(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 303 017 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.01.2024 Bulletin 2024/02

(21) Application number: **23177969.5**

(22) Date of filing: **07.06.2023**

(51) International Patent Classification (IPC):
B41J 2/18 *(2006.01)* ***B41J 2/19*** *(2006.01)*
B41J 2/14 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B41J 2/18; B41J 2/14233; B41J 2/19;
B41J 2002/14419; B41J 2002/14459; B41J 2202/12

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **04.07.2022 JP 2022107666**
31.03.2023 JP 2023057974

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(54) DISCHARGE HEAD AND DISCHARGE APPARATUS

(57) A discharge head (100) includes: multiple nozzles (111) from each of which a liquid is discharged; multiple pressure chambers (121) respectively communicating with the multiple nozzles (111); multiple supply branch channels (152) each communicating with two or more of the multiple pressure chambers (121) to supply the liquid to the two or more of the pressure chambers (121); multiple collection branch channels (153) each communicating with two or more of the multiple pressure chambers (121) to collect the liquid from the two or more of the pressure chambers (121); a supply main channel (156) communicating with each of the multiple supply branch channels (152) to supply the liquid to the multiple supply branch channels (152); and a collection main channel (157) communicating with each of the multiple collection branch channels (153) to collect the liquid from the multiple collection branch channels (153).

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Description

BACKGROUND

Technical Field

[0001] Embodiments of this disclosure relate to a discharge head and a discharge apparatus.

Related Art

[0002] Among liquid discharge heads, for example, some are designed to include a plurality of nozzles arranged in a two-dimensional matrix manner and to not only supply liquid from a supply main channel to a pressure chamber via a supply branch channel but also collect the liquid from the pressure chamber via a collection branch channel into a collection main channel.

[0003] Conventionally, a liquid discharge head including a bypass channel and a flow rate controller is known. The bypass channel connects a common liquid chamber and a circulation common liquid chamber without a pressure chamber (an individual liquid chamber), and the flow rate controller controls a flow rate of liquid flowing through the bypass channel (Japanese Unexamined Patent Application Publication No. 2017-159561). In Japanese Unexamined Patent Application Publication No. 2017-159561, the liquid discharge head is provided to enhance bubble dischargeability and retain an effect of reducing or eliminating a change in viscosity due to circulation.

[0004] In addition, a liquid discharge head including a common supply channel, a common collection channel, and a communication path connected from the common supply channel to the common collection channel is known. In such a liquid discharge head, liquid flows from the common supply channel to the common collection channel via a pressure chamber, and one portion of the common collection channel is disposed above the common supply channel (Japanese Unexamined Patent Application Publication No. 2019-209595). In Japanese Unexamined Patent Application Publication No. 2019-209595, the liquid discharge head is provided to enhance dischargeability of bubbles inside the common supply channel.

[0005] According to each of the related-art techniques, the configuration including the bypass channel has been proposed to enhance dischargeability of bubbles inside the head. However, bubbles are not adequately discharged although a bypass channel including a unit for adjusting a flow rate of matter to be discharged (hereinafter also referred to as liquid) is disposed between a supply-side common liquid chamber and a collection-side common liquid chamber as described in the related-art techniques. For example, bubbles may remain in an individual liquid chamber at the time of initial filling or maintenance work. Moreover, bubbles may flow from a common liquid chamber or a tank to the individual liquid chamber at the time of printing operation. In such a case, discharge of liquid becomes unstable.

[0006] The present disclosure is directed to provide a discharge head that enhances bubble dischargeability at the time of initial filling and/or maintenance work and has enhanced stability of liquid discharge at the time of printing operation.

[0007] The present disclosure can provide a discharge head that enhances bubble dischargeability at the time of initial filling and/or maintenance work, and has enhanced discharge stability of liquid at the time of printing operation

SUMMARY

[0008] A discharge head includes: multiple nozzles from each of which a liquid is discharged; multiple pressure chambers respectively communicating with the multiple nozzles; multiple supply branch channels each communicating with two or more of the multiple pressure chambers to supply the liquid to the two or more of the pressure chambers; multiple collection branch channels each communicating with two or more of the multiple pressure chambers to collect the liquid from the two or more of the pressure chambers; a supply main channel communicating with each of the multiple supply branch channels to supply the liquid to the multiple supply branch channels; a collection main channel communicating with each of the multiple collection branch channels to collect the liquid from the multiple collection branch channels; a first bypass channel communicating with each of the supply main channel and the collection main channel to connect the supply main channel and the collection main channel; and a first open-close unit configured to: openably close the first bypass channel; and decrease a flow rate of the liquid flowing through the first bypass channel with an increase in a first pressure difference between an upstream side and a downstream side of the first open-close unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete appreciation of embodiments of the present disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings, wherein:

