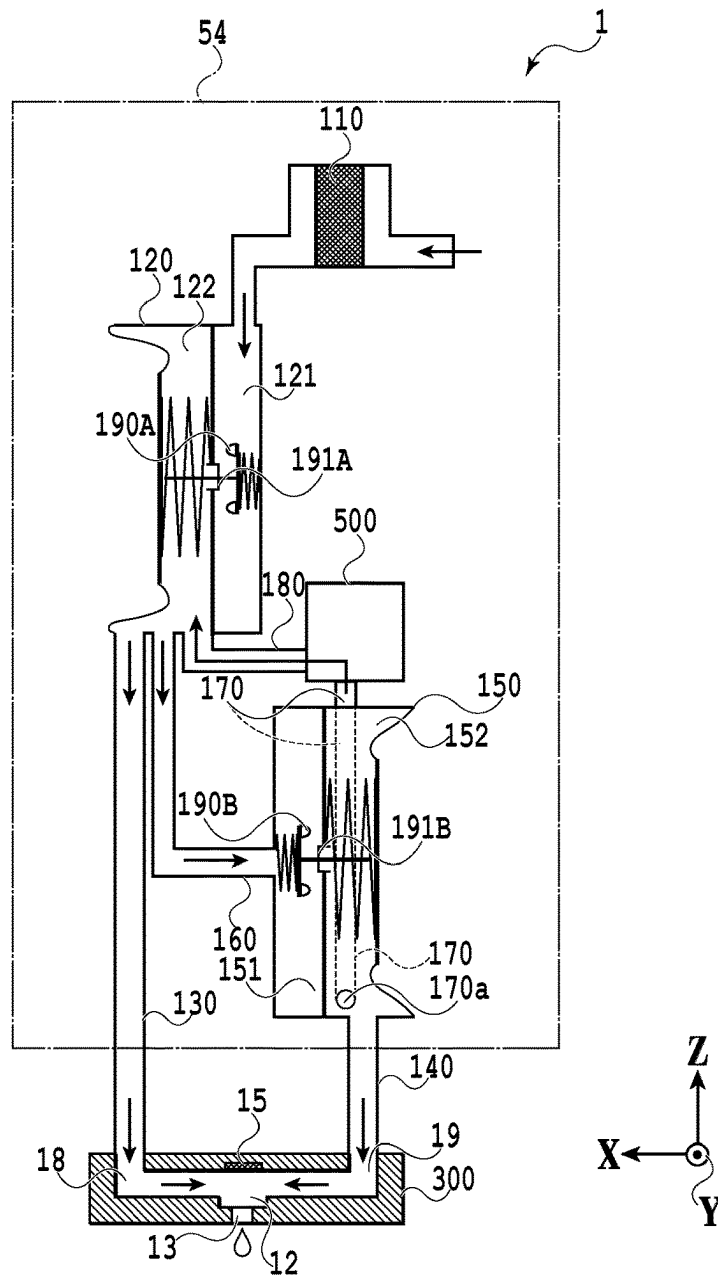


FIG.20B

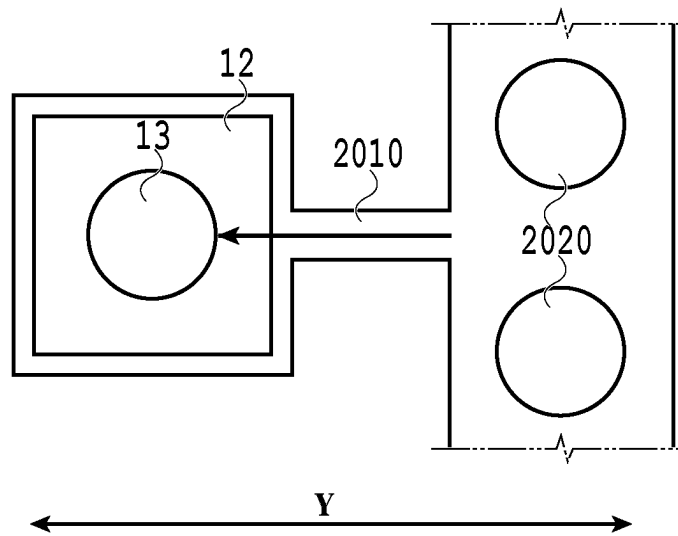


FIG.21A

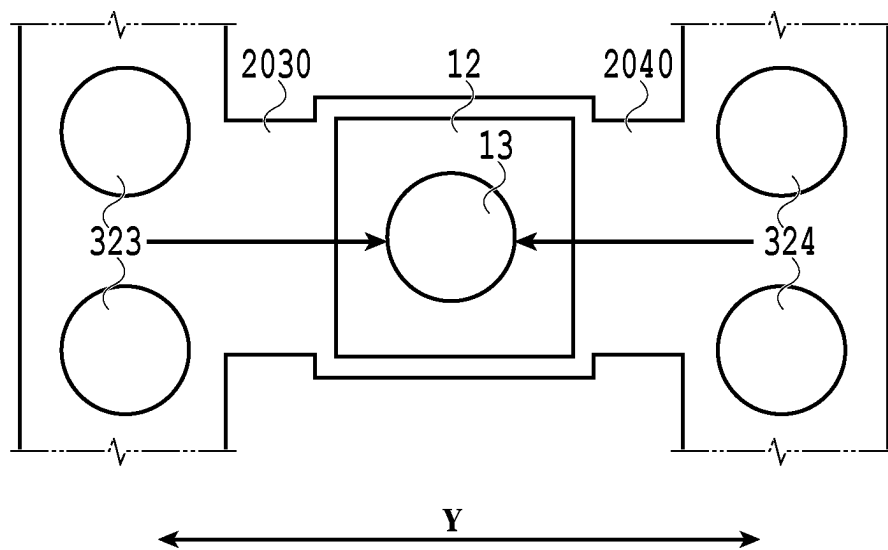
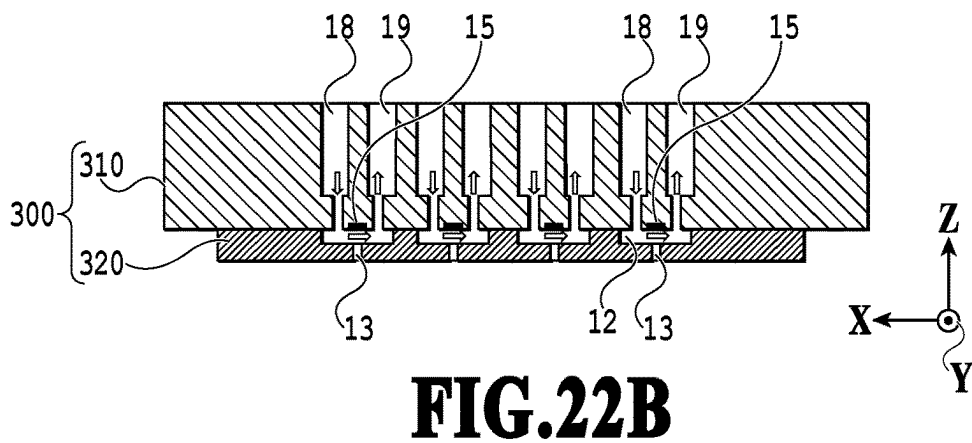
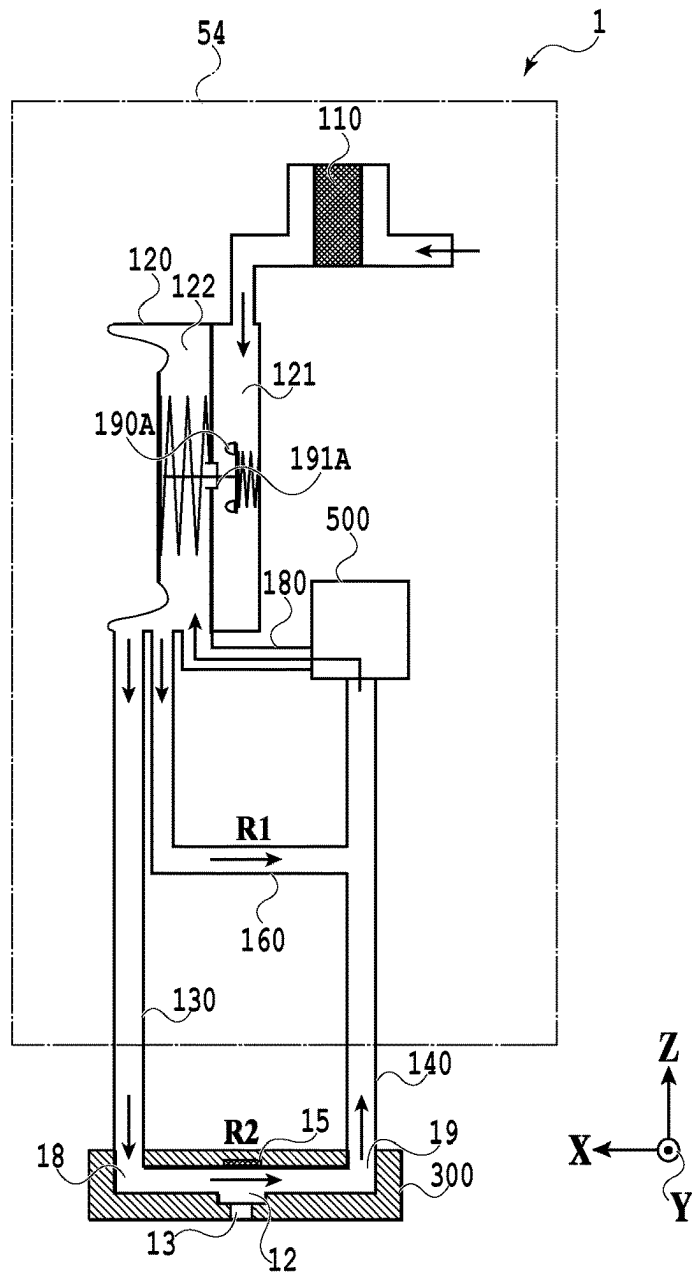


FIG.21B

FIG.22A



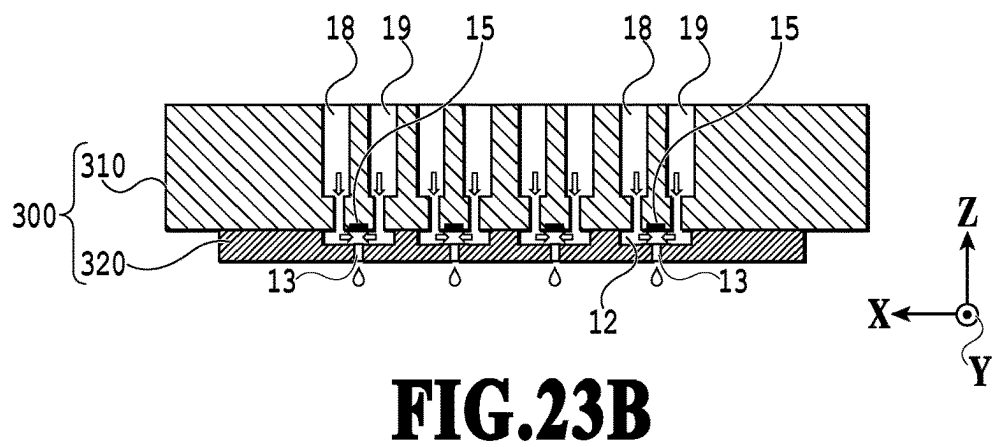
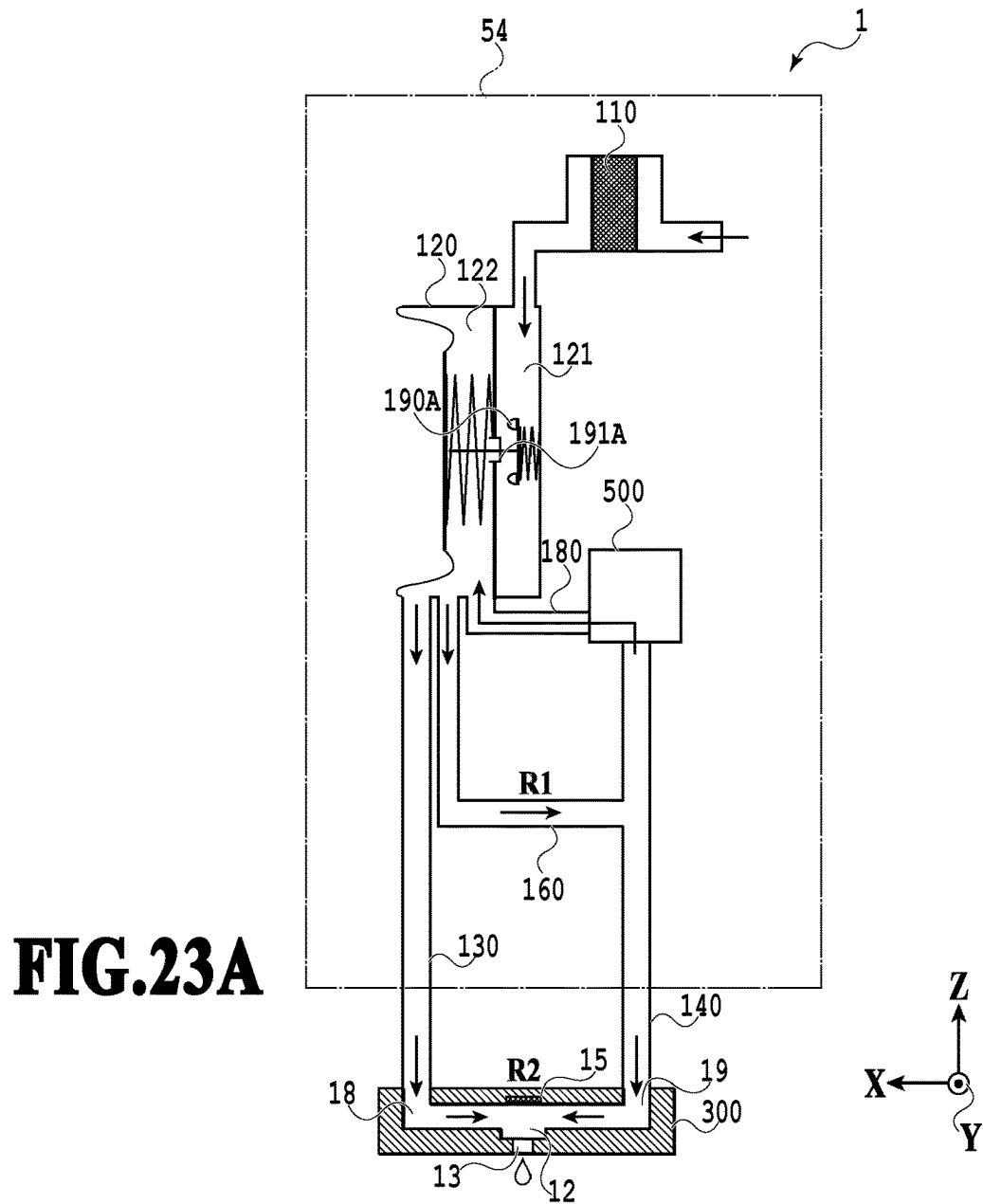


FIG.24A

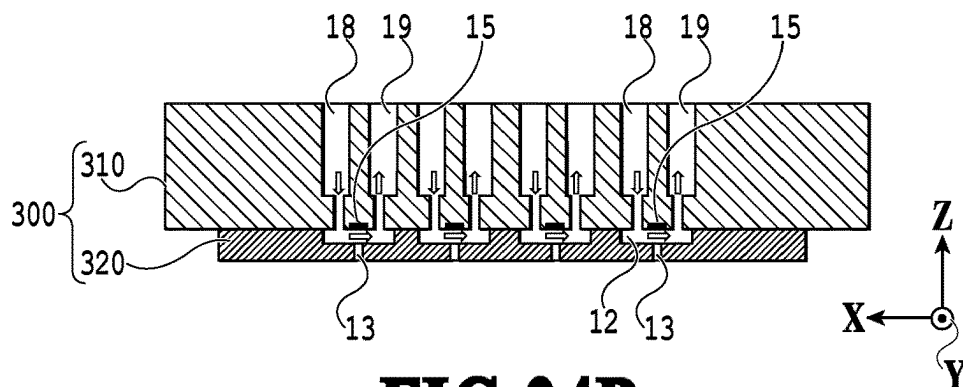
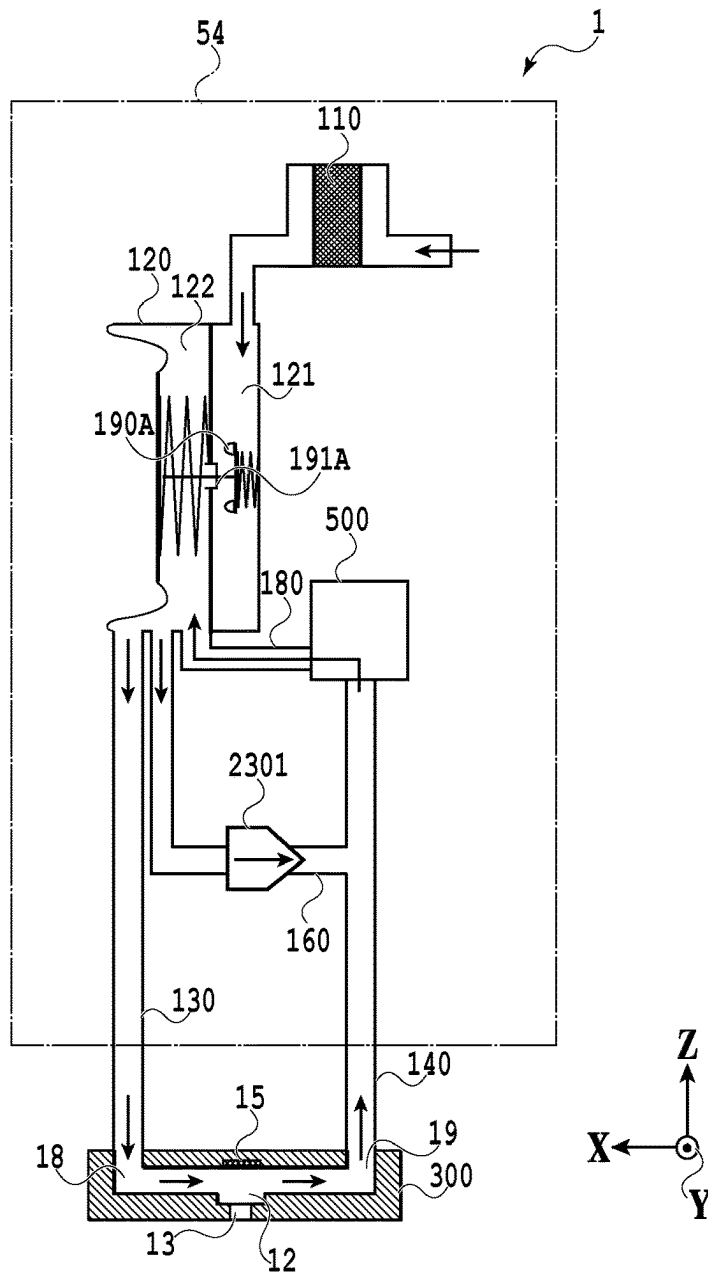


FIG.24B

FIG.25A

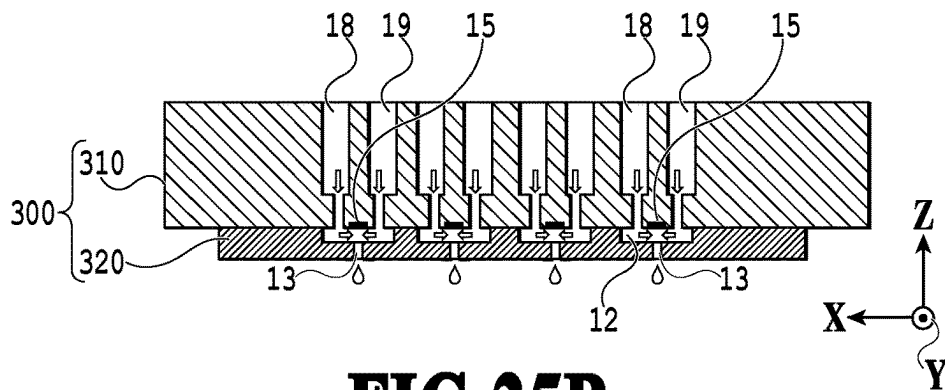
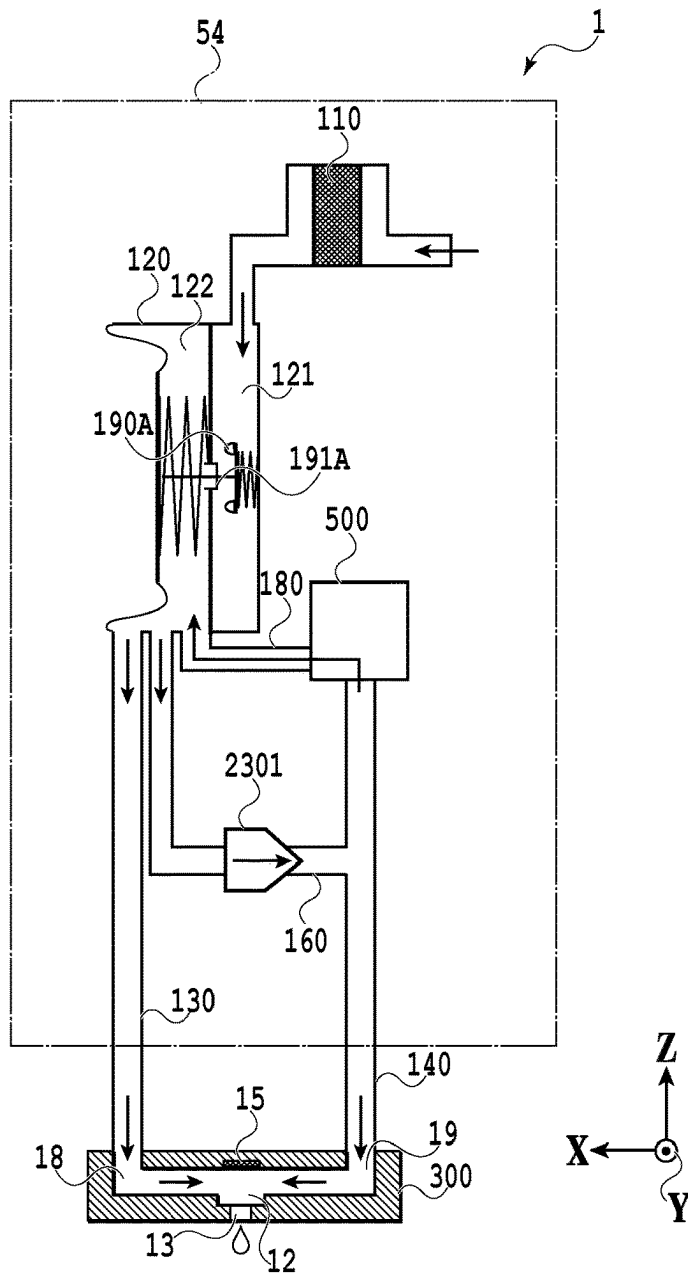