FIGS. 1A and 1B are cross-sectional views illustrating one example of a discharge head according to the present disclosure;
FIG. 2 is a plan view illustrating a channel arrangement of the discharge head;
FIG. 3 is a cross-sectional view along the line A-A of FIG. 2;
FIG. 4 is a cross-sectional view along the line D-D of FIG. 2;
FIGS. 5A and 5B are cross-sectional views respec-

tively illustrating a case where a pressure difference is small and a case where a pressure difference is large according to a comparative example;

FIGS. 6A and 6B are schematic views illustrating an open-close unit of the comparative example in a case where a pressure difference is small and a case where a pressure difference is large, respectively;

FIGS.7A and 7B are cross-sectional views respectively illustrating a case where a pressure difference is small and a case where a pressure difference is large according to a first embodiment;

FIGS. 8A, 8B, and 8C are schematic views illustrating one example of a first open-close unit in a case where a pressure difference is small, a case where a pressure difference is moderate, and a case where a pressure difference is large, respectively;

FIGS. 9A and 9B are cross-sectional views each illustrating a discharge head according to a second embodiment;

FIGS. 10A and 10B are cross-sectional views each illustrating the discharge head according to the second embodiment;

FIG. 11 is a plan view illustrating a channel arrangement of a discharge head according to a third embodiment;

FIG. 12 is a schematic view illustrating one example of a printing apparatus as a discharge apparatus according to the present disclosure;

FIG. 13 is a plan view illustrating a discharge unit of the printing apparatus; and

FIG. 14 is a schematic view illustrating one example of a circulation-type ink supply system.

[0010] The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. Also, identical or similar reference numerals designate identical or similar components throughout the several views.

DETAILED DESCRIPTION

[0011] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have a similar function, operate in a similar manner, and achieve a similar result.

[0012] Referring now to the drawings, embodiments of the present disclosure are described below. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0013] Hereinafter, a discharge head and a discharge apparatus according to the present disclosure are described with reference to the drawings. The present disclosure is not limited to the embodiments described below, and various modifications and enhancements are possible without departing from the scope of the disclosure. It is therefore to be understand that the present disclosure may be practiced otherwise than as specifically described herein.

[0014] The discharge head of the present disclosure includes a plurality of nozzles, a plurality of pressure chambers, a plurality of supply branch channels, a plurality of collection branch channels, a supply main channel, a collection main channel, a first bypass channel, and a first open-close unit. The plurality of nozzles discharges liquid, and the plurality of pressure chambers communicates with the plurality of respective nozzles. The plurality of supply branch channels each communicates with two or more of the pressure chambers, and the plurality of collection branch channels each communicates with two or more of the pressure chambers. The supply main channel communicates with the plurality of supply branch channels, and the collection main channel communicates with the plurality of collection branch channels. The first bypass channel communicates with each of the supply main channel and the collection main channel to connect the supply main channel and the collection main channel. The first open-close unit opens and closes the first bypass channel. The supply branch channel is a channel that supplies the liquid to the two or more of the pressure chambers, and the collection branch channel is a channel that collects the liquid from the two or more of the pressure chambers. The supply main channel is a channel that supplies the liquid to the plurality of supply branch channels. The collection main channel is a channel that collects the liquid from the plurality of collection branch channels. The liquid to flow through the first bypass channel has a flow rate that is decreased with an increase in a pressure difference between an upstream side and a downstream side of the first open-close unit.

[0015] FIGS. 1A and 1B are cross-sectional views illustrating a discharge head 100 according to the present disclosure. FIG. 1A is a cross-sectional view along the line B-B of FIG. 2, and FIG. 1B is a cross-sectional view along the line C-C of FIG. 2. FIG. 2 is a plan view illustrating a channel arrangement of the discharge head 100, and FIG. 3 is a cross-sectional view along the line A-A of FIG. 2.

[0016] The discharge head 100 includes a nozzle plate 110, an actuator member 101, and a common channel member 170 that also serves as a frame member. The actuator member 101 includes an individual channel member (channel plate) 120, a diaphragm member 130, a piezoelectric element 140, and a common channel member 150.

[0017] The nozzle plate 110 includes a plurality of nozzles 111 that discharge liquid that is material (medium) to be discharged. The plurality of nozzles 111 is arranged in a two-dimensional matrix manner.

[0018] The individual channel member 120 provides a plurality of pressure chambers (individual liquid chambers) 121, a plurality of individual supply channels 122, and a plurality of individual collection channels 123. The plurality of pressure chambers 121 communicates with the plurality of respective nozzles 111, and the plurality of individual supply channels 122 communicates with the plurality of respective pressure chambers 121. The plurality of individual collection channels 123 communicates with the plurality of respective pressure chambers 121. The individual supply channel 122 includes a supply-side fluid-resistant portion 126, whereas the individual collection channel 123 includes a collection-side fluid-resistant portion 127.

[0019] The diaphragm member 130 forms a diaphragm 131 that is a deformable wall of the pressure chamber 121, and the piezoelectric element 140 is integrally provided with the diaphragm 131. In the diaphragm member 130, a supply-side opening 132 that communicates with the individual supply channel 122, and a collection-side opening 133 that communicates with the individual collection channel 123 are formed. The piezoelectric element 140 is a pressure generator that deforms the diaphragm 131 to compress liquid inside the pressure chamber 121.