FIG.25B

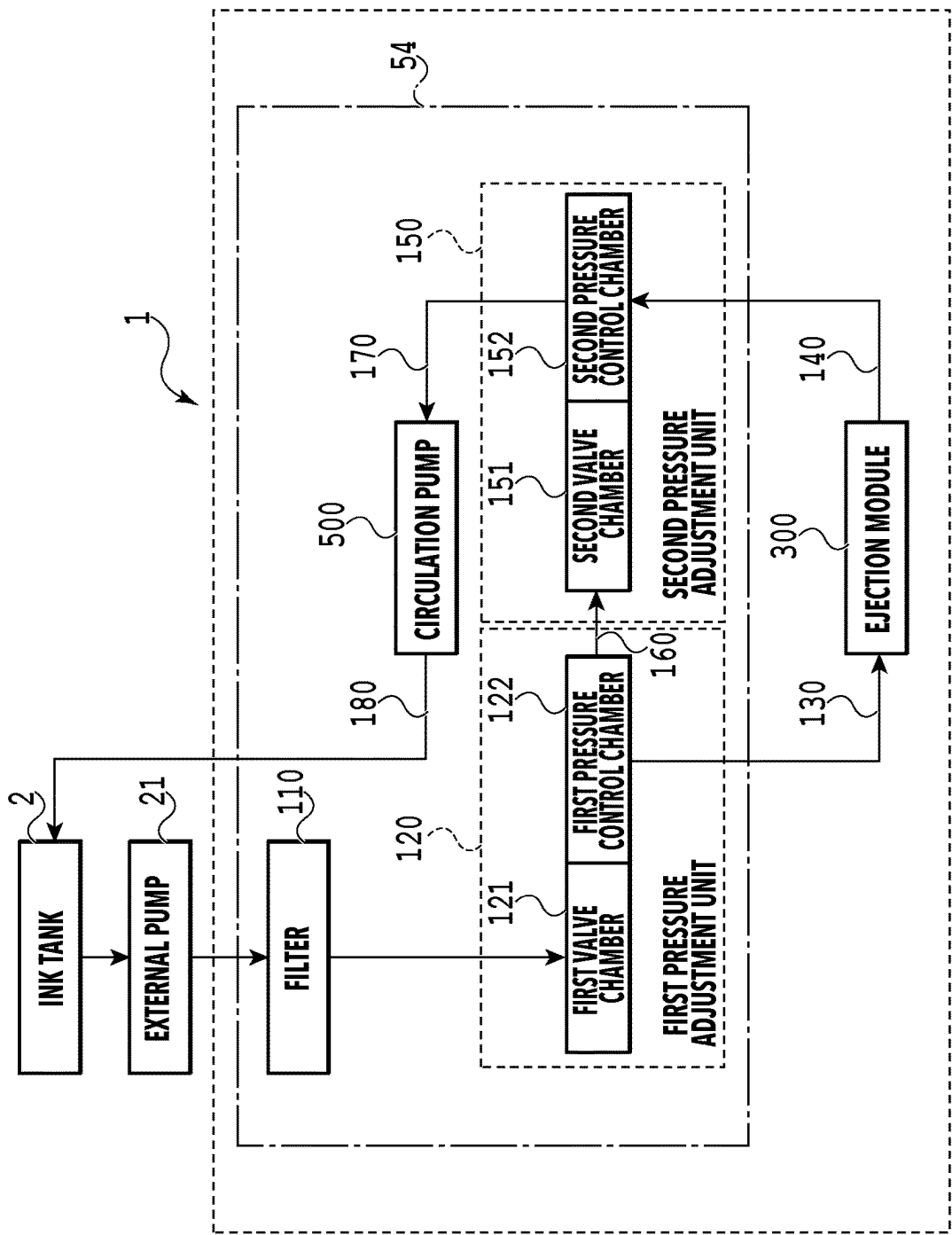


FIG.26

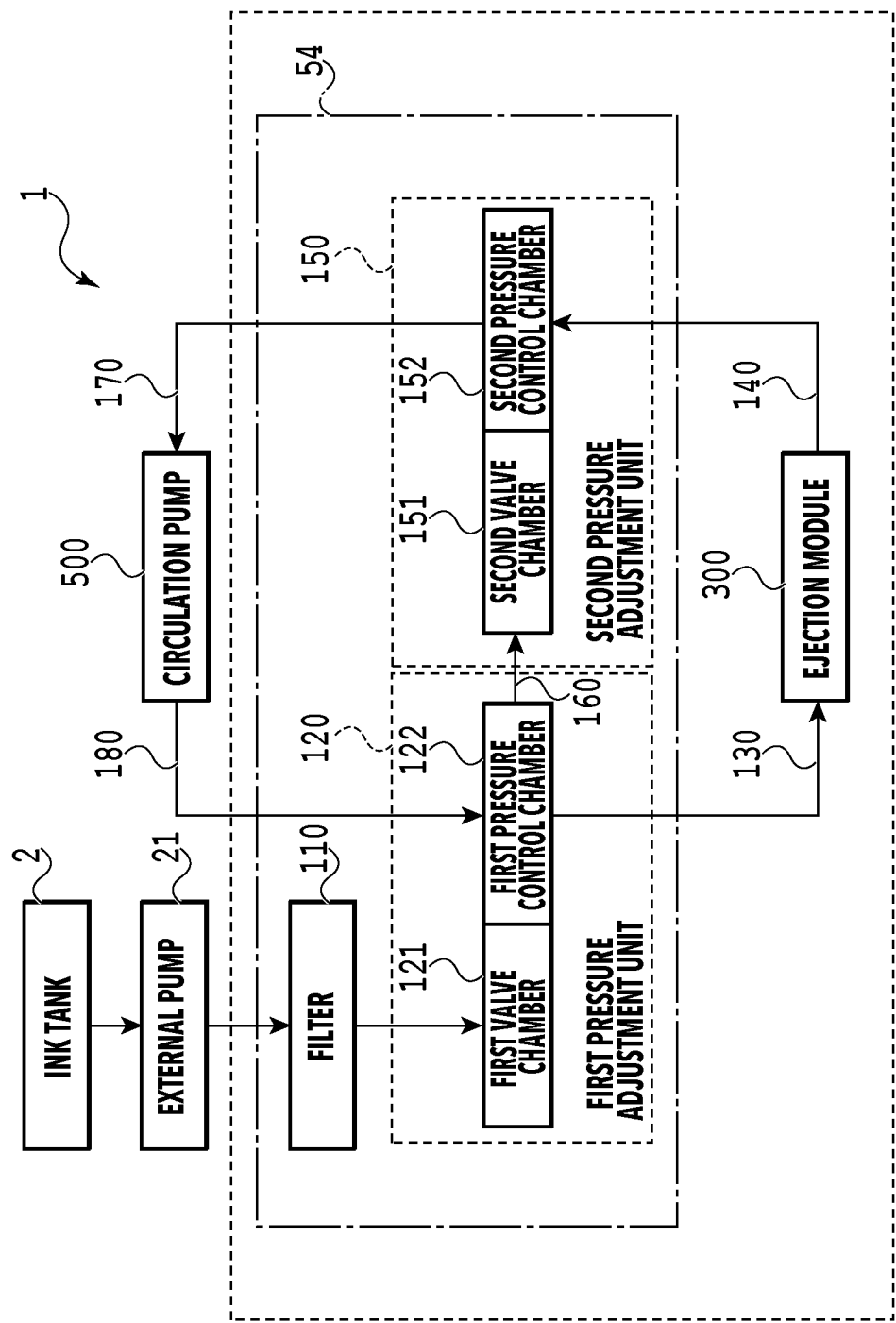


FIG.27

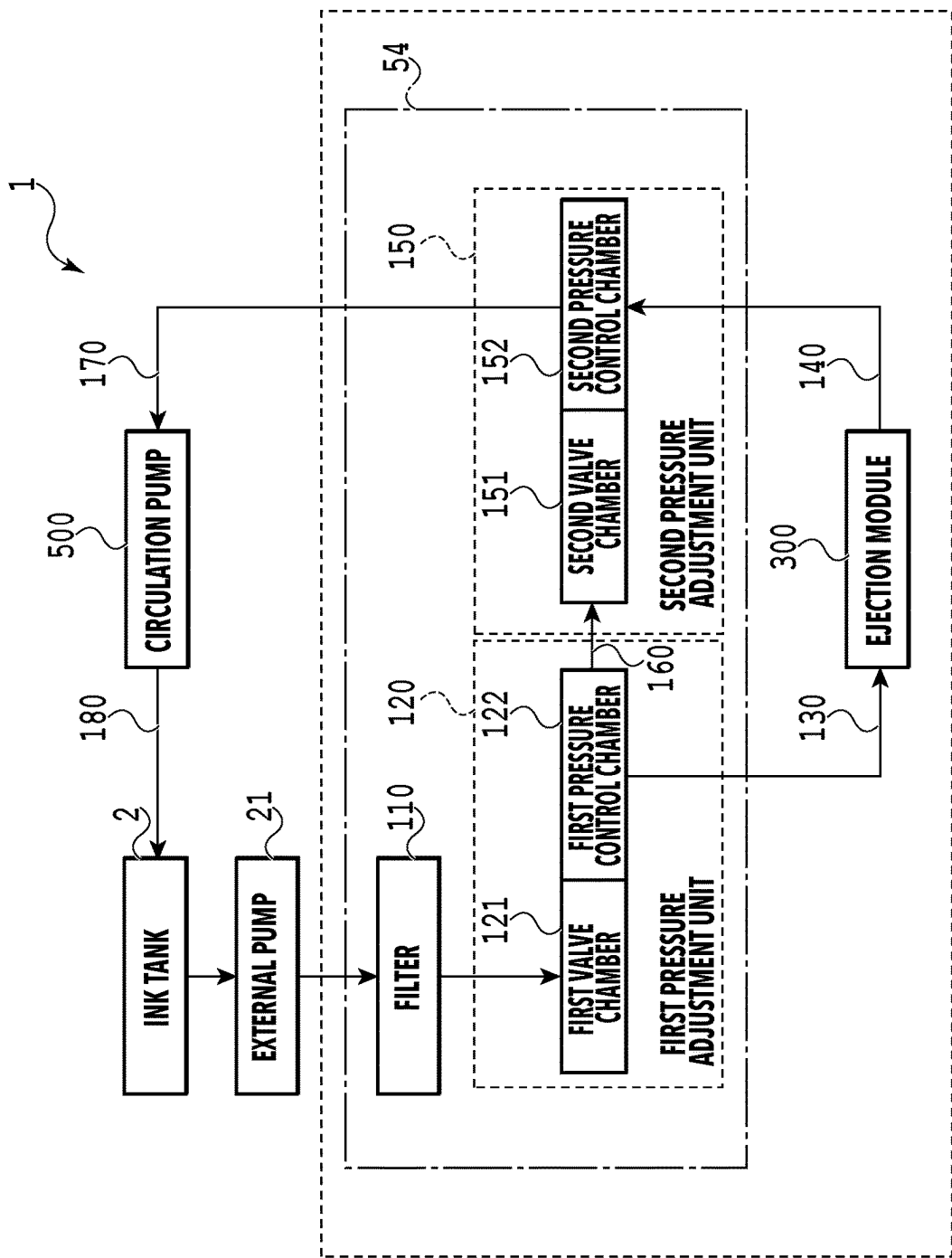


FIG. 28

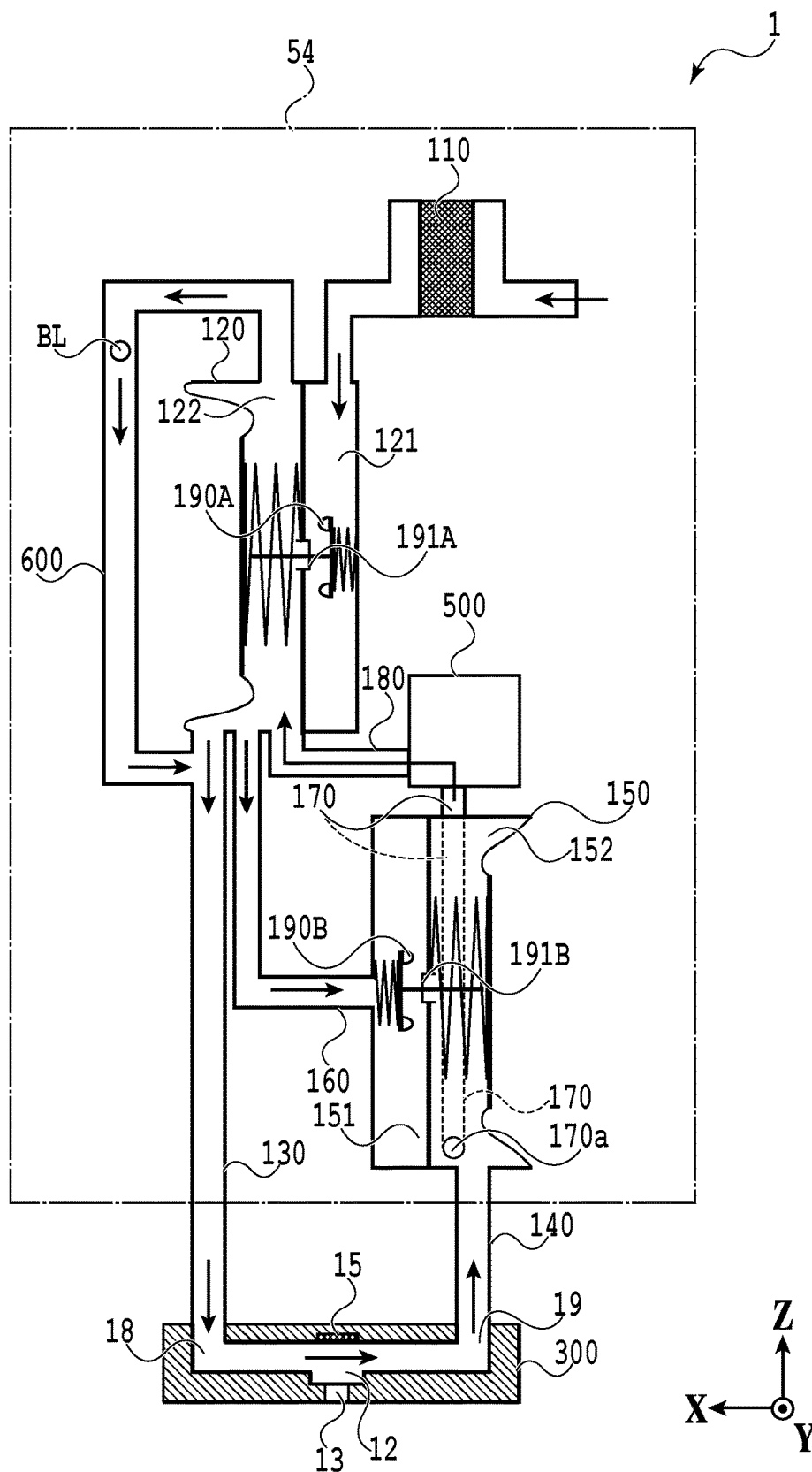


FIG.29

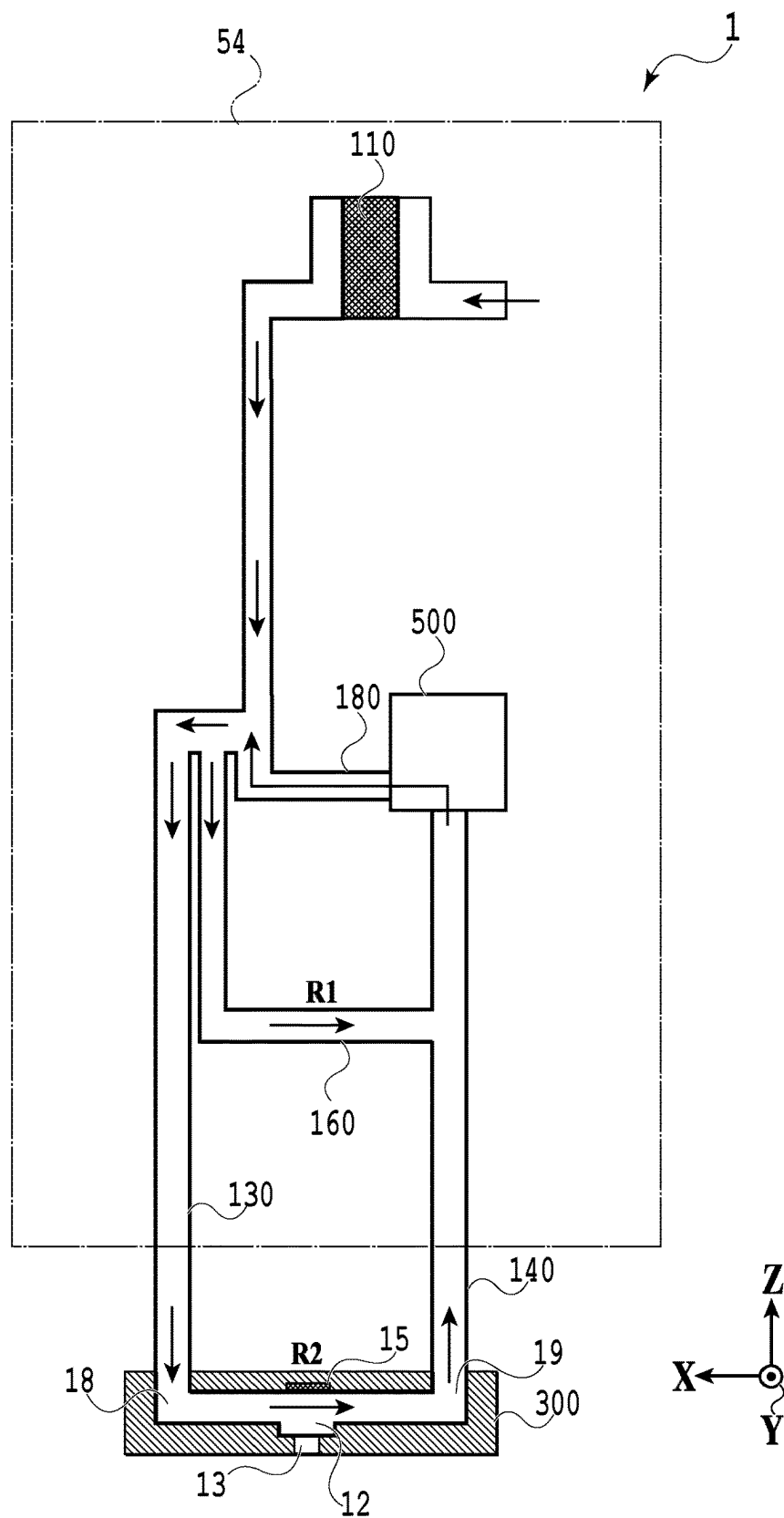


FIG.30

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LIQUID EJECTION HEAD AND LIQUID EJECTION APPARATUS

BACKGROUND

Field

The present disclosure relates to a liquid ejection head and a liquid ejection apparatus including a liquid ejection head.

Description of the Related Art

Circulation-type liquid ejection apparatuses have been known which circulate a liquid between a liquid ejection head and a liquid storage unit to discharge bubbles in channels and to suppress thickening of an ink in the vicinities of ejection ports. The circulation-type liquid ejection apparatuses include ones which circulate a liquid between a liquid ejection head and the main body by using a main body-side pump provided outside the liquid ejection head, and ones which circulate a liquid inside a liquid ejection head by using a pump provided inside the liquid ejection head.

Japanese Patent Laid-Open No. 2014-195932 (hereinafter referred to as Document 1) discloses a liquid ejection apparatus in which a piezoelectric circulation pump is mounted in a liquid ejection head to circulate an ink inside the liquid ejection head. In the configuration of Document 1, the ink supplied to a pressure control mechanism from the circulation pump is then supplied to pressure chambers through ink supply channels, and the ink not ejected is collected to the circulation pump through ink collection channels.

For example, in Document 1, the ink supplied to the pressure chambers is only the ink supplied from the pressure control mechanism through the ink supply channels. That is, the ink is never supplied to the pressure chambers by backing up through the ink collection channels. This is because the circulation pump, which circulates the ink, is equipped with a check valve and the configuration is therefore such that the ink is circulated only in one direction through the circulation channel. Hence, in a case where, for example, the ejection volume of the ink increases, the volume of the ink to be supplied to the ejection ports decreases, which leads to a possibility of lowering the ejection stability.

SUMMARY

According to an aspect of the present disclosure, a liquid ejection head includes a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port, an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber, a downstream channel which communicates with the pressure chamber, a pump which communicates with the upstream channel and the downstream channel and is configured to cause the liquid in the downstream channel to flow into the upstream channel, an inflow channel which communicates with the upstream channel and configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel, and a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and the downstream channel, wherein

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part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are a perspective view and a block diagram illustrating a liquid ejection apparatus.

FIG. 2 is an exploded perspective view and a top view of a liquid ejection head.

FIGS. 3A and 3B are a vertical cross-sectional view of the liquid ejection head and an enlarged cross-sectional view of an ejection module.

FIG. 4 is a schematic external view of a circulation unit.

FIG. 5 is a vertical cross-sectional view illustrating a circulation path.

FIG. 6 is a block diagram schematically illustrating the circulation path.

FIGS. 7A to 7C are cross-sectional views illustrating an example of pressure adjustment units.

FIGS. 8A and 8B are external perspective views of a circulation pump.

FIG. 9 is a cross-sectional view of the circulation pump illustrated in FIG. 8A along the IX-IX line.

FIGS. 10A to 10E are diagrams describing a flow of an ink inside the liquid ejection head.

FIGS. 11A and 11B are schematic views illustrating a circulation path in an ejection unit.

FIG. 12 is a view illustrating an opening plate.

FIG. 13 is a view illustrating an ejection element substrate.

FIGS. 14A to 14C are cross-sectional views illustrating ink flows in the ejection unit.

FIGS. 15A and 15B are cross-sectional views illustrating the vicinity of an ejection port.

FIGS. 16A and 16B are cross-sectional views illustrating a comparative example of the vicinity of an ejection port.

FIG. 17 is a view illustrating a comparative example of an ejection element substrate.

FIGS. 18A and 18B are views illustrating a channel configuration of the liquid ejection head.

FIG. 19 is a view illustrating a connection state between a main body unit of the liquid ejection apparatus and the liquid ejection head.

FIGS. 20A and 20B are views schematically illustrating backflow of inks in the vicinities of ejection ports;

FIGS. 21A and 21B are views describing ink supply inside an ejection module;

FIGS. 22A and 22B are views schematically illustrating circulation paths;

FIGS. 23A and 23B are views schematically illustrating the circulation paths;

FIGS. 24A and 24B are views schematically illustrating circulation paths;

FIGS. 25A and 25B are views schematically illustrating the circulation paths;

FIG. 26 is a block diagram schematically illustrating a circulation path;

FIG. 27 is a block diagram schematically illustrating a circulation path;

FIG. 28 is a block diagram schematically illustrating a circulation path;

FIG. 29 is a view schematically illustrating a circulation path; and

FIG. 30 is a view schematically illustrating a circulation path.

DESCRIPTION OF THE EMBODIMENTS

A preferred embodiment of the present disclosure will be specifically described with reference to the accompanying drawings. Note that the following embodiment does not limit the contents of the present disclosure, and not all of the combinations of the features described in these embodiments are necessarily essential for the present disclosure. Note that identical constituent elements are denoted by the same reference numeral. The present embodiment will be described using an example in which a thermal type ejection element that ejects a liquid by generating a bubble with an electrothermal conversion element is employed as each ejection element that ejects a liquid, but is not limited to this example. The present embodiment is applicable also to liquid ejection heads employing an ejection method in which a liquid is ejected using a piezoelectric element as well as liquid ejection heads employing other ejection methods. Moreover, the pumps, pressure adjustment units, and so on to be described below are not limited to the configurations described in the embodiment and illustrated in the drawings. In the following description, a basic configuration of the present disclosure will be discussed first, and then characteristic features of the present disclosure will be described. <Liquid Ejection Apparatus>

FIG. 1A is a view for describing a liquid ejection apparatus, and is an enlarged view of a liquid ejection head of the liquid ejection apparatus and its vicinity. First, a schematic configuration of a liquid ejection apparatus 50 in the present embodiment will be described with reference to FIGS. 1A and 1B. FIG. 1A is a perspective view schematically illustrating the liquid ejection apparatus using the liquid ejection head 1. The liquid ejection apparatus 50 in the present embodiment is configured as a serial inkjet printing apparatus that performs printing on a print medium P by ejecting inks as liquids while scanning the liquid ejection head 1.

The liquid ejection head 1 is mounted on a carriage 60. The carriage 60 reciprocally moves in a main scanning direction (X direction) along a guide shaft 51. The print medium P is conveyed in a sub scanning direction (Y direction) crossing (in this example, perpendicularly crossing) the main scanning direction by conveyance rollers 55, 56, 57, and 58. Note that, in drawings to be referred to below, the Z direction represents a vertical direction and crosses (in this example, perpendicularly crosses) a X-Y plane defined by the X direction and the Y direction. The liquid ejection head 1 is configured to be attachable to and detachable from the carriage 60 by a user.

The liquid ejection head 1 includes circulation units 54 and a later-described ejection unit 3 (see FIGS. 2A and 2B). While a specific configuration will be described later, the ejection unit 3 includes a plurality of ejection ports and energy generation elements (hereinafter referred to as "ejection elements") that generate ejection energy for ejecting liquids from the respective ejection ports.

The liquid ejection apparatus 50 also includes ink tanks 2 serving as ink supply sources and external pumps 21. The inks stored in the ink tanks 2 are supplied to the circulation units 54 through ink supply tubes 59 by driving forces of the external pumps 21.

The liquid ejection apparatus 50 forms a predetermined image on the print medium P by repeating a printing scan involving performing printing by causing the liquid ejection head 1 mounted on the carriage 60 to eject the inks while moving in the main scanning direction, and a conveyance operation involving conveying the print medium P in the sub scanning direction. Note that the liquid ejection head 1 in the

present embodiment is capable of ejecting four types of inks, namely black (B), cyan (C), magenta (M), and yellow (Y) inks, and printing full-color images with these inks. Here, the inks ejectable from the liquid ejection head 1 are not limited to the above four types of inks. The present disclosure is also applicable to liquid ejection heads for ejecting other types of inks. In short, the types and number of inks to be ejected from the liquid ejection head are not limited.

Also, in the liquid ejection apparatus 50, a cap member (not illustrated) capable of covering the ejection port surface of the liquid ejection head 1 in which its ejection ports are formed is provided at a position separated from the conveyance path for the print medium P in the X direction. The cap member covers the ejection port surface of the liquid ejection head 1 during a non-print operation, and is used for prevention of drying of the ejection ports, protection of the ejection ports, an ink suction operation from the ejection ports, and so on.

Note that the liquid ejection head 1 illustrated in FIG. 1A represents an example where four circulation units 54 corresponding to the four types of inks are included in the liquid ejection head 1, but it suffices that the circulation units 54 included correspond to the types of liquids to be ejected. Also, a plurality of circulation units 54 may be included for the same type of liquid. In sum, the liquid ejection head 1 can have a configuration including one or more circulation units. The liquid ejection head 1 may be configured not to circulate all of the four types of inks but only circulate at least one of the inks.

FIG. 1B is a block diagram illustrating a control system of the liquid ejection apparatus 50. A CPU 103 functions as a control unit that controls the operation of each unit of the liquid ejection apparatus 50 based on a program such as a process procedure stored in a ROM 101. ARAM 102 is used as a work area or the like for the CPU 103 to execute processes. The CPU 103 receives image data from a host apparatus 400 outside the liquid ejection apparatus 50 and controls a head driver 1A to control the driving of the ejection elements provided in the ejection unit 3. The CPU 103 also controls drivers for various actuators provided in the liquid ejection apparatus. For example, the CPU 103 controls a motor driver 105A for a carriage motor 105 for moving the carriage 60, a motor driver 104A for a conveyance motor 104 for conveying the print medium P, and the like. Moreover, the CPU 103 controls a pump driver 500A for later-described circulation pumps 500, a pump driver 21A for the external pumps 21, and the like. Note that FIG. 1B illustrates a configuration in which the image data is received from the host apparatus 400 and processes are performed, but the liquid ejection apparatus 50 may perform the processes regardless of whether data is given from the host apparatus 400.

<Basic Configuration of Liquid Ejection Head>

FIG. 2 is an exploded perspective view and a top view of the liquid ejection head 1 in the present embodiment. FIGS. 3A and 3B are cross-sectional views of the liquid ejection head 1 illustrated in FIG. 2 along the IIIA-III A line. FIG. 3A is a vertical cross-sectional view of the entire liquid ejection head 1, and FIG. 3B is an enlarged view of an ejection module illustrated in FIG. 3A. A basic configuration of the liquid ejection head 1 in the present embodiment will be described below with reference mainly to FIGS. 2 to 3B and to FIG. 1A as appropriate.

As illustrated in FIG. 2, the liquid ejection head 1 includes the circulation units 54 and the ejection unit 3 for ejecting the inks supplied from the circulation units 54 onto the print medium P. The liquid ejection head 1 in the present embodi-

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ment is fixedly supported on the carriage 60 of the liquid ejection apparatus 50 by a positioning unit and electric contacts (not illustrated) which are provided to the carriage 60. The liquid ejection head 1 performs printing on the print medium P by ejecting the inks while moving along with the carriage 60 in the main scanning direction (X direction) illustrated in FIG. 1A.

The external pumps 21 connected to the ink tanks 2 serving as ink supply sources include the ink supply tubes 59 (see FIG. 1A). A liquid connector (not illustrated) is provided at the tip of each of these ink supply tubes 59. In the state where the liquid ejection head 1 is mounted to the liquid ejection apparatus 50, the liquid connectors which are provided at the tips of the ink supply tubes 59 and are inlets through which the liquids are introduced are hermetically connected to liquid connector insertion slots 53a that are provided on a head housing 53 of the liquid ejection head 1. As a result, ink supply paths extending from the ink tanks 2 to the liquid ejection head 1 through the external pumps 21 are formed. In the present embodiment, four types of inks are used. Hence, four sets each including an ink tank 2, an external pump 21, an ink supply tube 59, and a circulation unit 54 are provided for the respective inks, and four ink supply paths corresponding to the respective inks are formed independently of each other. As described above, the liquid ejection apparatus 50 in the present embodiment includes ink supply systems to which the inks are supplied from the ink tanks 2 provided outside the liquid ejection head 1. Note that the liquid ejection apparatus 50 in the present embodiment does not include ink collection systems that collect the inks in the liquid ejection head 1 into the ink tanks 2. Accordingly, the liquid ejection head 1 includes the liquid connector insertion slots 53a to connect the ink supply tubes 59 of the ink tanks 2 but does not include connector insertion slots to connect tubes for collecting the inks in the liquid ejection head 1 into the ink tanks 2. Note that a liquid connector insertion slot 53a is provided for each ink.

In FIG. 3A, reference signs 54B, 54C, 54M, and 54Y denote the circulation units for the black, cyan, magenta, and yellow inks, respectively. The circulation units have substantially the same configuration, and each circulation unit will be denoted as "circulation unit 54" in the present embodiment unless otherwise distinguished.

In FIGS. 2 and 3A, the ejection unit 3 includes two ejection modules 300, the first support member 4, the second support member 7, an electric wiring member (electric wiring tape) 5, and an electric contact substrate 6. As illustrated in FIG. 3B, each ejection module 300 includes a silicon substrate 310 with a thickness of 0.5 mm to 1 mm and a plurality of ejection elements 15 provided in one surface of the silicon substrate 310. The ejection elements 15 in the present embodiment each includes an electrothermal conversion element (heater) that generates thermal energy as ejection energy for ejecting the liquid. Electric power through an electric wiring formed on the silicon substrate 310 by a film forming technique is supplied to each of the ejection elements 15.

Also, a discharge port forming member 320 is formed on a surface of the silicon substrate 310 (the lower surface in FIG. 3B). In the discharge port forming member 320, a plurality of pressure chambers 12 corresponding to the plurality of ejection elements 15 and a plurality of ejection ports 13 to eject the inks are formed by a photolithographic technique. Moreover, common supply channels 18 and common collection channels 19 are formed in the silicon substrate 310. Furthermore, in the silicon substrate 310, there are formed supply connection channels 323 through which

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the common supply channels 18 and the pressure chambers 12 communicate with one another, and collection connection channels 324 through which the common collection channels 19 and the pressure chambers 12 communicate with one another. In the present embodiment, one ejection module 300 is configured to eject two types of inks. Specifically, in the two ejection modules illustrated in FIG. 3A, the ejection module 300 located on the left side in FIG. 3A ejects the black and cyan inks, and the ejection module 300 located on the right side in FIG. 3A ejects the magenta and yellow inks. Note that this combination is a mere example, and any combination of inks may be employed. The configuration may be such that one ejection module ejects one type of ink or ejects three or more types of inks. The two ejection modules 300 do not have to eject the same number of types of inks. The configuration may be such that only one ejection module 300 is included, or three or more ejection modules 300 are included. Moreover, in the example illustrated in FIGS. 3A and 3B, two ejection port arrays extending in the Y direction are formed for an ink of one color. A pressure chamber 12, a common supply channel 18, and a common collection channel 19 are formed for each of the plurality of ejection ports 13 forming each ejection port array.