[0020] The common channel member 150 serves as a common branch channel member, and provides a plurality of supply branch channels 152 as common supply branch channels communicating with two or more individual supply channels 122, and a plurality of collection branch channels 153 as common collection branch channels communicating with two or more individual collection channels 123. The supply branch channels 152 and the collection branch channels 153 are alternately provided in an adjacent manner. The supply branch channel 152 is a channel through which liquid as matter to be discharged is supplied to two or more pressure chambers 121, whereas the collection branch channel 153 is a channel through which liquid as matter to be discharged is collected from two or more pressure chambers 121.

[0021] In the common channel member 150, a supply port 154 and a collection port 155 are formed. The supply port 154 communicates with each of the supply-side opening 132 of the individual supply channel 122 and the supply branch channel 152 to connect the supply-side opening 132 and the supply branch channel 152. The collection port 155 communicates with each of the collection-side opening 133 of the individual collection channel 123 and the collection branch channel 153 to connect the collection-side opening 133 and the collection branch channel 153.

[0022] In addition, the common channel member 150 provides one portion 156a of one or a plurality of common supply main channels 156 communicating with the plurality of supply branch channels 152, and one portion 157a of one or a plurality of common collection main channels 157 communicating with the plurality of collection branch channel 153. The one portion 156a and the one portion 157a are provided by the common channel member 150 and the common channel member 170.

[0023] The common channel member 170 serves as a common main channel member, and provides one portion 156b of the supply main channel 156 communicating with the plurality of supply branch channels 152 and one portion 157b of the collection main channel 157 communicating with the plurality of collection branch channels 153. The one portion 156b and the one portion 157b are provided by the common channel member 170 and the common channel member 150. The one portion 156b of the supply main channel 156 communicates with a supply port 171, and the one portion 157b of the collection main channel 157 communicates with a supply port 172.

[0024] The supply main channel 156 is a channel through which liquid as matter to be discharged is supplied to the plurality of supply branch channels 152, and the collection main channel 157 is a channel through which liquid as matter to be discharged is collected from the plurality of collection branch channels 153.

[0025] A supply-side tank 181 and a collection-side tank 182 are arranged outside the common channel member 170. The supply-side tank 181 is a tank from which liquid is supplied to the supply main channel 156 via the supply port 171, and the collection-side tank 182 is a tank to which liquid is discharged from the collection main channel 157 via the supply port 172. The supply-side tank 181 includes a supply port 183 to which liquid is externally supplied. The collection-side tank 182 includes a collection port 184 from which liquid is externally discharged.

[0026] In the present disclosure, a first bypass channel 253 is arranged. The first bypass channel 253 communicates with each of the supply main channel 156 and the collection main channel 157 to connect the supply main channel 156 and the collection main channel 157. Herein, the first bypass channel 253 is preferably a channel that connects a downstream end portion of the supply main channel 156 and an upstream end portion of the collection main channel 157. In FIG. 2, although the supply port 183 and the collection port 184 are omitted for the sake of simplicity, the supply port 183 is arranged on the left side (i.e., the upstream side) of the supply main channel 156, and the collection port 184 is arranged on the left side (i.e., the downstream side) of the collection main channel 157.

[0027] Bubbles tend to be accumulated in a downstream end portion (the extreme downstream side) of the supply main channel 156 and an upstream end portion (the extreme upstream side) of the collection main channel 157 since pressure is weaker and a flow rate is lower in each of the downstream end portion of the supply main channel 156 and the upstream end portion of the collection main channel 157. Thus, the connection of the downstream end portion of the supply main channel 156 and the upstream end portion of the collection main channel 157 by the first bypass channel 253 can enhance bubble dischargeability.

[0028] In addition, a second bypass channel 251 is arranged. The second bypass channel 251 communicates with each of the supply branch channel 152 and the collection main channel 157 to connect the supply branch channel 152 and the collection main channel 157. The second bypass channel 251 connects an end portion (the extreme downstream side) of the supply branch channel 152 and the collection main channel 157. Accordingly, bubbles are prevented from remaining in the end portion of the supply branch channel 152 at the time of filling.

[0029] A third bypass channel 252 is also arranged. The third bypass channel 252 communicates with each of the collection branch channel 153 and the supply main channel 156 to connect the collection branch channel 153 and the supply main channel 156. The third bypass channel 252 connects an end portion (the extreme upstream side) of the collection branch channel 153 and the supply main channel 156. Thus, bubbles are prevented from remaining in the end portion of the collection branch channel 153 at the time of filling.

[0030] The first bypass channel 253 has a first open-close unit 257 that opens and closes the first bypass channel 253. The second bypass channel 251 has a second open-close unit 255 that opens and closes the second bypass channel 251. The third bypass channel 252 has a third open-close unit 256 that opens and closes the third bypass channel 252.