Later-described ink supply ports and ink collection ports are formed on the back surface (the upper surface in FIG. 3B) side of the silicon substrate 310. Through the ink supply ports, the inks are supplied into the plurality of common supply channels 18 from ink supply channels 48. Through the ink collection ports, the inks are collected into ink collection channels 49 from the plurality of common collection channels 19.

Note that the ink supply ports and the ink collection ports correspond to openings for supplying and collecting the inks during later-described forward ink circulation, respectively. Specifically, during the forward ink circulation, the inks are supplied from the ink supply ports into the common supply channels 18, and the inks are collected from the common collection channels 19 into the ink collection ports. Note that ink circulation in which the inks are caused to flow in the opposite direction may also be performed. In this case, the inks are supplied from the above-described ink collection ports into the common collection channels 19, and the inks are collected from the common supply channels 18 into the ink supply ports.

As illustrated in FIG. 3A, the back surfaces (the upper surfaces in FIG. 3A) of the ejection modules 300 are adhesively fixed to one surface of the first support member 4 (the lower surface in FIG. 3A). The ink supply channels 48 and the ink collection channels 49, which penetrate from one surface of the first support member 4 to the opposite surface of the first support member 4, are formed in the first support member 4. The openings of the ink supply channels 48 on one side communicate with the above-mentioned ink supply ports in the silicon substrate 310. The openings of the ink collection channels 49 on the one side communicate with the above-mentioned ink collection ports in the silicon substrate 310. Note that the ink supply channels 48 and the ink collection channels 49 are provided independently for each type of ink.

Also, the second support member 7 having openings 7a (see FIG. 2) to insert the ejection modules 300 are adhesively fixed to one surface (the lower surface in FIG. 3A) of the first support member 4. The electric wiring member 5 to be electrically connected to the ejection modules 300 is held on the second support member 7. The electric wiring member 5 is a member for applying electric signals for ink ejection to the ejection modules 300. The electric connection

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parts of the ejection modules **300** and the electric wiring member **5** are sealed with a sealant (not illustrated) to be protected from corrosion by the inks and external impacts.

Also, the electric contact substrate **6** is joined to an end portion **5a** of the electric wiring member **5** (see FIG. 2) by thermocompression bonding with an anisotropic conductive film (not illustrated), and the electric wiring member **5** and the electric contact substrate **6** are electrically connected to each other. The electric contact substrate **6** has external signal input terminals (not illustrated) for receiving electric signals from the liquid ejection apparatus **50**.

Moreover, a joint member **8** (FIG. 3A) is provided between the first support member **4** and the circulation units **54**. In the joint member **8**, a supply port **88** and a collection port **89** are formed for each type of ink. Through the supply ports **88** and the collection ports **89**, the ink supply channels **48** and the ink collection channels **49** in the first support member **4** and channels formed in the circulation units **54** communicate with each other. Incidentally, in FIG. 3A, a supply port **88B** and a collection port **89B** are for the black ink, and a supply port **88C** and a collection port **89C** are for the cyan ink. Moreover, a supply port **88M** and a collection port **89M** are for the magenta ink, and a supply port **88Y** and a collection port **89Y** are for the yellow ink.

Note that the openings at one end of the ink supply channels **48** and the ink collection channels **49** in the first support member **4** have small opening areas matching the ink supply ports and the ink collection ports in the silicon substrate **310**. On the other hand, the openings at the other end of the ink supply channels **48** and the ink collection channels **49** in the first support member **4** have a large shape whose opening area is the same opening area formed in the joint member **8** to match the channels in the circulation units **54**. Employing such a configuration can suppress an increase in channel resistance on the ink collected from each collection channel. Note that the shapes of the openings at one end and the other end of the ink supply channels **48** and the ink collection channels **49** are not limited to the above example.

In the liquid ejection head **1** having the above configuration, the inks supplied to the circulation units **54** pass through the supply ports **88** in the joint member **8** and the ink supply channels **48** in the first support member **4** and flow into the common supply channels **18** from the ink supply ports in the ejection modules **300**. Thereafter, the inks flow from the common supply channels **18** into the pressure chambers **12** through the supply connection channels **323**. Part of the inks flowing into the pressure chambers is ejected from the ejection ports **13** as the ejection elements **15** are driven. The remaining inks not ejected pass through the collection connection channels **324** and the common collection channels **19** from the pressure chambers **12**, and flow from the ink collection ports into the ink collection channels **49** in the first support member **4**. Then, the inks flowing into the ink collection channels **49** flow into the circulation units **54** through the collection ports **89** in the joint member **8** and are collected.

<Constituent Elements of Circulation Units>

FIG. 4 is a schematic external view of one circulation unit **54** for one type of ink used in a printing apparatus in the present embodiment. A circulation pump **500** is mounted in the circulation unit **54**. Moreover, it is preferable that the circulation unit **54** have a filter **110**, a first pressure adjustment unit **120**, and a second pressure adjustment unit **150**. These constituent elements are connected by channels as illustrated in FIGS. 5 and 6 to thereby form a circulation path for supplying and collecting the ink to and from the ejection module **300** inside the liquid ejection head **1**.

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<Circulation Path in Liquid Ejection Head>

FIG. 5 is a vertical cross-sectional view schematically illustrating the circulation path for one type of ink (ink of one color) formed in the liquid ejection head **1**. The relative positions of the components in FIG. 5 (such as the first pressure adjustment unit **120**, the second pressure adjustment unit **150**, and the circulation pump **500**) are simplified for a clearer description of the circulation path. Thus, the relative positions of the components are different from those of the components in FIG. 19 to be mentioned later. Incidentally, FIG. 6 is a block diagram schematically illustrating the circulation path illustrated in FIG. 5. As illustrated in FIGS. 5 and 6, the first pressure adjustment unit **120** includes the first valve chamber **121** and the first pressure control chamber **122**. The second pressure adjustment unit **150** includes the second valve chamber **151** and the second pressure control chamber **152**. The first pressure adjustment unit **120** is configured such that the controlled pressure therein is higher than that in the second pressure adjustment unit **150**. In the present embodiment, these two pressure adjustment units **120** and **150** are used to implement circulation within a certain pressure range inside the circulation path. Also, the configuration is such that the ink flows through the pressure chambers **12** (ejection elements **15**) at a flow rate corresponding to the pressure difference between the first pressure adjustment unit **120** and the second pressure adjustment unit **150**. A circulation path in the liquid ejection head **1** and a flow of the ink in the circulation path will be described below with reference to FIGS. 5 and 6. Note that the arrows in FIGS. 5 and 6 indicate the flow direction of the ink.

First, how the constituent elements in the liquid ejection head **1** are connected will be described.

The external pump **21**, which sends the ink stored in the ink tank **2** (FIG. 6) provided outside the liquid ejection head **1** to the liquid ejection head **1**, is connected to the circulation unit **54** through the ink supply tube **59** (FIG. 1). The ink channel (inflow channel) located on an upstream side of the circulation unit **54** is provided with the filter **110**. The ink supply path (inflow channel) located downstream of the filter **110** is connected to the first valve chamber **121** of the first pressure adjustment unit **120**. The first valve chamber **121** communicates with the first pressure control chamber **122** through a communication port **191A** openable and closable by a valve **190A** illustrated in FIG. 5. Note that the inflow channel is a channel through which the liquid in the ink tank **2** provided outside the liquid ejection head **1** flows into the liquid ejection head **1** to be supplied to the pressure chambers **12**. Specifically, the inflow channel is a flow channel through which the ink tank **2** and the liquid ejection head **1** communicate with each other and the liquid in the ink tank flows into the liquid ejection head. As will be described later, the inflow channel communicates with an upstream channel in the liquid ejection head **1**. In this way, the liquid having flowed into the upstream channel through the inflow channel and flowed through the bypass channel **160** can be supplied into the pressure chambers **12** through a downstream channel.

The first pressure control chamber **122** is connected to a supply channel **130**, a bypass channel **160**, and a pump outlet channel **180** of the circulation pump **500**. The supply channel **130** is connected to the common supply channels **18** through the above-mentioned ink supply ports provided in the ejection module **300**. Also, the bypass channel **160** is connected to the second valve chamber **151** provided in the second pressure adjustment unit **150**. The second valve chamber **151** communicates with the second pressure con-

trol chamber 152 through a communication port 191B that is opened and closed by a valve 190B illustrated in FIG. 5. Note that FIGS. 5 and 6 illustrate an example where one end of the bypass channel 160 is connected to the first pressure control chamber 122 of the first pressure adjustment unit 120, and the other end of the bypass channel 160 is connected to the second valve chamber 151 of the second pressure adjustment unit 150. However, the one end of the bypass channel 160 may be connected to the supply channel 130, and the other end of the bypass channel may be connected to the second valve chamber 151.

The second pressure control chamber 152 is connected to a collection channel 140. The collection channel 140 is connected to the common collection channels 19 through the above-mentioned ink collection ports provided in the ejection module 300. Moreover, the second pressure control chamber 152 is connected to the circulation pump 500 through a pump inlet channel 170. Note that reference sign 170a in FIG. 5 denotes an inlet port of the pump inlet channel 170.

Next, the flow of the ink in the liquid ejection head 1 having the above configuration will be described. As illustrated in FIG. 6, the ink stored in the ink tank 2 is pressurized by the external pump 21 provided in the liquid ejection apparatus 50, becomes an ink flow at a positive pressure, and is supplied to the circulation unit 54 of the liquid ejection head 1.

The ink supplied to the circulation unit 54 passes through the filter 110 so that foreign substances such as dust and bubbles are removed. The ink then flows into the first valve chamber 121 provided in the first pressure adjustment unit 120. The pressure on the ink decreases due to the pressure loss in a case where the ink passes through the filter 110, but the pressure on the ink is still positive at this point. Thereafter, in a case where the valve 190A is open, the ink flowing into the first valve chamber 121 passes through the communication port 191A and flows into the first pressure control chamber 122. Due to the pressure loss in a case where the ink passes through the communication port 191A, the pressure on the ink flowing into the first pressure control chamber 122 switches from the positive pressure to a negative pressure.

Next, the flow of the ink in the circulation path will be described. The circulation pump 500 operates such that the ink sucked from the pump inlet channel 170 located upstream of the circulation pump 500 is sent to the pump outlet channel 180 located downstream of the circulation pump 500. Thus, as the pump is driven, the ink supplied to the first pressure control chamber 122 flows into the supply channel 130 and the bypass channel 160 along with the ink sent from the pump outlet channel 180. In the present embodiment, while details will be described later, a piezoelectric diaphragm pump using a piezoelectric element attached to a diaphragm as a driving source is used as a circulation pump capable of sending the liquid. The piezoelectric diaphragm pump is a pump that sends a liquid by inputting a driving voltage to a piezoelectric element to change the volume of a pump chamber and alternatively moving two check valves in response to the changes in pressure.

The ink flowing into the supply channel 130 flows from the ink supply ports in the ejection module 300 into the pressure chambers 12 through the common supply channels 18. Part of the ink is ejected from the ejection ports 13 as the ejection elements 15 are driven (generate heat). Also, the remaining ink not used in the ejection flows through the pressure chambers 12 and passes through the common

collection channels 19. Thereafter, the ink flows into the collection channel 140 connected to the ejection module 300. The ink flowing into the collection channel 140 flows into the second pressure control chamber 152 of the second pressure adjustment unit 150.

On the other hand, the ink flowing from the first pressure control chamber 122 into the bypass channel 160 flows into the second valve chamber 151, passes through the communication port 191B, and then flows into the second pressure control chamber 152. The ink flowing into the second pressure control chamber 152 through the bypass channel 160 and the ink collected from the collection channel 140 are sucked into the circulation pump 500 through the pump inlet channel 170 as the circulation pump 500 is driven. Then, the inks sucked into the circulation pump 500 are sent to the pump outlet channel 180 and flow into the first pressure control chamber 122 again. Thereafter, the ink flowing from the first pressure control chamber 122 into the second pressure control chamber 152 through the supply channel 130 and the ejection module 300 and the ink flowing into the second pressure control chamber 152 through the bypass channel 160 flow into the circulation pump 500. Then, the inks are sent from the circulation pump 500 to the first pressure control chamber 122. The ink circulation is performed within the circulation path in this manner.

Here, a channel through which first portions of the pressure chambers 12 and the circulation pump 500 communicate with each other and the liquid is supplied to the pressure chambers 12 will be referred to as "upstream channel". Moreover, a channel through which second portions of the pressure chambers 12 and the circulation pump 500 communicate with each other and the liquid is collected mainly from the pressure chambers 12 will be referred to as "downstream channel".

The upstream channel includes the first pressure adjustment unit 120, a first channel (supply channel 130) through which the first pressure adjustment unit 120 and the first portions of the pressure chambers 12 communicate with each other, and a third channel (pump outlet channel 180) through which the circulation pump 500 and the first pressure adjustment unit 120 communicate with each other. The downstream channel includes the second pressure adjustment unit 150, a second channel (collection channel 140) through which the second portions of the pressure chambers 12 and the second pressure adjustment unit 150 communicate with each other, and a fourth channel (pump inlet channel 170) through which the second pressure adjustment unit 150 and the circulation pump 500 communicate with each other. In other words, the circulation pump 500 causes the liquid in the downstream channel to flow into the upstream channel. Note that the upstream channel only needs to be such that the circulation pump 500 and the first portions of the pressure chambers 12 communicate with each other therethrough, and the downstream channel only needs to be such that the second portions of the pressure chambers 12 and the circulation pump 500 communicate with each other therethrough.

Thus, in the present embodiment, the liquid flows through the circulation pump 500, the third channel 180, the first pressure adjustment unit 120, the first channel 130, the pressure chambers 12, the second channel 140, the second pressure adjustment unit 150, the fourth channel 170, and the circulation pump 500 in this order as a circulation path.

As described above, in the present embodiment, the liquids can be circulated through the respective circulation paths formed in the liquid ejection head 1 with the circulation pump 500. This makes it possible to suppress thickening

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of the inks and deposition of precipitating components of the inks of the color materials in the ejection modules 300. Accordingly, the excellent fluidity of the inks in the ejection modules 300 and excellent ejection characteristics at the ejection ports can be maintained.

Also, the circulation paths in the present embodiment are configured to complete within the liquid ejection head 1. Thus, the length of the circulation paths is significantly short as compared to a case where the inks are circulated between the ink tanks 2 disposed outside the liquid ejection head 1 and the liquid ejection head 1. Accordingly, the inks can be circulated with small circulation pumps.

Moreover, the configuration is such that only channels for supplying the inks are included as the channels connecting between the liquid ejection head 1 and the ink tanks 2. In other words, a configuration that does not require channels for collecting the inks from the liquid ejection head 1 into the ink tanks 2 is employed. Accordingly, only ink supply tubes connecting between the ink tanks 2 and the liquid ejection head 1 are needed, and no ink collection tube is required. The inside of the liquid ejection apparatus 50 therefore has a simpler configuration having less tubes. This can downsize the entire apparatus. Moreover, the reduction in the number of tubes reduces the fluctuations in ink pressure due to the swinging of the tubes caused by main scanning of the liquid ejection head 1. Also, the swinging of the tubes during main scanning of the liquid ejection head 1 increases a driving load on the carriage motor driving the carriage 60. Hence, the reduction of the number of tubes reduces the driving load of the carriage motor, which makes it possible to simplify the main scanning mechanism including the carriage motor and the like. Furthermore, since the inks do not need to be collected into the ink tanks from the liquid ejection head 1, the external pumps 21 can be downsized as well. As described above, according to the present embodiment, it is possible to downsize the liquid ejection apparatus 50 and reduce costs.

<Pressure Adjustment Units>

FIGS. 7A to 7C are views illustrating an example of the pressure adjustment units. Configurations and operation of the pressure adjustment units incorporated in the above-described liquid ejection head 1 (first pressure adjustment unit 120 and second pressure adjustment unit 150) will be described in more detail with reference to FIGS. 7A to 7C. Note that the first pressure adjustment unit 120 and the second pressure adjustment unit 150 have substantially the same configuration. Thus, the following description will be given by taking the first pressure adjustment unit 120 as an example. As for the second pressure adjustment unit 150, only the reference signs of its portions corresponding to those of the first pressure adjustment unit are presented in FIGS. 7A to 7C. In a case of the second pressure adjustment unit 150, the first valve chamber 121 and the first pressure control chamber 122 described below should be read as the second valve chamber 151 and the second pressure control chamber 152, respectively.

The first pressure adjustment unit 120 has the first valve chamber 121 and the first pressure control chamber 122 formed in a cylindrical housing 125. The first valve chamber 121 and the first pressure control chamber 122 are separated by a partition 123 provided inside the cylindrical housing 125. However, the first valve chamber 121 communicates with the first pressure control chamber 122 through a communication port 191 formed in the partition 123. A valve 190, which switches between allowing communication between the first valve chamber 121 and the first pressure control chamber 122 through the communication port 191

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and blocking the communication, is provided in the first valve chamber 121. The valve 190 is held by a valve spring 200 at a position opposite to the communication port 191, and has a tight contact configuration to the partition 123 by a biasing force from the valve spring 200. The valve 190 blocks the ink flow through the communication port 191 by being in tight contact with the partition 123. Note that the portion of the valve 190 to be in contact with the partition 123 is preferably formed of an elastic member in order to enhance the tightness of the contact with the partition 123. Also, a valve shaft 190a to be inserted through the communication port 191 is provided in a protruding manner on a center portion of the valve 190. By pressing this valve shaft 190a against the biasing force from the valve spring 200, the valve 190 gets separated from the partition 123, thereby allowing the ink to flow through the communication port 191. In the following, the state where the valve 190 blocks the ink flow through the communication port 191 will be referred to as "closed state", and the state where the ink can flow through the communication port 191 will be referred to as "open state".

The opening portion of the cylindrical housing 125 is closed by a flexible member 230 and a pressing plate 210. These flexible member 230 and pressing plate 210, the peripheral wall of the housing 125, and the partition 123 form the first pressure control chamber 122. The pressing plate 210 is configured to be displaceable with displacement of the flexible member 230. While the materials of the pressing plate 210 and the flexible member 230 are not particularly limited, for example, the pressing plate 210 can be made as a molded resin component, and the flexible member 230 can be made from a resin film. In this case, the pressing plate 210 can be fixed to the flexible member 230 by thermal welding.

A pressure adjustment spring 220 (biasing member) is provided between the pressing plate 210 and the partition 123. As illustrated in FIG. 7A, the pressing plate 210 and the flexible member 230 are biased by a biasing force from the pressure adjustment spring 220 in a direction in which the inner volume of the first pressure control chamber 122 increases. Also, as the pressure in the first pressure control chamber 122 decreases, the pressing plate 210 and the flexible member 230 get displaced against the pressure from the pressure adjustment spring 220 in the direction in which the inner volume of the first pressure control chamber 122 decreases. Then, in a case where the inner volume of the first pressure control chamber 122 decreases to a certain volume, the pressing plate 210 abuts the valve shaft 190a of the valve 190. As the inner volume of the first pressure control chamber 122 then decreases further, the valve 190 moves with the valve shaft 190a against the biasing force from the valve spring 200, thereby being separated from the partition 123. As a result, the communication port 191 shifts to the open state (the state of FIG. 7B).