[0031] Each of the first open-close unit 257, the second open-close unit 255, and the third open-close unit 256 opens and closes the corresponding channel depending on a pressure difference (differential pressure), and an opening amount of the channel changes in response to the pressure difference (depending on a degree of differential pressure). Such a configuration in which an opening amount of the channel changes in response to a pressure difference can be obtained by, for example, a method using a valve described below. A change in opening amount of the channel in response to a pressure difference changes a flow rate of liquid that flows through a bypass channel in response to the pressure difference.

[0032] The term "pressure difference" used herein represents a difference in pressure between an upstream side and a downstream side of the open-close unit. The term "upstream side of the open-close unit" is, for example, an area not only on an upstream side of the open-close unit but also in the vicinity of the open-close unit. Similarly, the term "downstream side of the open-close unit" is, for example, an area not only on a downstream side of the open-close unit but also in the vicinity of the open-close unit. Alternatively, an upstream side of the open-close unit may be an inlet of the open-close unit, and a downstream side of the open-close unit may be an outlet of the open-close unit. In such a case, a pressure difference is a difference in pressure between an inlet and an outlet of each of the first open-close unit 257, the second open-close unit 255, and the third open-close unit 256.

[0033] In the present disclosure, a pressure difference when the first open-close unit 257 is opened is also referred to as a first predetermined value. A pressure difference when the second open-close unit 255 is opened is also referred to as a second predetermined value, and a pressure difference when the third open-close unit 256 is opened is also referred to as a third predetermined value.

[0034] FIG. 4 is a cross-sectional view along the line D-D of FIG. 2. In FIG. 4, the first bypass channel 253, which communicates with the supply main channel 156 and the collection main channel 157 to connect the supply main channel 156 and the collection main channel 157, is illustrated. The first bypass channel 253 includes the first open-close unit 257 which opens and closes the first bypass channel 253. In FIG. 4, the nozzle plate 110 is omitted. Other elements including the pressure chamber (the individual liquid chamber) 121 are schematically illustrated, and shapes thereof are not limited thereto.

[0035] FIGS. 5A and 5B are sectional views along the line D-D of FIG. 2 and illustrating a configuration of a comparative example that is not included in one example of the present disclosure. FIG. 5A illustrates a case where a pressure difference is small, whereas FIG. 5B illustrates a case where a pressure difference is large. An arrow in each of FIGS. 5A and 5B schematically indicates a flow of liquid. FIGS. 6A and 6B are diagrams illustrating a flow rate adjustment mechanism in the comparative example. FIG. 6A illustrates a case where a pressure difference is small and corresponds to the case illustrated in FIG. 5A. FIG. 6B illustrates a case where a pressure difference is large and corresponds to the case illustrated in FIG. 5B.

[0036] In each of FIGS. 6A and 6B, a valve 273 and a regulation member 271 are illustrated. In a case where the valve 273 contacts the regulation member 271, a first open-close unit 257 is closed. In a case where the valve 273 is not in contact with the regulation member 271, the first open-close unit 257 is opened. The regulation member 271 can be disposed as a separate member or as one portion of the channel.

[0037] As illustrated in FIGS. 5A and 6A, in a case where a pressure difference is small, the valve 273 contacts the regulation member 271, and the first open-close unit 257 is closed. Accordingly, in a case where a pressure difference is small, liquid does not flow through a first bypass channel 253. On the other hand, in a case where pressure difference is large as illustrated in FIGS. 5B and 6B, an inclination of the valve 273 is changed to separate the valve 273 from the regulation member 271, and the first open-close unit 257 is opened. Accordingly, liquid flows through the first bypass channel 253. In the comparative example, the adjustment mechanism by which an increase in pressure difference increases a flow rate of the first bypass channel 253 is provided.

[0038] A description is given of an example of bubble discharge at the time of initial filling or maintenance work in the comparative example. First, a supply main channel 156 and the downstream side of the supply main channel

156 (i.e., a supply branch channel 152 and a pressure chamber 121) are filled with liquid. Subsequently, liquid is supplied such that a pressure difference of the first open-close unit 257 is increased. Thus, the first open-close unit 257 is opened, and a flow rate of the first bypass channel 253 is increased. Such an increase in the flow rate causes bubbles, for example, generated or mixed in the supply main channel 156 or the supply branch channel 152 to move to a collection main channel 157, and the bubbles are discharged to an external circulation path from the collection main channel 157.

[0039] When initial filling or maintenance work is performed, in general, a supply amount of liquid is adjusted to increase a flow rate of the entire head, and thus a pressure difference between a supply port 183 and a collection port 184 increases. Accordingly, in the comparative example, a flow rate of the first bypass channel 253 increases at the initial filling or maintenance work as illustrated in FIGS. 5B and 6B. In this case, liquid is not adequately supplied to the pressure chamber 121. Consequently, the bubbles inside the pressure chamber 121 cannot be discharged adequately. The bubbles remaining inside the pressure chamber 121 causes irregularity in an image.

[0040] When discharge is performed, on the other hand, a meniscus pressure difference is expected to be small. Accordingly, a supply amount of liquid is adjusted to reduce a pressure difference between the supply port 183 and the collection port 184. In the comparative example, as illustrated in FIGS. 5A and 6A, a flow rate of the first bypass channel 253 is lower at the time of discharge. In this case, a flow rate of the entire head is lower, and bubbles in the supply-side tank 181 or the supply main channel 156 flows to the pressure chamber 121. Consequently, stable discharge is affected by the bubbles which have flowed to the pressure chamber 121.

[0041] In the comparative example, although the bypass channel having the mechanism capable of adjusting a flow rate of liquid is disposed between a supply-side common liquid chamber and a collection-side common liquid chamber, bubbles do not tend be adequately discharged. For example, when initial filling or maintenance work is performed, bubbles inside an individual liquid chamber do not tend to move. Consequently, the bubbles remain inside the individual liquid chamber. Moreover, when discharge is performed, bubbles from a common liquid chamber or a tank may flow to the individual liquid chamber. In such a case, discharge becomes unstable.

[0042] In embodiments of the present disclosure, on the other hand, a flow rate adjustment mechanism of the first open-close unit 257 is devised. In the embodiments, a flow rate of liquid that flows through the first bypass channel 253 is decreased with an increase in a pressure difference between the upstream side and the downstream side of the first open-close unit 257. In other words, a flow rate of the first bypass channel 253 changes in response to a pressure difference. Thus, a flow rate decreases as a pressure difference increases, and a flow rate increases as a pressure difference decreases. According to the embodiments, bubble dischargeability at the time of initial filling or maintenance work can be enhanced, and discharge stability at the time of discharge can be enhanced.

[0043] FIGS. 7A and 7B illustrate one example (a first embodiment) of the present disclosure. Each of FIGS. 7A and 7B is a cross sectional view along the line D-D of FIG. 2. FIG. 7A schematically illustrates a case where a pressure difference is small, and FIG. 7B schematically illustrates a case where a pressure difference is large. An arrow in each of FIGS. 7A and 7B schematically indicates a flow of liquid. FIGS. 8A, 8B, and 8C are diagrams illustrating a flow rate adjustment mechanism according to the first embodiment. FIG. 8A illustrates a case where a pressure difference is small, and corresponds to the case illustrated in FIG. 7A. FIG. 8B illustrates a case where a pressure difference is moderate. FIG. 8C illustrates a case where a pressure difference is large, and corresponds to the case illustrated in FIG. 7B.

[0044] In each of FIGS. 8A, 8B, and 8C, a valve 273 and a regulation member 271 are illustrated. In a case where the valve 273 contacts the regulation member 271, the first open-close unit 257 is closed. The first open-close unit 257 is configured such that a flow rate is adjusted in response to a pressure difference. In a case where the valve 273 is not in contact with the regulation member 271, the first open-close unit 257 is opened. The regulation member 271 can be disposed as a separate member or as one portion of the channel.

[0045] As illustrated in FIGS. 7A and 8A, in a case where a pressure difference is small, an inclination of the valve 273 is changed to separate the valve 273 from the regulation member 271, and the first open-close unit 257 is opened. Accordingly, liquid flows through the first bypass channel 253. In the first embodiment, the adjustment mechanism by which reduction in pressure difference increases a flow rate of the first bypass channel 253 is provided. On the other hand, in a case where a pressure difference is large as illustrated in FIGS. 7B and 8C, the valve 273 contacts the regulation member 271, and the first open-close unit 257 is closed. Accordingly, liquid does not flow through the first bypass channel 253.

[0046] The phrase "a case where a pressure difference is small" represents not only a case where there is no pressure difference but also a case where a pressure difference is smaller than a predetermined value. The phrase "a pressure difference is small" used herein represents a case where a pressure difference is smaller than a first predetermined value, where the first predetermined value is a pressure difference when the first open-close unit 257 is opened. Moreover, in a case where a pressure difference is generated, a pressure on the upstream side is increased, whereas a pressure on the downstream side is reduced since liquid is supplied from the upstream side and then collected on the downstream side.

[0047] A description is given of an example of bubble discharge at the time of initial filling or maintenance work according to the first embodiment. First, the supply main channel 156 and the downstream side of the supply main channel 156 (i.e., the supply branch channel 152 and the pressure chamber 121) are filled with liquid Subsequently, liquid is supplied such that a pressure difference of the first open-close unit 257 is increased. In the first embodiment, as illustrated in FIGS. 7B and 8C, the first open-close unit 257 is closed, and liquid does not flow through the first bypass channel 253 or a flow rate decreases. In such a case in which liquid does not flow through the first bypass channel 253 or a flow rate decreases, a flow rate of liquid to the pressure chamber 121 increases, so that pressure can be applied to the pressure chamber 121. Accordingly, bubbles inside the pressure chamber 121 moves to the collection main channel 157, and then the bubbles are discharged to an external circulation path from the collection main channel 157. Hence, bubbles dischargeability at the time of filling or maintenance work can be enhanced.