In the present embodiment, the connections in the circulation path are set such that the pressure in the first valve chamber 121 in a case where the communication port 191 shifts to the open state is higher than the pressure in the first pressure control chamber 122. In this way, in a case where the communication port 191 shifts to the open state, the ink flows from the first valve chamber 121 into the first pressure control chamber 122. The inflow of the ink displaces the flexible member 230 and the pressing plate 210 in the direction in which the inner volume of the first pressure control chamber 122 increases. As a result, the pressing plate 210 gets separated from the valve shaft 190a of the valve 190, and the valve 190 is brought into tight contact with the

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partition **123** by the biasing force from the valve spring **200** so that the communication port **191** shifts to the closed state (the state of FIG. 7C).

As described above, in the first pressure adjustment unit **120** in the present embodiment, in a case where the pressure in the first pressure control chamber **122** decreases to a certain pressure or less (e.g., in a case where the negative pressure becomes strong), the ink flows from the first valve chamber **121** through the communication port **191**. This configuration limits the pressure in the first pressure control chamber **122** from decreasing any further. Accordingly, the pressure in the first pressure control chamber **122** is controlled to be maintained within a certain range.

Next, the pressure in the first pressure control chamber **122** will be described in more detail. Consider a state where the flexible member **230** and the pressing plate **210** are displaced according to the pressure in the first pressure control chamber **122** as described above so that the pressing plate **210** abuts the valve shaft **190a** and brings the communication port **191** into the open state (the state of FIG. 7B). The relation between the forces acting on the pressing plate **210** at this time is represented by Equation 1 below.

$$P2 \times S2 + F2 + (P1 - P2) \times S1 + F1 = 0 \quad \text{Equation 1}$$

Moreover, Equation 1 is summarized for P2 as below.

$$P2 = -(F1 + F2 + P1 \times S1) / (S2 - S1) \quad \text{Equation 2}$$

P1: Pressure (gauge pressure) in the first valve chamber **121**

P2: Pressure (gauge pressure) in first pressure control chamber **122**

F1: Spring force of the valve spring **200**

F2: Spring force of the pressure adjustment spring **220**

S1: Pressure reception area of the valve **190**

S2: Pressure reception area of the pressing plate **210**

Here, as for the spring force F1 of the valve spring **200** and the spring force F2 of the pressure adjustment spring **220**, the direction in which they push the valve **190** and the pressing plate **210** is defined as the forward direction (the leftward direction in FIGS. 7A to 7C). Also, the configuration is such that the pressure P1 in the first valve chamber **121** and the pressure P2 in the first pressure control chamber **122** satisfy a relation of $P1 \geq P2$.

The pressure P2 in the first pressure control chamber **122** when the communication port **191** shifts to the open state is determined by Equation 2 and, since the configuration is such that the relation of $P1 \geq P2$ is satisfied, the ink flows into the first pressure control chamber **122** from the first valve chamber **121** when the communication port **191** shifts to the open state. As a result, the pressure P2 in the first pressure control chamber **122** does not decrease any further, and the pressure P2 is kept at a pressure within a certain range.

On the other hand, as illustrated in FIG. 7C, the relation between the forces acting on the pressing plate **210** in a case where the pressing plate **210** does not abut on the valve shaft **190a** and the communication port **191** shifts to the closed state is represented by Equation 3 below.

$$P3 \times S3 + F3 = 0 \quad \text{Equation 3}$$

Here, Equation 3 is summarized for P3 as below.

$$P3 = -F3 / S3 \quad \text{Equation 4}$$

F3: Spring force of the pressure adjustment spring **220** in a state where the pressing plate **210** does not abut on the valve shaft **190a**

P3: Pressure (gauge pressure) in the first pressure control chamber **122** in the state where the pressing plate **210** does not abut on the valve shaft **190a**

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S3: Pressure reception area of the pressing plate **210** in a state where the pressing plate **210** does not abut on the valve shaft **190a**

Here, FIG. 7C illustrates a state where the pressing plate **210** and the flexible member **230** are displaced in the leftward direction in FIG. 7C up to the limit to which they can be displaced. The pressure P3 in the first pressure control chamber **122**, the spring force F3 of the pressure adjustment spring **220**, and the pressure reception area S3 of the pressing plate **210** change depending on the amount of displacement of the pressing plate **210** and the flexible member **230** in displacement to the state of FIG. 7C. Specifically, in a case where the pressing plate **210** and the flexible member **230** are situated on the right side in FIG. 7C relative to themselves in FIG. 7C, the pressure reception area S3 of the pressing plate **210** is smaller and the spring force F3 of the pressure adjustment spring **220** is larger. Accordingly, the pressure P3 in the first pressure control chamber **122** is smaller in accordance with the relation in Equation 4. Thus, with Equations 2 and 4, the pressure in the first pressure control chamber **122** gradually increases (that is, the negative pressure weakens toward a value close to the positive pressure side) in shifting from the state of FIG. 7B to the state of FIG. 7C. Specifically, the pressure in the first pressure control chamber **122** gradually increases while the pressing plate **210** and the flexible member **230** are gradually displaced in the leftward direction from the state where the communication port **191** is in the open state to the state where the inner volume of the first pressure control chamber reaches the limit to which the pressing plate **210** and the flexible member **230** can be displaced. In other words, the negative pressure weakens. In the present embodiment, the first pressure adjustment unit **120** adjusts the pressure in the upstream channel, and the second pressure adjustment unit **150** adjusts the pressure in the downstream channel. In particular, the first pressure adjustment unit **120** adjusts the pressure in the first channel (supply channel **130**), and the second pressure adjustment unit **150** adjusts the pressure in the second channel (collection channel **140**).

<Circulation Pumps>

Next, a configuration and operation of each circulation pump **500** incorporated in the above liquid ejection head **1** will be described in detail with reference to FIGS. 8A and 8B and FIG. 9.

FIGS. 8A and 8B are external perspective views of the circulation pump **500**. FIG. 8A is an external perspective view illustrating the front side of the circulation pump **500**, and FIG. 8B is an external perspective view illustrating the back side of the circulation pump **500**. An outer shell of the circulation pump **500** includes a pump housing **505** and a cover **507** fixed to the pump housing **505**. The pump housing **505** includes a housing-part main body **505a** and a channel connection member **505b** adhesively fixed to the outer surface of the housing-part main body **505a**. In each of the housing-part main body **505a** and the channel connection member **505b**, a pair of through-holes communicating with each other are formed at two different positions. One of the pair of through-holes provided at one position forms a pump supply hole **501**. The other of the pair of through-holes provided at the other position forms a pump discharge hole **502**. The pump supply hole **501** is connected to the pump inlet channel **170** connected to the second pressure control chamber **152**. The pump discharge hole **502** is connected to the pump outlet channel **180** connected to the first pressure control chamber **122**. The ink supplied from the pump

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supply hole **501** passes through a later-described pump chamber **503** (see FIG. **9**) and is discharged from the pump discharge hole **502**.

FIG. **9** is a cross-sectional view of the circulation pump **500** illustrated in FIG. **8A** along the IX-IX line. A diaphragm **506** is joined to the inner surface of the pump housing **505**, and the pump chamber **503** is formed between this diaphragm **506** and a recess formed in the inner surface of the pump housing **505**. The pump chamber **503** communicates with the pump supply hole **501** and the pump discharge hole **502** formed in the pump housing **505**. Also, a check valve **504a** is provided at an intermediate portion of the pump supply hole **501**. A check valve **504b** is provided at an intermediate portion of the pump discharge hole **502**. That is, the circulation pump **500** includes check valves in channels through which the downstream channel and the upstream channel communicate with each other. These check valves prevent the liquid in the upstream channel from flowing into the downstream channel through the circulation pump **500**. Note that in the present embodiment, check valves are included in the channels in the circulation pump **500** through which the fourth channel **170** and the third channel **180** communicate with each other. Specifically, the check valve **504a** is disposed such that a part thereof is movable in the leftward direction in FIG. **9** within a space **512a** formed at an intermediate portion of the pump supply hole **501**. The check valve **504b** is disposed such that a part thereof is movable in the rightward direction in FIG. **9** within a space **512b** formed at an intermediate portion of the pump discharge hole **502**.

As the diaphragm **506** is displaced so as to increase the volume of the pump chamber **503**, the pump chamber **503** is depressurized. In response to this displacement, the check valve **504a** is separated from the opening of the pump supply hole **501** in the space **512a** (that is, moves in the leftward direction in FIG. **9**). By being separated from the opening of the pump supply hole **501** in the space **512a**, the check valve **504a** shifts to an open state in which the ink is allowed to flow through the pump supply hole **501**. As the diaphragm **506** is displaced so as to reduce the volume of the pump chamber **503**, the pump chamber **503** is pressurized. In response to this displacement, the check valve **504a** comes into tight contact with the wall surface around the opening of the pump supply hole **501**. The check valve **504a** is thus in a closed state in which the check valve **504a** blocks the ink flow through the pump supply hole **501**.

The check valve **504b**, on the other hand, comes into tight contact with the wall surface around an opening in the pump housing **505** as the pump chamber **503** is depressurized, thereby shifting to a closed state in which the check valve **504b** blocks the ink flow through the pump discharge hole **502**. Also, as the pump chamber **503** is pressurized, the check valve **504b** is separated from the opening in the pump housing **505** and moves toward the space **512b** (that is, moves in the rightward direction in FIG. **9**), thereby allowing the ink to flow through the pump discharge hole **502**.

Note that the material of each of the check valves **504a** and **504b** only needs to be one that is deformable according to the pressure in the pump chamber **503**. For example, the material of each of the check valves **504a** and **504b** can be made from an elastic material such as Ethylene-Propylene-Diene Methylene linkage (EPDM) or an elastomer, or a film or thin plate of polypropylene or the like. However, the material is not limited to these.

As described above, the pump chamber **503** is formed by joining the pump housing **505** and the diaphragm **506**. Thus, the pressure in the pump chamber **503** changes as the

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diaphragm **506** is deformed. For example, in a case where the diaphragm **506** is displaced toward the pump housing **505** (displaced toward the right side in FIG. **9**), thereby reducing the volume of the pump chamber **503**, the pressure in the pump chamber **503** increases. As a result, the check valve **504b** disposed so as to face the pump discharge hole **502** shifts to the open state so that the ink in the pump chamber **503** is discharged. At this time, the check valve **504a** disposed so as to face the pump supply hole **501** is in tight contact with the wall surface around the pump supply hole **501**, thereby suppressing backflow of the ink from the pump chamber **503** into the pump supply hole **501**.

Conversely, in a case where the diaphragm **506** is displaced in the direction in which the pump chamber **503** widens, the pressure in the pump chamber **503** decreases. As a result, the check valve **504a** disposed so as to face the pump supply hole **501** shifts to the open state so that the ink is supplied into the pump chamber **503**. At this time, the check valve **504b** disposed in the pump discharge hole **502** comes into tight contact with the wall surface around an opening formed in the pump housing **505** to close this opening. This suppresses backflow of the ink from the pump discharge hole **502** into the pump chamber **503**.

As described above, in the circulation pump **500**, the ink is sucked and discharged as the diaphragm **506** is deformed and thereby changes the pressure in the pump chamber **503**. At this time, in a case where bubbles have entered the pump chamber **503**, the displacement of the diaphragm **506** changes the pressure in the pump chamber **503** to a lesser extent due to the expansion or shrinkage of the bubbles. Accordingly, the amount of the liquid to be sent decreases. To resolve this phenomenon, the pump chamber **503** is disposed in parallel with gravity so that the bubbles having entered the pump chamber **503** can easily gather in an upper portion of the pump chamber **503**. In addition, the pump discharge hole **502** is disposed higher than the center of the pump chamber **503**. This improves the ease of discharge of bubbles in the pump and thus stabilizes the flow rate.

<Flow of Ink Inside Liquid Ejection Head>

FIGS. **10A** to **10E** are diagrams describing a flow of an ink inside the liquid ejection head. The circulation of the ink performed inside the liquid ejection head **1** will be described with reference to FIGS. **10A** to **10E**. The relative positions of the components in FIGS. **10A** to **10E** such as the first pressure adjustment unit **120**, the second pressure adjustment unit **150**, and the circulation pump **500** are simplified for a clearer description of the ink circulation path. Thus, the relative positions of the components are different from those of the components in FIG. **19** to be mentioned later. FIG. **10A** schematically illustrates the flow of the ink in a case of performing a print operation of performing printing by ejecting the ink from the ejection ports **13**. Note that the arrows in FIG. **10A** indicate the flow of the ink. In the present embodiment, to perform a print operation, both the external pump **21** and the circulation pump **500** start being driven. Incidentally, the external pump **21** and the circulation pump **500** may be driven regardless of whether a print operation is to be performed or not. The external pump **21** and the circulation pump **500** do not have to be driven in conjunction with each other, and may be driven independently of each other.

During the print operation, the circulation pump **500** is in an ON state (driven state) so that the ink flowing out of the first pressure control chamber **122** flows into the supply channel **130** and the bypass channel **160**. The ink having flowed into the supply channel **130** passes through the ejection module **300** and then flows into the collection

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channel 140. Thereafter, the ink is supplied into the second pressure control chamber 152.

On the other hand, the ink flowed into the bypass channel 160 from the first pressure control chamber 122 flows into the second pressure control chamber 152 through the second valve chamber 151. The ink flowed into the second pressure control chamber 152 passes through the pump inlet channel 170, the circulation pump 500, and the pump outlet channel 180 and then flows into the first pressure control chamber 122 again. At this time, based on the relation in Equation 2 mentioned above, the controlled pressure in the first valve chamber 121 is set higher than the controlled pressure in the first pressure control chamber 122. Thus, the ink in the first pressure control chamber 122 does not flow into the first valve chamber 121 but is supplied to the ejection module 300 again through the supply channel 130. The ink flowed into the ejection module 300 flows into the first pressure control chamber 122 again through the collection channel 140, the second pressure control chamber 152, the pump inlet channel 170, the circulation pump 500, and the pump outlet channel 180. Ink circulation that completes within the liquid ejection head 1 is performed as described above.

In the above ink circulation, the differential pressure between the controlled pressure in the first pressure control chamber 122 and the controlled pressure in the second pressure control chamber 152 determines the amount of circulation (flow rate) of the ink within the ejection module 300. Moreover, this differential pressure is set to obtain an amount of circulation that can suppress thickening of the ink near the ejection ports in the ejection module 300. Incidentally, the amount of the ink consumed by the printing is supplied from the ink tank 2 to the first pressure control chamber 122 through the filter 110 and the first valve chamber 121. How the consumed ink is supplied will now be described in detail. The ink in the circulation path decreases by the amount of the ink consumed by the printing. Accordingly, the pressure in the first pressure control chamber 122 decreases, resulting in decreasing the ink in the first pressure control chamber. As the ink in the first pressure control chamber 122 decreases, the inner volume of the first pressure control chamber 122 decreases accordingly. As this inner volume of the first pressure control chamber 122 decreases, the communication port 191A shifts to the open state so that the ink is supplied from the first valve chamber 121 to the first pressure control chamber 122. A pressure loss occurs in this supplied ink as this ink supplied from the first valve chamber 121 passes through the communication port 191A. As the ink flows into the first pressure control chamber 122, the positive pressure on the ink switches to a negative pressure. As the ink flows from the first valve chamber 121 into the first pressure control chamber 122, the pressure in the first pressure control chamber increases. The communication port 191A shifts to the closed state when the inner volume of the first pressure control chamber increases. As described above, the communication port 191A repetitively switches between the open state and the closed state according to the ink consumption. Incidentally, the communication port 191A is kept in the closed state in a case where the ink is not consumed.

FIG. 10B schematically illustrates the flow of the ink immediately after the print operation is finished and the circulation pump 500 shifts to an OFF state (stop state). At the point when the print operation is finished and the circulation pump 500 shifts to the OFF state, the pressure in the first pressure control chamber 122 and the pressure in the second pressure control chamber 152 are both the controlled pressures used in the print operation. For this reason, the ink

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moves as illustrated in FIG. 10B according to the differential pressure between the pressure in the first pressure control chamber 122 and the pressure in the second pressure control chamber 152. Specifically, the ink flow from the first pressure control chamber 122 to the ejection module 300 through the supply channel 130 and then to the second pressure control chamber 152 through the collection channel 140 continues to be generated. Moreover, the ink flow from the first pressure control chamber 122 to the second pressure control chamber 152 through the bypass channel 160 and the second valve chamber 151 continues to be generated.

The amount of the ink moved from the first pressure control chamber 122 to the second pressure control chamber 152 by these ink flows is supplied from the ink tank 2 to the first pressure control chamber 122 through the filter 110 and the first valve chamber 121. Accordingly, the inner volume of the first pressure control chamber 122 is maintained constant. According to the relation in Equation 2 mentioned above, the spring force F1 of the valve spring 200, the spring force F2 of the pressure adjustment spring 220, the pressure reception area S1 of the valve 190, and the pressure reception area S2 of the pressing plate 210 are maintained constant in a case where the inner volume of the first pressure control chamber 122 is constant. Thus, the pressure in the first pressure control chamber 122 is determined depending on the change of the pressure (gauge pressure) P1 in the first valve chamber 121. In this way, in a case where the pressure P1 in the first valve chamber 121 does not change, the pressure P2 in the first pressure control chamber 122 is maintained at the same pressure as the controlled pressure in the print operation.

On the other hand, the pressure in the second pressure control chamber 152 changes with time according to the change in inner volume by the inflow of the ink from the first pressure control chamber 122. Specifically, the pressure in the second pressure control chamber 152 changes according to Equation 2 until the communication port 191 shifts from the state of FIG. 10B to the closed state to allow no communication between the second valve chamber 151 and the second pressure control chamber 152 as illustrated in FIG. 10C. Thereafter, the pressing plate 210 does not abut on the valve shaft 190a so that the communication port 191 shifts to the closed state. Then, as illustrated in FIG. 10D, the ink flows from the collection channel 140 into the second pressure control chamber 152. This inflow of the ink displaces the pressing plate 210 and the flexible member 230. The pressure in the second pressure control chamber 152 changes according to Equation 4. Specifically, the pressure increases until the inner volume of the second pressure control chamber 152 reaches the maximum.