[0048] The phrase "at the time of filling or maintenance work" used herein represents at the time of filling and/or maintenance work. That is, bubbles dischargeability not only at the time of filling but also even at the time of maintenance work can be enhanced.

[0049] At the time of discharge, since a meniscus pressure needs to be reduced, a pressure difference between the supply port 183 and the collection port 184 is reduced. Accordingly, in the first embodiment, as illustrated in FIGS. 7A and 8A, the first open-close unit 257 is opened, and a flow rate of liquid in the first bypass channel 253 is increased. Thus, a flow rate of the entire head can be increased, thereby enhancing fillability. At the time of printing operation, since liquid can flow through the first bypass channel 253, the liquid can be prevented from excessively flowing into the pressure chamber 121, and a suitable amount of liquid flows into the pressure chamber 121. Thus, bubbles generated or mixed in the supply main channel 156 or the supply-side tank 181 can be prevented from moving to the pressure chamber 121. Hence, discharge stability at the time of printing operation can be enhanced.

[0050] In the printing operation, since a flow rate of the entire head can be increased, a temperature is more easily controlled at the time of circulation. This also enhances fillability and dischargeability. The fillability herein is not limited to fillability of the pressure chamber 121, and fillability of the supply main channel 156 and the supply-side tank 181 can be enhanced.

[0051] For example, a pressure difference between a supply side and a collection side (e.g., a pressure difference between the supply port 183 and the collection port 184) is increased at the time of maintenance work (including initial filling), and a pressure difference between the supply side and the collection side is reduced at the time of discharge. For such adjustment of the pressure difference, for example, an air pump is disposed to each of a supply-side tank and a collection-side tank that are externally attached to a discharge head, so that a pressure can be controlled by the air pumps.

[0052] FIG. 14 illustrates one example of a circulation-type ink supply system for description of the aforementioned air pump. However, the present embodiment is not limited thereto. As illustrated in FIG. 14, air pumps 281 and 282 are respectively disposed to the supply-side tank 181 and the collection-side tank 182. In FIG. 14, arrows schematically indicate one example of control of positive pressure and negative pressure by the air pumps 281 and 282. The air pumps 281 and 282, a valve 283, and an ink supply pump 284 are adjusted to supply ink from an ink tank 285. In addition, the ink can be circulated, and a pressure difference can be adjusted.

[0053] In the present embodiment, each of the second open-close unit 255 and the third open-close unit 256 is configured such that a flow rate of liquid becomes smaller as a pressure difference becomes larger, and a flow rate of liquid becomes larger as a pressure difference becomes smaller, as similar to the first open-close unit 257. With the second open-close unit 255 and the third open-close unit 256, a flow rate of liquid becomes smaller as a pressure difference becomes larger so that pressure can be applied to an individual channel and bubbles in the individual channel can be efficiently discharged.

[0054] In the present embodiment, each of the second open-close unit 255 and the third open-close unit 256 is preferably opened by a pressure difference that is larger than a pressure difference by which the first open-close unit 257 is opened. That is, where a pressure difference when the first open-close unit 257 is opened is a first predetermined value, a pressure difference when the second open-close unit 255 is opened is a second predetermined value, and a pressure difference when the third open-close unit 256 is opened is a third predetermined value, the second predetermined value is preferably greater than the first predetermined value, and the third pressure difference value is preferably greater than the first predetermined value. If such relations are satisfied, opening of the second open-close unit 255 and the third open-close unit 256 tends to be more difficult than opening of the first open-close unit 257 when a printing operation is performed subsequent to filling, and liquid can be prevented from flowing to a portion other than the nozzle portion. Thus, liquid is supplied to the pressure chamber 121 more easily when a printing operation is performed.

[0055] In the present embodiment as described above, the first open-close unit 257 is configured such that a flow rate of liquid changes in response to a pressure difference, and a flow rate of liquid becomes smaller as a pressure difference becomes larger. As illustrated in FIGS. 8A, 8B, and 8C, the first open-close unit 257 in the present embodiment has a cantilever structure, and includes the valve 273 including a fixed end 273a on one end side and a free end 273b on the other end side. In a case where the free end 273b of the valve 273 and the regulation member 271 are in contact with each other, the first open-close unit 257 is closed. Such a state is illustrated in FIG. 8C.

[0056] The regulation member 271 is disposed in the first bypass channel 253 to regulate the free end 273b of the valve 273 in a predetermined position.

[0057] If a pressure difference between the upstream side and the downstream side of the first open-close unit 257 is smaller than a threshold value, the free end 273b of the valve 273 is positioned upstream from a position in which the free end 273b contacts the regulation member 271 in a direction in which liquid flows. Such a state is illustrated in FIGS. 8A and 8B.

[0058] The valve 273 may be made of, for example, an elastically deformable member.