Note that, once the state of FIG. 10C is reached, there is no more ink flow from the first pressure control chamber 122 into the second pressure control chamber 152 through the bypass channel 160 and the second valve chamber 151. Thus, the ink flow to the second pressure control chamber 152 through the collection channel 140 is only generated after the ink in the first pressure control chamber 122 is supplied to the ejection module 300 through the supply channel 130. As mentioned above, the ink moves from the first pressure control chamber 122 to the second pressure control chamber 152 according to the differential pressure between the pressure in the first pressure control chamber 122 and the pressure in the second pressure control chamber 152. Thus, in a case where the pressure in the second pressure control chamber 152 becomes equal to the pressure in the first pressure control chamber 122, the ink stops moving.

Also, in the state where the pressure in the second pressure control chamber **152** is equal to the pressure in the first pressure control chamber **122**, the second pressure control chamber **152** expands to the state illustrated in FIG. **10D**. In a case where the second pressure control chamber **152** expands as illustrated in FIG. **10D**, a reservoir portion capable of holding the ink is formed in the second pressure control chamber **152**. Note that the transition to the state of FIG. **10D** after stopping the circulation pump **500** takes about 1 minute to 2 minutes. The time may vary depending on the shapes and sizes of the channels and properties of the ink. As the circulation pump **500** is driven in the state where the ink is held in the reservoir portion as illustrated in FIG. **10D**, the ink in the reservoir portion is supplied to the first pressure control chamber **122** by the circulation pump **500**. Accordingly, as illustrated in FIG. **10E**, the amount of the ink in the first pressure control chamber **122** increases so that the flexible member **230** and the pressing plate **210** are displaced in the expanding direction. Then, as the circulation pump **500** continues to be driven, the state inside the circulation path changes to the state illustrated in FIG. **10A**.

Note that, in the above description, FIG. **10A** has been described as an example of the ink circulation during a print operation. However, the ink may be circulated without a print operation, as mentioned above. Even in this case, the ink flows as illustrated in FIGS. **10A** to **10E** in response to the driving and stopping of the circulation pump **500**.

Also, as described above, in the present embodiment, an example in which the communication port **191B** in the second pressure adjustment unit **150** shifts to the open state in a case where the ink is circulated by driving the circulation pump **500**, and shifts to the closed state in a case where the ink circulation stops, has been used. However, the present embodiment is not limited to this example. The controlled pressure may be set such that the communication port **191B** in the second pressure adjustment unit **150** is in the closed state even in a case where the ink is circulated by driving the circulation pump **500**. This will be specifically described below along with the function of the bypass channel **160**.

The bypass channel **160** connecting between the first pressure adjustment unit **120** and the second pressure adjustment unit **150** is provided in order that the ejection module **300** can avoid the effect of the strong negative pressure, for example, in a case where the negative pressure generated inside the circulation path becomes stronger than a preset value. The bypass channel **160** is also provided in order to supply the ink to the pressure chambers **12** from both the supply channel **130** and the collection channel **140**.

First, a description will be given of an example of avoiding the effect of the negative pressure becoming stronger than the preset value on the ejection module **300** by providing the bypass channel **160**. For example, a change in environmental temperature sometimes changes a property (e.g., viscosity) of the ink. As the viscosity of the ink changes, the pressure loss within the circulation path changes as well. For example, as the viscosity of the ink decreases, the amount of pressure loss within the circulation path decreases. As a result, the flow rate of the circulation pump **500** driven at a constant driving amount increases, and the flow rate through the ejection module **300** increases. Here, the ejection module **300** is kept at a constant temperature by a temperature adjustment mechanism (not illustrated). Hence, the viscosity of the ink inside the ejection module **300** is maintained constant even if the environmental temperature changes. The viscosity of the ink inside the ejection module **300** remains unchanged whereas the flow

rate of the ink flowing through the ejection module **300** increases, and therefore the negative pressure in the ejection module **300** becomes accordingly stronger due to flow resistance. If the negative pressure in the ejection module **300** becomes stronger than the preset value as described above, there is a possibility that the menisci in the ejection ports **13** may break and the ambient air may be taken into the circulation path, which may lead to a failure to perform normal ejection. Also, even if the menisci do not break, there is still a possibility that the negative pressure in the pressure chambers **12** may become stronger than a predetermined level and affect the ejection.

For these reasons, in the present embodiment, the bypass channel **160** is formed in the circulation path. By providing the bypass channel **160**, the ink flows through the bypass channel **160** in a case where the negative pressure is stronger than the preset value. Thus, the pressure in the ejection module **300** is kept constant. Thus, for example, the controlled pressure may be set such that the communication port **191B** in the second pressure adjustment unit **150** is maintained in the closed state even in a case where the circulation pump **500** is driven. Moreover, the controlled pressure in the second pressure adjustment unit **150** may be set such that the communication port **191B** in the second pressure adjustment unit **150** shifts to the open state in a case where the negative pressure becomes stronger than the preset value. In other words, the communication port **191B** may be in the closed state in a case where the circulation pump **500** is driven as long as the menisci do not collapse or a predetermined negative pressure is maintained even if the flow rate of the pump changes due to the change in viscosity caused by an environmental change or the like.

Next, a description will be given of an example where the bypass channel **160** is provided in order to supply the ink to the pressure chambers **12** from both the supply channel **130** and the collection channel **140**. The pressure in the circulation path may fluctuate due to the ejection operations of the ejection elements **15**. This is because the ejection operations generate a force that draws the ink into the pressure chambers.

In the following, a description will be given of the fact that the ink to be supplied to the pressure chambers **12** is supplied from both the supply channel **130** side and the collection channel **140** side in a case of continuing high-duty printing. While the definition of "duty" may vary depending on various conditions, in the following, a state where a 1200 dots per inch (dpi) grid cell is printed with a single 4 picoliter (pl) ink droplet will be considered 100%. "High-duty printing" is, for example, printing performed at a duty of 100%.

In a case of continuing high-duty printing, the amount of the ink flowing from the pressure chambers **12** into the second pressure control chamber **152** through the collection channel **140** decreases. On the other hand, the circulation pump **500** causes the ink to flow out in a constant amount. This breaks the balance between the inflow into and the outflow from the second pressure control chamber **152**. Consequently, the ink inside the second pressure control chamber **152** decreases and the negative pressure in the second pressure control chamber **152** becomes stronger so that the second pressure control chamber **152** shrinks. As the negative pressure in the second pressure control chamber **152** becomes stronger, the amount of inflow of the ink into the second pressure control chamber **152** through the bypass channel **160** increases, and the second pressure control chamber **152** becomes stable in the state where the outflow and the inflow are balanced. Thus, the negative pressure in the second pressure control chamber **152** becomes stronger

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according to the duty. Also, as mentioned above, under the configuration in which the communication port 191B is in the closed state in a case where the circulation pump 500 is driven, the communication port 191B shifts to the open state depending on the duty so that the ink flows from the bypass channel 160 into the second pressure control chamber 152.

Moreover, as high-duty printing is continued further, the amount of inflow into the second pressure control chamber 152 from the pressure chambers 12 through the collection channel 140 decreases and conversely the amount of inflow into the second pressure control chamber 152 from the communication port 191B through the bypass channel 160 increases. As this state progresses further, the amount of the ink flowing into the second pressure control chamber 152 from the pressure chambers 12 through the collection channel 140 reaches zero so that the ink flowing from the communication port 191B is the entire ink flowing out into the circulation pump 500. As this state progresses further, the ink backs up from the second pressure control chamber 152 into the pressure chambers 12 through the collection channel 140. In this state, the ink flowing from the second pressure control chamber 152 into the circulation pump 500 and the ink flowing from the second pressure control chamber 152 into the pressure chambers 12 will flow from the communication port 191B into the second pressure control chamber 152 through the bypass channel 160. In this case, the ink from the supply channel 130 and the ink from the collection channel 140 are filled into the pressure chambers 12 and ejected therefrom.

Note that this ink backflow that occurs in a case where the printing duty is high is a phenomenon that occurs due to the installation of the bypass channel 160. Also, as described above, an example has been described in which the communication port 191B in the second pressure adjustment unit shifts to the open state for the backflow of the ink. However, the backflow of the ink may also occur in the state where the communication port 191B in the second pressure adjustment unit is in the open state. Moreover, in a configuration without the second pressure adjustment unit, the above backflow of the ink can also occur by installing the bypass channel 160.

<Configuration of Ejection Unit>

FIGS. 11A and 11B are schematic views illustrating a circulation path for an ink of one color in the ejection unit 3 in the present embodiment. FIG. 11A is an exploded perspective view of the ejection unit 3 as seen from the first support member 4 side. FIG. 11B is an exploded perspective view of the ejection unit 3 as seen from the ejection module 300 side. Note that the arrows denoted as "IN" and "OUT" in FIGS. 11A and 11B indicate the ink flow, and the ink flow will be described only for one color, but the inks of the other colors flow similarly. Moreover, in FIGS. 11A and 11B, illustration of the second support member 7 and the electric wiring member 5 is omitted, and description of them is also omitted in the following description of the configuration of the ejection unit. Moreover, as for the first support member 4 in FIG. 11A, a cross section along the line XI-XI in FIG. 3A is illustrated. Each ejection module 300 includes an ejection element substrate 340 and an opening plate 330. FIG. 12 is a view illustrating the opening plate 330. FIG. 13 is a view illustrating the ejection element substrate 340.

The ejection unit 3 is supplied with an ink from each circulation unit 54 through the joint member 8 (see FIG. 3A). An ink path for an ink to return to the joint member 8 after passing the joint member 8 will now be described. Note that illustration of the joint member 8 is omitted in drawings to be mentioned below.

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Each ejection module 300 includes the ejection element substrate 340 and the opening plate 330, which are the silicon substrate 310, and further includes the discharge port forming member 320. The ejection element substrate 340, the opening plate 330, and the discharge port forming member 320 form the ejection module 300 by being stacked and joined such that each ink's channels communicate with each other. The ejection module 300 is supported on the first support member 4. The ejection unit 3 is formed by supporting each ejection module 300 on the first support member 4. The ejection element substrate 340 includes the discharge port forming member 320, and the discharge port forming member 320 includes a plurality of ejection port arrays each being a plurality of ejection ports 13 forming a line. Part of the ink supplied through ink channels in the ejection module 300 is ejected from the ejection ports 13. The ink not ejected is collected through ink channels in the ejection module 300.

As illustrated in FIGS. 11A and 11B and FIG. 12, the opening plate 330 includes a plurality of arrayed ink supply ports 311 and a plurality of arrayed ink collection ports 312. As illustrated in FIG. 13 and FIGS. 14A to 14C, the ejection element substrate 340 includes a plurality of arrayed supply connection channels 323 and a plurality of arrayed collection connection channels 324. The ejection element substrate 340 further includes the common supply channels 18 communicating with the plurality of supply connection channels 323 and the common collection channels 19 communicating with the plurality of collection connection channels 324. The ink supply channels 48 and the ink collection channels 49 (see FIGS. 3A and 3B) disposed in the first support member 4 and the channels disposed in each ejection module 300 communicate with each other to form the ink channels inside the ejection unit 3. Support member supply ports 211 are openings in cross section forming the ink supply channels 48. Support member collection ports 212 are openings in cross section forming the ink collection channels 49.

The ink to be supplied to the ejection unit 3 is supplied from the circulation unit 54 (see FIG. 3A) side to the ink supply channels 48 (see FIG. 3A) in the first support member 4. The ink flowed through the support member supply ports 211 in the ink supply channels 48 is supplied to the common supply channels 18 in the ejection element substrate 340 through the ink supply channels 48 (see FIG. 3A) and the ink supply ports 311 in the opening plate 330, and enters the supply connection channels 323. The channels up to this point are the supply-side channels. Thereafter, the ink passes through the pressure chambers 12 (see FIG. 3B) in the discharge port forming member 320 and flows into the collection connection channels 324 of the collection-side channels. Details of the ink flow in the pressure chambers 12 will be described below.

In the collection-side channels, the ink entered the collection connection channels 324 flows into the common collection channels 19. Thereafter, the ink flows from the common collection channels 19 into the ink collection channels 49 in the first support member 4 through the ink collection ports 312 in the opening plate 330, and is collected into the circulation unit 54 through the support member collection ports 212.

Regions of the opening plate 330 where the ink supply ports 311 or the ink collection ports 312 are not present correspond to regions of the first support member 4 for separating the support member supply ports 211 and the support member collection ports 212. Also, the first support member 4 does not have openings at these regions. Such

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regions are used as bonding regions in a case of bonding the ejection module 300 and the first support member 4.

In FIG. 12, a plurality of arrays of openings arranged along the X direction are provided side by side in the Y direction in the opening plate 330, and the openings for supply (IN) and the openings for collection (OUT) are arranged alternately in the Y direction while being shifted from each other by a half pitch in the X direction. In FIG. 13, in the ejection element substrate 340, the common supply channels 18 communicating with the plurality of supply connection channels 323 arrayed in the Y direction and the common collection channels 19 communicating with the plurality of collection connection channels 324 arrayed in the Y direction are arrayed alternately in the X direction. The common supply channels 18 and the common collection channels 19 are separated by the ink type. Moreover, the number of ejection port arrays for each color determines the numbers of common supply channels 18 and common collection channels 19 to be disposed. Also, the number of the disposed supply connection channels 323 and the number of the disposed collection connection channels 324 corresponds to the number of ejection ports 13. Note that a one-to-one correspondence is not necessarily essential, and a single supply connection channel 323 and a single collection connection channel 324 may correspond to a plurality of ejection ports 13.

Each ejection module 300 is formed by stacking and joining the opening plate 330 and the ejection element substrate 340 as above such that each ink's channels communicate with each other, and is supported on the first support member 4. As a result, ink channels including the supply channels and the collection channels as above are formed.

FIGS. 14A to 14C are cross-sectional views illustrating ink flows at different portions of the ejection unit 3. FIG. 14A is a cross section taken along the line XIVA-XIVA in FIG. 11A, and illustrates a cross section of a portion of the ejection unit 3 where ink supply channels 48 and ink supply ports 311 communicate with each other. FIG. 14B is a cross section taken along the line XIVB-XIVB in FIG. 11A, and illustrates a cross section of a portion of the ejection unit 3 where ink collection channels 49 and ink collection ports 312 communicate with each other. Also, FIG. 14C is a cross section taken along the line XIVC-XIVC in FIG. 11A, and illustrates a cross section of a portion where the ink supply ports 311 and the ink collection ports 312 do not communicate with channels in the first support member 4.

As illustrated in FIG. 14A, the supply channels for supplying the inks supply the inks from the portions where the ink supply channels 48 in the first support member 4 and the ink supply ports 311 in the opening plate 330 overlap and communicate with each other. Moreover, as illustrated in FIG. 14B, the collection channels for collecting the inks collect the inks from the portions where the ink collection channels 49 in the first support member 4 and the ink collection ports 312 in the opening plate 330 overlap and communicate with each other. Furthermore, as illustrated in FIG. 14C, the ejection unit 3 locally has regions where no opening is provided in the opening plate 330. At such regions, the inks are neither supplied or collected between the ejection element substrate 340 and the first support member 4. The inks are supplied at the regions where the ink supply ports 311 are provided, as illustrated in FIG. 14A. The inks are collected at regions where the ink collection ports 312 are provided, as illustrated in FIG. 14B. Note that the present embodiment has been described by taking the configuration using the opening plate 330 as an example, but

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a configuration not using the opening plate 330 may be employed. For example, the configuration in which channels corresponding to the ink supply channels 48 and the ink collection channels 49 are formed in the first support member 4, and the ejection element substrate 340 is joined to the first support member 4 may be employed.

FIGS. 15A and 15B are cross-sectional views illustrating the vicinity of an ejection port 13 in an ejection module 300. FIGS. 16A and 16B are cross-sectional views illustrating an ejection module having a configuration as a comparative example in which the common supply channels 18 and the common collection channels 19 are widened in the X direction. Note that the bold arrows illustrated in the common supply channel 18 and the common collection channel 19 in FIGS. 15A and 15B and FIGS. 16A and 16B indicate the oscillating movement of an ink which occurs in the configuration using the serial liquid ejection apparatus 50. The ink supplied to the pressure chamber 12 through the common supply channel 18 and the supply connection channel 323 is ejected from the ejection port 13 as the ejection element 15 is driven. In a case where the ejection element 15 is not driven, the ink is collected from the pressure chamber 12 into the common collection channel 19 through the collection connection channel 324, which is a collection channel.

In a case of ejecting the ink circulated as above in the configuration using the serial liquid ejection apparatus 50, the ink ejection is affected to no small extent by the oscillating movement of the ink inside the ink channels caused by the main scanning of the liquid ejection head 1. Specifically, the influence of the oscillating movement of the ink inside the ink channels appears as a difference in the amount of the ink ejected and a deviation in ejection direction. As illustrated in FIGS. 16A and 16B, in a case where the common supply channels 18 and the common collection channels 19 have cross-sectional shapes which are wide in the X direction, which is the main scanning direction, the inks inside the common supply channels 18 and the common collection channels 19 more easily receive inertial forces in the main scanning direction so that the inks oscillates greatly. This leads to a possibility that the oscillating movements of the inks may affect the ejection of the inks from the ejection ports 13. Moreover, widening the common supply channels 18 and the common collection channels 19 in the X direction widens the distance between the colors. This may lower the printing efficiency.

Hence, each common supply channel 18 and each common collection channel 19 in the present embodiment whose cross sections are illustrated in FIGS. 15A and 15B have a configuration that, each common supply channel 18 and each common collection channel 19 extend in the Y direction and also extend in the Z direction, which is perpendicular to the X direction, which is the main scanning direction. With such a configuration, the common supply channel 18 and the common collection channel 19 are given small channel widths in the main scanning direction. By giving the common supply channel 18 and the common collection channel 19 small channel widths in the main scanning direction, the oscillating movement of the ink inside the common supply channel 18 and the common collection channel 19 by the inertial force acting on the ink and exerted in the direction opposite to the main scanning direction (the black bold arrows in FIGS. 15A and 15B) during main scanning becomes smaller. This reduces the influence of the oscillating movement of the ink in the ejection of the ink. Moreover, by extending the common supply channel 18 and the common collection channel 19 in

the Z direction, their cross-sectional areas are increased. This reduces the channel pressure drop.

As described above, each common supply channel 18 and each common collection channel 19 are given small channel widths in the main scanning direction. This configuration reduces the oscillating movement of the ink inside the common supply channel 18 and the common collection channel 19 during main scanning but does not eliminate the oscillating movement. Thus, in the present embodiment, in order to reduce the difference in ejection between the ink types that may be generated by the reduced oscillating movement, the configuration is such that the common supply channel 18 and the common collection channel 19 are disposed at positions overlapping each other in the X direction.

As described above, in the present embodiment, the supply connection channels 323 and the collection connection channels 324 are provided so as to correspond to the ejection ports 13. Moreover, the correspondence relationship between the supply connection channels 323 and the collection connection channels 324 establishes such that the supply connection channels 323 and the collection connection channels 324 are arrayed in the X direction with the ejection ports 13 interposed therebetween. Thus, if the common supply channel 18 and the common collection channel 19 have a portion(s) where the common supply channel 18 and the common collection channel 19 do not overlap each other in the X direction, the correspondence between the supply connection channels 323 and the collection connection channels 324 in the X direction breaks. This incorespondence affects the ink flow in the pressure chambers 12 in the X direction and the ink ejection. If this incorespondence is combined with the influence of the oscillating movement of the ink, there is a possibility that it may further affects the ink ejection from each ejection port.