[0059] In the first open-close unit 257 according to the present embodiment, if there is no pressure difference or a pressure difference is smaller than a predetermined pressure difference, the first open-close unit 257 is opened as illustrated in FIG. 8A. In FIG. 8A, the valve 273 is widely opened, and a flow rate increases.

[0060] An inclination of the valve 273 changes as illustrated in FIGS. 8A, 8B and 8C in order as a pressure difference increases, and the first open-close unit 257 is closed. On the other hand, an inclination of the valve 273 changes as illustrated in FIGS. 8C, 8B, and 8A in order as a pressure difference decreases, and the first open-close unit 257 is opened.

[0061] Such a configuration can be expressed differently as follows. That is, where a line connecting the fixed end 273a and the free end 273b of the valve 273 is a first line, and a direction in which liquid in the first bypass channel 253 flows is a second line, an angle between the first line and the second line changes with an increase in a pressure difference between the upstream side and the downstream side of the first open-close unit 257. If the pressure difference exceeds a threshold value, an angle at which the free end 273b of the valve 273 contacts the regulation member 271 is provided. Accordingly, in the first open-close unit 257, an increase in the pressure difference can reduce a flow rate more easily.

[0062] In this case, however, the valve 273 does not need to be a straight member, for example, a plate member. The valve 273 may be deformed in a curved manner. Even in such a case, a first line can be defined. Moreover, even in a case where a direction in which liquid flows changes in the first open-close unit 257 as illustrated in FIG. 8B, a second line can be defined. For example, a direction from the left to the right on a paper surface can be defined as a second line. In a state in which a pressure difference is small, the configuration can be expressed as long as inclination of the valve 273 to the upstream side in a direction in which liquid flows can be expressed.

[0063] Next, another example (a second embodiment) of the present disclosure is described with reference to FIGS. 9A and 9B. A discharge head 100 according to the second embodiment is illustrated in FIGS. 9A and 9B. FIG. 9A is a sectional view along a supply main channel, and FIG. 9B is a sectional view along a collection main channel.

[0064] The discharge head 100 of the second embodiment includes a fourth bypass channel 254 that communicates with a supply-side tank 181 and a collection-side tank 182 to connect the supply-side tank 181 and the collection-side tank 182. The fourth bypass channel 254 includes a fourth open-close unit 258 that opens and closes the fourth bypass channel 254. The fourth open-close unit 258 includes a valve. The valve opens and closes the fourth bypass channel 254 depending on a pressure difference, and an opening amount of the fourth bypass channel 254 changes in response to the pressure difference.

[0065] In the second embodiment, a pressure difference by which a first open-close unit 257 is opened is greater than a pressure difference by which the fourth open-close unit 258 is opened. In the second embodiment, each of a second open-close unit 255 and a third open-close unit 256 can be opened by a pressure difference that is greater than a pressure difference by which the first open-close unit 257 is opened, as similar to the first embodiment. In the second embodiment, where a pressure difference when the first open-close unit 257 is opened is a first predetermined value, and a pressure difference when the fourth open-close unit 258 is opened is a fourth predetermined value, the first predetermined value is greater than the fourth predetermined value. In the second embodiment, moreover, the fourth open-close unit 258 is configured such that an increase in a pressure difference reduces a flow rate of liquid.

[0066] In the second embodiment, as similar to the above-described embodiment, when an initial filling is performed, a first bypass channel 253 between a supply main channel 156 and a collection main channel 157 is opened, and then a pressure difference is further increased. Such a further increase in the pressure difference causes the fourth open-close unit 258 is opened. With the opening of the fourth open-close unit, a supply-side tank 181 and a collection-side tank 182 communicate with each other via the fourth bypass channel 254.

[0067] Accordingly, liquid flows from the supply-side tank 181 to the collection-side tank 182, and the collection-side tank 182 is reliably filled with liquid.

[0068] Therefore, first, a pressure chamber 121 is filled with liquid by low pressure circulation, and then a circulation pressure is gradually increased. Such a gradual increase in the circulation pressure opens a bypass channel between a common main channel and a common branch channel, a bypass channel between common main channels, and a bypass channel between tanks in order, thereby filling the common branch channel, the common main channel, and the collection-side tank with liquid in order.

[0069] Herein, the fourth bypass channel 254 communicating with each of the supply-side tank 181 and the collection-side tank 182 may be a channel that is constantly opened. In such a case, liquid flows from the supply-side tank 181 to the collection-side tank 182 from the beginning when initial filling is performed.

[0070] Consequently, liquid needs to be supplied by large pressure to discharge bubbles inside channels such as the supply main channel 156, a supply branch channel 152, the collection main channel 157, a collection branch channel 153, the pressure chamber 121, an individual supply channel 122, and an individual collection channel 123.