Thus, by disposing the common supply channel 18 and the common collection channel 19 at positions overlapping each other in the X direction, the oscillating movement of the ink inside the common supply channel 18 and the common collection channel 19 during main scanning is substantially the same at any position in the Y direction, in which the ejection ports 13 are arrayed. Thus, the pressure differences generated in the pressure chambers 12 between the common supply channel 18 side and the common collection channel 19 side do not greatly vary. These low pressure differences enable stable ejection.

Also, some liquid ejection heads which circulate an ink therein are configured such that the channel for supplying the ink to the liquid ejection head and the channel for collecting the ink are the same channel. However, in the present embodiment, the common supply channel 18 and the common collection channel 19 are different channels. Moreover, the supply connection channels 323 and the pressure chambers 12 communicate with each other, the pressure chambers 12 and the collection connection channels 324 communicate with each other, and the inks are ejected from the ejection ports 13 in the pressure chambers 12. That is, the configuration that the pressure chambers 12 serving as paths connecting the supply connection channels 323 and the collection connection channels 324 include the ejection ports 13, is formed. Hence, in each pressure chamber 12, an ink flow flowing from the supply connection channel 323 side to the collection connection channel 324 side is generated, and the ink inside the pressure chamber 12 is efficiently circulated. The ink inside the pressure chamber 12, which tends to be affected by evaporation of the ink from the

ejection port 13, is kept fresh by efficiently circulating the ink inside the pressure chamber 12.

Also, since the two channels, namely the common supply channel 18 and the common collection channel 19, communicate with the pressure chamber 12, the ink can be supplied from both channels in a case where it is necessary to perform ejection with a high flow rate. That is, compared to the configuration in which only a single channel is formed for ink supply and collection, the configuration in the present embodiment has an advantage that not only efficient circulation can be performed but also ejection at a high flow rate can be handled.

Incidentally, the oscillating movement of the ink causes a less effect in a case where the common supply channel 18 and the common collection channel 19 are disposed at positions close to each other in the X direction. The common supply channel 18 and the common collection channel 19 are desirably disposed such that the gap between the channels is 75 μm to 100 μm .

FIG. 17 is a view illustrating an ejection element substrate 340 as a comparative example. Note that illustration of the supply connection channels 323 and the collection connection channels 324 is omitted in FIG. 17. The inks having received thermal energy from the ejection elements 15 in the pressure chambers 12 flow into the common collection channels 19. Hence, the temperature of the inks flowing through the common collection channels 19 is higher than the temperature of the inks in the common supply channels 18. Here, in the comparative example, only the common collection channels 19 are present at one portion of the ejection element substrate 340 in the X direction, as indicated by a portion α circled with the long dashed short dashed line in FIG. 17. In this case, the temperature may locally rise at that portion, thereby causing temperature unevenness within the ejection module 300. This temperature unevenness may affect the ejection.

The temperature of the inks flowing through the common supply channels 18 is lower than that in the common collection channels 19. Thus, if the common supply channels 18 and the common collection channels 19 are close to each other, the ink in the common supply channels 18 whose temperature is relatively lower lowers the temperature of the ink in the common collection channels 19 at the points where both channels are close. This suppresses a temperature rise. For this reason, it is preferable that the common supply channels 18 and the common collection channels 19 have substantially the same length, be present at positions overlapping each other in the X direction, and be close to each other.

FIGS. 18A and 18B are views illustrating a channel configuration of the liquid ejection head 1 for the inks of the three colors of cyan (C), magenta (M), and yellow (Y). In the liquid ejection head 1, a circulation channel is provided for each ink type as illustrated in FIG. 18A. The pressure chambers 12 are provided along the X direction, which is the main scanning direction of the liquid ejection head 1. Also, as illustrated in FIG. 18B, the common supply channels 18 and the common collection channels 19 are provided along the ejection port arrays, which are arrays of ejection ports 13. The common supply channels 18 and the common collection channels 19 are provided so as to extend in the Y direction with the ejection port arrays therebetween.

<Connection of Main Body Units and Liquid Ejection Head>

FIG. 19 is a schematic configuration diagram more specifically illustrating a state where an ink tank 2 and an external pump 21 provided as main body units of the liquid

ejection apparatus **50** in the present embodiment and the liquid ejection head **1** are connected, and an arrangement of a circulation pump and so on. The liquid ejection apparatus **50** in the present embodiment has such a configuration that only the liquid ejection head **1** can be easily replaced in a case where a trouble occurs in the liquid ejection head **1**. Specifically, the liquid ejection apparatus **50** in the present embodiment has the liquid connection parts **700**, with which the respective ink supply tubes **59** connected to the respective external pumps **21** and the liquid ejection head **1** can be easily connected to and disconnected from each other. This enables only the liquid ejection head **1** to be easily attached to and detached from the liquid ejection apparatus **50**.

As illustrated in FIG. **19**, each liquid connection part **700** has a liquid connector insertion slot **53a** which is provided in a protruding manner on the head housing **53** of the liquid ejection head **1**, and a cylindrical liquid connector **59a** into which this liquid connector insertion slot **53a** is insertable. The liquid connector insertion slot **53a** is fluidly connected to an ink supply channel (inflow channel) formed in the liquid ejection head **1**, and is connected to the first pressure adjustment unit **120** through the filter **110** mentioned earlier. The liquid connector **59a** is provided at the tip of the ink supply tube **59** connected to the external pump **21**, which supplies the ink in the ink tank **2** to the liquid ejection head **1** by pressurization.

As described above, the liquid ejection head **1** illustrated in FIG. **19** has the liquid connection part **700**. This facilitates the work of attaching, detaching, and replacing the liquid ejection head **1**. However, in a case where the sealing performance between the liquid connector insertion slot **53a** and the liquid connector **59a** deteriorates, there is a possibility that the ink supplied by pressurization by the external pump **21** may leak from the liquid connection part **700**. The leaked ink may cause a trouble in the electrical system if attached to the circulation pump **500**, for example. To address this, in the present embodiment, the circulation pump, etc. are disposed as below.

<Arrangement of Circulation Pump, Etc.>

As illustrated in FIG. **19**, in the present embodiment, in order to avoid attachment of the ink leaking from the liquid connection part **700** to the circulation pump **500**, the circulation pump **500** is disposed higher than the liquid connection part **700** in the direction of gravity. Specifically, the circulation pump **500** is disposed higher than the liquid connector insertion slot **53a**, which is a liquid inlet in the liquid ejection head **1**, in the direction of gravity. Moreover, the circulation pump **500** is disposed at such a position as to be out of contact with the constituent members of the liquid connection part **700**. In this way, even if the ink leaks from the liquid connection part **700**, the ink flows in a horizontal direction which is the opening direction of the opening of the liquid connector **59a** or downward in the direction of gravity. This prevents the ink from reaching the circulation pump **500** located higher in the direction of gravity. Moreover, disposing the circulation pump **500** at a position separated from the liquid connection part **700** also reduces the possibility of the ink reaching the circulation pump **500** through members.

Furthermore, an electric connection part **515** electrically connecting the circulation pump **500** and the electric contact substrate **6** through a flexible wiring member **514** is provided higher than the liquid connection part **700** in the direction of gravity. Thus, the possibility of the ink from the liquid connection part **700** causing an electrical trouble is reduced.

In addition, in the present embodiment, a wall portion **52b** of the head housing **53** is provided. Thus, even if the ink jets out of the liquid connection part **700** from its opening **59b**, the wall portion **53b** blocks that ink and thus reduces the possibility of the ink reaching the circulation pump **500** or the electric connection part **515**.

<Backflow of Inks in Vicinities of Ejection Ports>

Next, a characteristic feature of the present embodiment will be described below. FIGS. **20A** and **20B** are views schematically illustrating backflow of inks in the vicinities of ejection ports. FIG. **20A** is a view schematically illustrating the circulation path illustrated in FIG. **5**. FIG. **20B** is an enlarged view of the ejection module illustrated in FIG. **3B**. FIGS. **5** and **3B** illustrate flows such that the inks in the pressure chambers **12** have flowed therein from the common supply channels **18**, and pass through the pressure chambers **12** and flow out through the common collection channels **19**. As mentioned earlier, in the case of continuing high-duty printing, the inks set back into the pressure chambers **12** from the collection channel **140** side as well. That is, as illustrated in FIGS. **20A** and **20B**, each pressure chamber **12** is refilled with the ink from both the supply channel **130** (common supply channel **18**) and the collection channel **140** (common collection channel **19**). Specifically, the ink supplied to the bypass channel **160** from the first pressure control chamber **122** is supplied to the second pressure control chamber **152** of the second pressure adjustment unit **150** through the second valve chamber **151**. Thereafter, part of the ink supplied to the second pressure control chamber **152** is supplied to the collection channel **140** and then supplied to the ejection ports **13** through the common collection channel **19**.

FIGS. **21A** and **21B** are views describing ink supply inside an ejection module **300**. FIG. **21A** is a view illustrating a channel configuration in the vicinity of a pressure chamber **12**, and is a view illustrating a comparative example different from the present embodiment. FIG. **21A** represents a configuration in which only one side of the pressure chamber **12** communicates with a flow channel **2010**. In this configuration, the supply of an ink to the pressure chamber **12** is one-side supply in which the ink is supplied only from the channel **2010**. In the configuration of FIG. **21A**, independent supply ports **2020** communicating with the pressure chamber **12** are connected to either the common supply channel **18** or the common collection channel **19** or both of them. In a case of using in particular a thermal-type ejection element as the ejection element **15**, the ink is ejected from the ejection port **13** by generating a bubble inside the pressure chamber **12**. Also, the pressure chamber **12** is refilled with the ink by bubble disappearance corresponding to the bubble generation. In such a channel configuration, the channel **2010** connected to the pressure chamber **12** is narrowed and lengthened to increase the rear resistance at the time of the bubble generation. This makes the generated bubble more symmetrical and improves the formation of a droplet. On the other hand, in a configuration as illustrated in FIG. **21A**, the increased rear resistance lowers the ease of supply in the ink refill of the pressure chamber **12** at the time of the bubble disappearance after ejection. Accordingly, with the channel configuration illustrated in FIG. **21A**, it is generally difficult to improve the refill frequency. In particular, in a case of performing a high-duty print operation, the amount of the ink to be supplied to each ejection port becomes small, which leads to a possibility of lowering the ejection stability.

FIG. **21B**, on the other hand, is a view illustrating a channel configuration in the vicinity of a pressure chamber

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12 in the present embodiment. The supply connection channels 323 serving as first independent supply ports connect a first liquid channel 2030 communicating with the pressure chamber 12 and the common supply channel 18. The collection connection channels 324 serving as second independent supply ports connect a second liquid channel 2040 communicating with the pressure chamber 12 and the common collection channel 19. As mentioned earlier, in the present embodiment, the pressure chamber 12 is refilled the amount of the ink ejected from the ejection port 13 from the first liquid channel 2030 and the second liquid channel 2040. As illustrated in FIG. 21B, a both-side supply configuration is employed in which both sides of the pressure chamber 12 communicate with the first liquid channel 2030 and the second liquid channel 2040. With such a configuration, although the channels communicating with the pressure chamber 12 are widened and shortened as illustrated in FIG. 21B, symmetrical rear resistances are exerted at the time of bubble generation, so that it is easier for the generated bubble to be more symmetrical. This tends to improve the formation of an ink droplet. Moreover, the rear resistances do not have to be increased. This improves the ease of ink supply in the ink refill of the pressure chamber 12 at the time of the bubble disappearance after ejection. As described above, according to the present embodiment, the ejection stability is improved even in the case of performing a high-duty print operation. That is, both the droplet formation and the refill frequency are improved.

Note that a case of using thermal-type ejection elements has been mainly described in the above embodiment. However, piezoelectric-type ejection elements may be used. With the thermal type, however, it is more difficult to improve both the droplet formation and the refill frequency. Hence, the thermal type is more preferable in the present embodiment.

<<Modifications>>

Next, various modifications of the above-described embodiment will be described. A configuration in which an ink sets back toward the pressure chambers 12 from the collection channel 140 only needs to be such that the bypass channel 160 is provided and no mechanism that functions as a check valve is provided between the merging portion between the bypass channel 160 and the collection channel 140 and the pressure chambers 12. In the present embodiment, the circulation pump 500 is a pump that sends the liquid in one direction, as described earlier. Thus, it suffices that the merging portion of the bypass channel 160 be provided upstream of the circulation pump 500. In other words, it suffices that the bypass channel 160 allow the upstream channel and the downstream channel to communicate with each other without the pressure chambers 12 therebetween. Such a configuration enables the bypass channel 160 to supply the liquid to the pressure chambers 12 through the downstream channel.

<First Modification>

FIGS. 22A and 22B and FIGS. 23A and 23B are views schematically illustrating circulation paths in a first modification. FIGS. 22A and 22B illustrate the circulation paths in a case of performing circulation without performing ejection. FIGS. 23A and 23B illustrate the circulation paths in a case of performing high-duty printing. The first modification represents an example in which the second pressure adjustment unit 150 is not disposed, the bypass channel 160 and the collection channel 140 are directly connected to each other.

In this configuration, the flow resistance of a channel through which the ink flows to the collection channel 140

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through the bypass channel 160 is denoted as R1, and the flow resistance of a channel through which the ink flows to the collection channel 140 from the supply channel 130 through the ejection module 300 will be denoted as R2. The amount of the ink flowing through each channel is in inverse ratio to the resistance. For this reason, the ratio of the flow rate through the channel passing through the bypass channel 160 to the flow rate through the channel passing through the ejection module 300 is R2 to R1. Based on this relationship, each flow resistance is set to obtain an amount of circulation that can suppress thickening of the ink near the ejection ports 13 in the ejection module 300. Specifically, each flow resistance is set such that the flow velocity of the liquid in the pressure chambers will be a predetermined flow velocity or more. The flow resistance R1 of the bypass channel 160 is controlled by, for example, changing its channel area or channel length or providing a constriction.

In the first modification too, in the case of performing a high-duty print operation, an ink is supplied to each pressure chamber 12 from both sides, as illustrated in FIGS. 23A and 23B. Specifically, the ink supplied to the supply channel 130 from the first pressure control chamber 122 is supplied to the ejection ports 13 through the common supply channels 18 in the ejection module 300. On the other hand, part of the ink supplied to the bypass channel 160 from the first pressure control chamber 122 is supplied to the first pressure control chamber 122 through the circulation pump 500 and the pump outlet channel 180. Also, part of the ink supplied to the bypass channel 160 is supplied to the collection channel 140 and then supplied to the ejection ports 13 through the common collection channels 19 in the ejection module 300. Thus, the ink to be ejected from the ejection ports 13 is supplied from both the supply channel 130 and the collection channel 140.

<Second Modification>

FIGS. 24A and 24B and FIGS. 25A and 25B are views schematically illustrating circulation paths in a second modification. FIGS. 24A and 24B illustrate the circulation paths in a case of performing circulation without performing ejection. FIGS. 25A and 25B illustrate the circulation paths in a case of performing high-duty printing. The second modification represents an example in which the second pressure adjustment unit 150 is not disposed, the bypass channel 160 and the collection channel 140 are directly connected to each other, and a relief valve 2301 is disposed in the bypass channel 160.

The relief valve 2301 is configured such that the ink flows into the relief valve from the upstream side toward the downstream side of the relief valve in a case where the pressure downstream of the relief valve reaches a predetermined value or less. Specifically, the relief valve is configured to open in a case where the pressure on the collection channel side of the relief valve becomes lower than the pressure on the supply channel side of the relief valve to a predetermined degree or more. The flow of the ink to be supplied is basically the same as that in a configuration in which the second pressure adjustment unit 150 is disposed as illustrated in FIG. 5 and FIGS. 20A and 20B. The differential pressure between the controlled pressure in the first pressure control chamber 122 and the controlled pressure in the relief valve 2301 determines the amount of circulation within the ejection module 300. The controlled pressure in the relief valve 2301 is set to obtain an amount of circulation that can suppress thickening of the ink near the ejection ports 13 in the ejection module 300.

With the configuration of the second modification too, in the case of performing a high-duty print operation, an ink is

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supplied to each pressure chamber 12 from both sides, as illustrated in FIGS. 25A and 25B. Specifically, the ink supplied to the supply channel 130 from the first pressure control chamber 122 is supplied to the ejection ports 13 through the common supply channels 18 in the ejection module 300. On the other hand, part of the ink supplied to the bypass channel 160 from the first pressure control chamber 122 passes through the relief valve 2301 and is supplied to the first pressure control chamber 122 through the circulation pump 500 and the pump outlet channel 180. Also, part of the ink supplied to the bypass channel 160 passes through the relief valve 2301, is supplied to the collection channel 140, and is then supplied to the ejection ports 13 through the common collection channels 19 in the ejection module 300. Thus, the ink to be ejected from the ejection ports 13 is supplied from both the supply channel 130 and the collection channel 140.

<Third Modification>

Next, various modifications of circulation channels will be collectively described as a third modification. As mentioned earlier, a configuration in which an ink sets back toward the pressure chambers 12 from the collection channel 140 only needs to be such that the bypass channel 160 is provided and no mechanism that functions as a check valve is provided between the merging portion of the bypass channel 160 and the pressure chambers 12. Thus, with a circulation channel that can maintain this relationship, the ink can be supplied to the pressure chambers 12 from both sides, and the ejection stability can therefore be improved.

FIG. 26 is a block diagram schematically illustrating a circulation path. FIG. 26 represents an example in which the pump outlet channel 180 located downstream of the circulation pump 500 is configured to be connected to the ink tank 2, not to the first pressure control chamber 122. This configuration can also improve the ejection stability similarly to the configurations described above.

FIG. 27 is a block diagram schematically illustrating a circulation path. FIG. 27 represents an example in which each circulation pump 500, which is mounted in the liquid ejection head 1 in the above, is installed on the carriage 60 on the main body side of the liquid ejection apparatus 50. The configuration is also such that the pump inlet channel 170 and the pump outlet channel 180 are partly disposed outside the liquid ejection head 1. This configuration can also improve the ejection stability similarly to the configurations described above.

In FIG. 27, the circulation pump 500 is mounted on the carriage 60 on the main body side of the liquid ejection apparatus 50, and the first pressure adjustment unit 120 and the second pressure adjustment unit 150 are mounted in the liquid ejection head 1. Note that one or both of the first pressure adjustment unit 120 and the second pressure adjustment unit 150 may be mounted on the carriage 60 on the main body side of the liquid ejection apparatus 50. In the case where the first pressure adjustment unit 120 is mounted on the carriage 60 on the main body side of the liquid ejection apparatus 50, the configuration is such that the first channel 130 is partly disposed outside the liquid ejection head 1. In the case where the second pressure adjustment unit 150 is mounted on the carriage 60 on the main body side of the liquid ejection apparatus 50, the configuration is such that the second channel 140 is partly disposed outside the liquid ejection head 1.

FIG. 28 is a block diagram schematically illustrating a circulation path. FIG. 28 represents an example in which each circulation pump 500, which is mounted in the liquid ejection head 1 in the above, is installed on the main body

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side of the liquid ejection apparatus 50, and the pump outlet channel 180 is connected to the corresponding ink tank 2. This configuration can also improve the ejection stability similarly to the configurations described above.

<Fourth Modification>

FIG. 29 is a view schematically illustrating a circulation path in a fourth modification. The fourth modification represents an example in which a second supply channel 600 is included through which the first pressure control chamber 122 of the first pressure adjustment unit 120 and the supply channel 130 communicate with each other.

In the state in which the liquid ejection head 1 is used, the second supply channel 600 communicates at its one end portion with an upper end portion of the first pressure control chamber 122 in the direction of gravity, and communicates at its other end portion with the supply channel 130 (first channel), which is located lower than the one end portion in the vertical direction. Here, the used state refers to the state in which the liquid ejection head 1 is used, that is, the state of FIG. 2, in which the ejection ports for ejecting the liquids are oriented downward in the vertical direction. By including this second supply channel 600, bubbles having flowed into the first pressure adjustment unit 120 from the upstream side or bubbles generated inside the circulation channel are efficiently discharged to the outside.

Specifically, the first pressure control chamber 122 of the first pressure adjustment unit 120 is disposed on an upper side in the liquid ejection head 1 in the direction of gravity. Thus, bubbles BL having flowed into the first pressure adjustment unit 120 along with the ink from the upstream side of the liquid ejection head 1 or bubbles BL having flowed into the first pressure control chamber 122 from the circulation channel ascend to an upper portion of the first pressure control chamber 122 or an upper portion of the second supply channel 600 and are gathered there. Note that the gathered bubbles BL does not move to the ejection module 300 with the flow velocity of the liquid flowing through the supply channel 130 and the second supply channel 600 during an ink ejection operation. Thus, the second supply channel 600 is also referred to as "air accumulation channel".

The bubbles BL gathered in the upper portions of the first pressure control chamber 122 and the second supply channel 600 can be discharged along with the ink by performing a suction process of forcibly sucking the ink from the ejection ports in a state where no liquid ejection operation is performed. The suction process is performed by bringing the cap member into tight contact with the ejection port surface of the liquid ejection head 1, in which the ejection ports are formed, and applying a negative pressure to the ejection ports from a negative pressure source connected to the cap member to thereby forcibly suck the ink from the ejection ports. The flow rate of the ink generated inside the channels during this suction is higher than the flow velocity of the ink generated by a normal ink ejection operation. Hence, the bubbles BL gathered in the upper portions of the first pressure control chamber 122 and the second supply channel 600 move along with the ink to the pressure chambers 12 through the second supply channel 600 and the supply channel 130, and are then discharged from the ejection ports 13 along with the ink. Note that this suction process is generally executed in a suction recovery process which is performed by discharging a thickened ink and the like appearing in the ejection ports, the pressure chambers, or the like from the ejection ports to recover the ejection performance, an initial filling process of filling the ink into the channels, or the like.

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As described above, by forming the second supply channel, bubbles included in the ink within the liquid ejection head **1** can be gathered and discharged at once by the suction process. Thus, a process of discharging bubbles can be performed efficiently.

<Fifth Modification>

The liquid ejection head **1** illustrated in FIG. 1A has been described by taking, as an example, a so-called serial liquid ejection head which ejects inks while moving in the main scanning direction, but is not limited to this. The liquid ejection head **1** may be a so-called full-line liquid ejection head in which ejection ports are formed over the entire width of the print medium **P** and which is capable of ejecting the inks onto the whole region of the print medium **P** in the width direction without moving in the main scanning direction.

<Sixth Modification>

FIG. 30 is a view schematically illustrating a circulation path in a sixth modification. In the sixth modification, neither the first pressure adjustment unit **120** nor the second pressure adjustment unit **150** is included. Even in such a configuration, the liquid can be set back into the pressure chambers **12** from the collection channel **140** by including the bypass channel **160**, through which the upstream channel and the downstream channel communicate with each other without the pressure chambers **12** therebetween, as described above.

Also, a configuration having only one of the first pressure adjustment unit **120** or the second pressure adjustment unit **150** may be employed.

<<Other Embodiments>>

The disclosure of the present embodiment includes configurations as represented by the following liquid ejection head examples and liquid ejection apparatus examples.

<Configuration 1>

A liquid ejection head includes a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port, an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber, a downstream channel which communicates with the pressure chamber, a pump which communicates with the upstream channel and the downstream channel and is configured to cause the liquid in the downstream channel to flow into the upstream channel, an inflow channel which communicates with the upstream channel and configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel, and a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and the downstream channel, wherein part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

<Configuration 2>

The liquid ejection head according to configuration 1, wherein the pump includes a check valve in a channel through which the downstream channel and the upstream channel communicate with each other.

<Configuration 3>

The liquid ejection head according to configuration 1 or 2, wherein the upstream channel includes a first pressure adjustment unit communicating with the inflow channel, a first channel through which the first pressure adjustment unit and the pressure chamber communicate with each other, and wherein a third channel through which the pump and the first

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pressure adjustment unit communicate with each other, and the first pressure adjustment unit is configured to adjust a pressure in the first channel.

<Configuration 4>

The liquid ejection head according to configuration 3, wherein the first pressure adjustment unit includes a valve chamber, a pressure control chamber having a surface formed of a flexible member configured to be displaceable, an opening through which the valve chamber and the pressure control chamber communicate with each other, and a valve configured to be capable of opening and closing the opening, wherein the pressure control chamber includes a pressing plate capable of being displaced in conjunction with the flexible member, and a biasing member configured to bias the pressing plate in a direction in which a volume of the pressure control chamber increases, and wherein the pressure control chamber is configured to be capable of opening and closing the valve according to displacement of the pressing plate and the flexible member.

<Configuration 5>

The liquid ejection head according to configuration 4, wherein the inflow channel is connected to the valve chamber of the first pressure adjustment unit.

<Configuration 6>

The liquid ejection head according to configuration 4 or 5, wherein the first channel, the third channel, and the bypass channel are connected to the pressure control chamber of the first pressure adjustment unit.

<Configuration 7>

The liquid ejection head according to any one of configurations 3 to 6, wherein a relief valve is disposed in the bypass channel, and wherein the relief valve is configured to open in a case where a pressure in the downstream channel becomes lower than the pressure in the first channel to a predetermined degree or more.

<Configuration 8>

The liquid ejection head according to any one of configurations 1 to 7, wherein flow resistance of the bypass channel is set such that a flow velocity of the liquid in the pressure chamber is a predetermined flow velocity or more in a state in which the pump is driven, thereby circulating the liquid through the pressure chamber.

<Configuration 9>

The liquid ejection head according to any one of configurations 4 to 6, wherein the pressure control chamber of the first pressure adjustment unit includes an air accumulation channel communicating with the first channel, and wherein in a state in which the liquid ejection head is used, one end portion of the air accumulation channel communicates with an upper end portion of the pressure control chamber of the first pressure adjustment unit, and another end portion of the air accumulation channel communicates with the first channel, which is located lower than the one end portion in a direction of gravity.

<Configuration 10>

The liquid ejection head according to any one of configurations 1 to 9, wherein the downstream channel includes a second pressure adjustment unit, a second channel through which the pressure chamber and the second pressure adjustment unit communicate with each other, and a fourth channel through which the second pressure adjustment unit and the pump communicate with each other, and wherein the second pressure adjustment unit is configured to adjust a pressure in the second channel and wherein the bypass channel supplies the liquid to the pressure chamber through the second pressure adjustment unit and the second channel.

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<Configuration 11>

The liquid ejection head according to configuration 10, wherein the second pressure adjustment unit includes a valve chamber, a pressure control chamber having a surface formed of a flexible member configured to be displaceable, an opening through which the valve chamber and the pressure control chamber communicate with each other, and a valve configured to be capable of opening and closing the opening, wherein the pressure control chamber includes a pressing plate capable of being displaced in conjunction with the flexible member, and a biasing member configured to bias the pressing plate in a direction in which a volume of the pressure control chamber increases, and wherein the pressure control chamber is configured to be capable of opening and closing the valve according to displacement of the pressing plate and the flexible member.

<Configuration 12>

The liquid ejection head according to configuration 11, wherein the bypass channel is connected to the valve chamber of the second pressure adjustment unit.

<Configuration 13>

The liquid ejection head according to configuration 11 or 12, wherein the pressure control chamber of the second pressure adjustment unit is connected to the second channel and the fourth channel.

<Configuration 14>

The liquid ejection head according to any one of configurations 1 to 13, further includes an ejection unit configured to eject the liquid, and a circulation unit configured to circulate the liquid between the ejection unit and the circulation unit, wherein the circulation unit includes the pump, and the ejection unit includes the ejection port and the pressure chamber.

<Configuration 15>

A liquid ejection apparatus includes a liquid ejection head configured to eject a liquid, wherein the liquid ejection head includes a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port, an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber, a downstream channel which communicates with the pressure chamber, a pump which communicates with the upstream channel and the downstream channel and is configured to cause the liquid in the downstream channel to flow into the upstream channel, an inflow channel which communicates with the upstream channel and configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel, and a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and downstream channel and wherein part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

<Configuration 16>

A liquid ejection apparatus includes a liquid ejection head configured to eject a liquid, a circulation unit including a pump configured to circulate the liquid between the liquid ejection head and the circulation unit; and a carriage including a liquid-ejection-head mounting unit on which the liquid ejection head is mounted and a circulation-unit mounting unit on which the circulation unit is mounted, wherein the liquid ejection head includes a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port, an upstream channel

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which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber, and a downstream channel which communicates with the pressure chamber, an inflow channel configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel communicates with the upstream channel, the pump communicates with the upstream channel and the downstream channel and causes the liquid in the downstream channel to flow into the upstream channel, and the liquid ejection head includes a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and the downstream channel, and part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

<Configuration 17>

The liquid ejection apparatus according to configuration 15 or 16, further includes an ink tank configured to hold the liquid, wherein the inflow channel is a flow channel through which the ink tank and the liquid ejection head communicate with each other and is configured to cause the liquid in the ink tank to flow into the liquid ejection head.

<Configuration 18>

The liquid ejection apparatus according to any one of configurations 15 to 17, wherein the downstream channel includes a pressure adjustment unit configured to adjust a pressure in the downstream channel and wherein the bypass channel is connected to the pressure adjustment unit.

<Configuration 19>

The liquid ejection apparatus according to configuration 18, wherein the pressure adjustment unit includes a valve chamber, a pressure control chamber, and an opening through which the valve chamber and the pressure control chamber communicate with each other, the valve chamber includes a valve configured to be capable of opening and closing the opening according to a change in pressure in the pressure control chamber, and the bypass channel is connected to the valve chamber in the pressure adjustment unit.

<Configuration 20>

The liquid ejection apparatus according to any one of configurations 15 to 19, wherein the carriage moves relative to a print medium to which the liquid is ejected from the liquid ejection head.

Embodiments of the present disclosure can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described Embodiments and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described Embodiments, and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described Embodiments and/or controlling the one or more circuits to perform the functions of one or more of the above-described Embodiments. The computer may include one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium

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may include, for example, one or more of a hard disk, a random-access memory (RAM), a read-only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc™ (BD)), a flash memory 5 device, a memory card, and the like.

While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary 10 embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2021-205384, filed Dec. 17, 2021, and Japanese Patent Application No. 2022-166263, filed Oct. 17, 15 2022, each of which is hereby incorporated by reference in their entirety.

What is claimed is:

1. A liquid ejection head comprising:

a pressure chamber in which a pressure generated by an 20 ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port;
an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to 25 the pressure chamber;
a downstream channel which communicates with the pressure chamber;
a pump which directly communicates with both the upstream channel and the downstream channel and is 30 configured to cause the liquid in the downstream channel to flow into the upstream channel;
an inflow channel which communicates with both the upstream channel and configured to cause the liquid to be supplied to the pressure chamber to flow into the 35 upstream channel; and
a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream 40 channel and the downstream channel,
wherein part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

2. The liquid ejection head according to claim 1, wherein the pump includes a check valve in a channel through which 45 the downstream channel and the upstream channel communicate with each other.

3. The liquid ejection head according to claim 2, wherein the upstream channel includes:

a first pressure adjustment unit communicating with the 50 inflow channel,
a first channel through which the first pressure adjustment unit and the pressure chamber communicate with each other, and
a third channel through which the pump and the first 55 pressure adjustment unit communicate with each other, and
wherein the first pressure adjustment unit is configured to adjust a pressure in the first channel.

4. The liquid ejection head according to claim 3, wherein the first pressure adjustment unit includes:

a valve chamber,
a pressure control chamber having a surface formed of a 60 flexible member configured to be displaceable,
an opening through which the valve chamber and the pressure control chamber communicate with each 65 other, and

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a valve configured to be capable of opening and closing the opening,

wherein the pressure control chamber includes:

a pressing plate capable of being displaced in conjunction with the flexible member, and

a biasing member configured to bias the pressing plate in a direction in which a volume of the pressure control chamber increases, and

wherein the pressure control chamber is configured to be capable of opening and closing the valve according to displacement of the pressing plate and the flexible member.

5. The liquid ejection head according to claim 4, wherein the inflow channel is connected to the valve chamber of the first pressure adjustment unit.

6. The liquid ejection head according to claim 4, wherein the first channel, the third channel, and the bypass channel are connected to the pressure control chamber of the first pressure adjustment unit.

7. The liquid ejection head according to claim 4,

wherein a relief valve is disposed in the bypass channel, and

wherein the relief valve is configured to open in a case where a pressure in the downstream channel becomes lower than the pressure in the first channel to a predetermined degree or more.

8. The liquid ejection head according to claim 2, wherein flow resistance of the bypass channel is set such that a flow velocity of the liquid in the pressure chamber is a predetermined flow velocity or more in a state in which the pump is driven, thereby circulating the liquid through the pressure chamber.

9. The liquid ejection head according to claim 4,

wherein the pressure control chamber of the first pressure adjustment unit includes an air accumulation channel communicating with the first channel, and

wherein, in a state in which the liquid ejection head is used, one end portion of the air accumulation channel communicates with an upper end portion of the pressure control chamber of the first pressure adjustment unit, and another end portion of the air accumulation channel communicates with the first channel, which is located lower than the one end portion in a direction of gravity.

10. The liquid ejection head according to claim 2, wherein the downstream channel includes:

a second pressure adjustment unit,

a second channel through which the pressure chamber and the second pressure adjustment unit communicate with each other, and

a fourth channel through which the second pressure adjustment unit and the pump communicate with each other, and

wherein the second pressure adjustment unit is configured to adjust a pressure in the second channel and wherein the bypass channel supplies the liquid to the pressure chamber through the second pressure adjustment unit and the second channel.

11. The liquid ejection head according to claim 10,

wherein the second pressure adjustment unit includes:

a valve chamber,

a pressure control chamber having a surface formed of a flexible member configured to be displaceable,

an opening through which the valve chamber and the pressure control chamber communicate with each other, and

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a valve configured to be capable of opening and closing the opening,
 wherein the pressure control chamber includes:
 a pressing plate capable of being displaced in conjunction with the flexible member, and
 a biasing member configured to bias the pressing plate in a direction in which a volume of the pressure control chamber increases, and
 wherein the pressure control chamber is configured to be capable of opening and closing the valve according to displacement of the pressing plate and the flexible member.

12. The liquid ejection head according to claim 11, wherein the bypass channel is connected to the valve chamber of the second pressure adjustment unit.

13. The liquid ejection head according to claim 11, wherein the pressure control chamber of the second pressure adjustment unit is connected to the second channel and the fourth channel.

14. The liquid ejection head according to claim 1, further comprising:

an ejection unit configured to eject the liquid; and
 a circulation unit configured to circulate the liquid between the ejection unit and the circulation unit,
 wherein the circulation unit includes the pump, and the ejection unit includes the ejection port and the pressure chamber.

15. A liquid ejection apparatus comprising:

a liquid ejection head configured to eject a liquid;
 a carriage on which the liquid ejection head is mounted;
 and

wherein the liquid ejection head includes:

a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port,

an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber,

a downstream channel which communicates with the pressure chamber,

a pump which directly communicates with both the upstream channel and the downstream channel and is configured to cause the liquid in the downstream channel to flow into the upstream channel,

an inflow channel which communicates with the upstream channel and configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel, and

a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and the downstream channel and

wherein part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

16. A liquid ejection apparatus comprising:

a liquid ejection head configured to eject a liquid;
 a circulation unit including a pump configured to circulate the liquid between the liquid ejection head and the circulation unit; and

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a carriage including a liquid-ejection-head mounting unit on which the liquid ejection head is mounted and a circulation-unit mounting unit on which the circulation unit is mounted, wherein

the liquid ejection head includes

a pressure chamber in which a pressure generated by an ejection element configured to generate the pressure is exerted, wherein the pressure is for ejecting a liquid from an ejection port,

an upstream channel which communicates with the pressure chamber and is configured to supply the liquid to the pressure chamber, and

a downstream channel which communicates with the pressure chamber;

an inflow channel configured to cause the liquid to be supplied to the pressure chamber to flow into the upstream channel communicates with the upstream channel;

the pump directly communicates with both the upstream channel and the downstream channel and causes the liquid in the downstream channel to flow into the upstream channel; and

the liquid ejection head includes a bypass channel through which the upstream channel and the downstream channel communicate with each other without the pressure chamber between the upstream channel and the downstream channel, and part of the liquid flowing from the upstream channel into the bypass channel flows into the pressure chamber through the downstream channel.

17. The liquid ejection apparatus according to claim 15, further comprising an ink tank configured to hold the liquid, wherein the inflow channel is a flow channel through which the ink tank and the liquid ejection head communicate with each other and is configured to cause the liquid in the ink tank to flow into the liquid ejection head.

18. The liquid ejection apparatus according to claim 15, wherein the downstream channel includes a pressure adjustment unit configured to adjust a pressure in the downstream channel and

wherein the bypass channel is connected to the pressure adjustment unit.

19. The liquid ejection apparatus according to claim 18, wherein

the pressure adjustment unit includes a valve chamber, a pressure control chamber, and an opening through which the valve chamber and the pressure control chamber communicate with each other,

the valve chamber includes a valve configured to be capable of opening and closing the opening according to a change in pressure in the pressure control chamber, and

the bypass channel is connected to the valve chamber in the pressure adjustment unit.

20. The liquid ejection apparatus according to claim 15, wherein the carriage moves relative to a print medium to which the liquid is ejected from the liquid ejection head.

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