[0071] In the second embodiment, on the other hand, since second and third bypass channels 251 and 252, the first bypass channel 253, and the fourth bypass channel 254 are opened in order, a circulation differential pressure is gradually increased after the pressure chamber 121 is filled by low pressure circulation. Such a gradual increase in the circulation differential pressure enables a bypass channel between the common main channel and the common branch channel, a bypass channel between the common main channels, and a bypass channel between the tanks to be opened in order, thereby filling the common branch channel, the common main channel, and the tank with liquid in order.

[0072] The fourth bypass channel 254 can be disposed in a position as illustrated in FIGS. 9A and 9B. However, the fourth bypass channel 254 is preferably disposed in the uppermost portion of the supply-side tank 181 and the collection-side tank 182. FIGS. 10A and 10B are diagrams illustrating other examples of the fourth bypass channel 254. FIG. 10A is a cross-sectional view along a supply main channel, and FIG. 10B is a cross-sectional view along a collection main channel. The arrangement of the fourth bypass channel 254 in the uppermost portion of the tanks as illustrated in FIGS. 10A and 10B enables bubbles in an upper portion of the tanks to be removed by circulation.

[0073] Next, another example (a third embodiment) of the present disclosure is described with reference to FIG. 11. FIG. 11 is a plan view illustrating a channel arrangement of a discharge head 100 according to the third embodiment.

[0074] The discharge head 100 of the third embodiment includes a first bypass channel 253 that communicates with each of a supply main channel 156 and a collection main channel 157 to connect the supply main channel 156 and the collection main channel 157, as similar to the above-described embodiments. The first bypass channel 253 includes a first open-close unit 257 that opens and closes the first bypass channel 253.

[0075] The third embodiment differs from the above-described embodiments in having a fifth bypass channel 261a on the supply side and a fifth bypass channel 261b on the collection side. The fifth bypass channels 261a and 261b communicate with a supply branch channel 152 and a collection branch channel 153 that are adjacent to each other to connect the supply branch channel 152 and the collection branch channel 153.

[0076] Thus, for example, two fifth bypass channels 261a communicating with respective two supply branch channels 152 disposed on both sides of one collection branch channel 153 are disposed. Similarly, two fifth bypass channels 261b communicating with two respective collection branch channels 153 disposed on both sides of one supply branch channel 152 are disposed.

[0077] On a side nearer to the entry to the supply branch channel 152 from the supply main channel 156 and on a side nearer to the supply main channel 156 relative to a supply port 154 and a collection port 155, the fifth bypass channel 261b communicates with each of the supply branch channel 152 and the collection branch channel 153 to connect the supply branch channel 152 and the collection branch channel 153.

[0078] On a side nearer to the entry to the collection main channel 157 from the collection branch channel 153 and on a side nearer to the collection main channel 157 relative to the supply port 154 and the collection port 155, the fifth bypass channel 261a communicates with each of the supply branch channel 152 and the collection branch channel 153 to connect the supply branch channel 152 and the collection branch channel 153.

[0079] The fifth bypass channel 261a includes a fifth open-close unit 262a that opens and closes the fifth bypass channel 261a. Moreover, the fifth bypass channel 261b includes a fifth open-close unit 262b that opens and closes the fifth bypass channel 261b.

[0080] Similar to the first open-close unit 257, any of the fifth open-close units 262a and 262b includes a valve that opens and closes a channel depending on a pressure difference and an opening amount of the channel changes depending on a degree of the pressure difference.

[0081] In the present embodiment, any of the fifth open-close units 262a and 262b can open the channel by using a pressure difference that is smaller than a pressure difference used for the first open-close unit 257, and the fifth bypass channels 261a and 261b are opened by using a pressure difference that is smaller than a pressure difference used for the first bypass channel 253.

[0082] Next, liquid filling to the discharge head 100 having such a configuration is described. When the discharge head 100 is initially filled with liquid, bubbles inside channels such as a supply main channel 156, a supply branch channel 152, a collection main channel 157, a collection branch channel 153, a pressure chamber 121, an individual supply channel 122, and an individual collection channel 123 need to be discharged to a collection-side tank 182 or a collection port 184, as described above.

[0083] In the present embodiment, when a channel of the discharge head 100 is filled with liquid, first, liquid is supplied from the supply-side tank 181 to the supply main channel 156 via a supply port 171 by using a pressure that provides a pressure difference by which the fifth open-close units 262a and 262b are closed. Herein, each of the first open-close unit 257, the fifth open-close units 262a and 262b is being closed, and the first bypass channel 253, the fifth bypass channels 261a and 261b are closed.

[0084] Accordingly, the liquid supplied to the supply main channel 156 flows from the supply branch channel 152 and reaches the collection branch channel 153 via the individual supply channel 122, the pressure chamber 121, and the individual collection channel 123. Then, the liquid flows to the collection main channel 157 from the collection branch channel 153.

[0085] Subsequently, a pressure of the liquid to be supplied to the supply main channel 156 from the supply-side tank 181 via the supply port 171 is increased, and a pressure difference between the supply branch channel 152 and the collection branch channel 153 becomes a fifth predetermined value or more (the fifth predetermined value < a first predetermined value). Thus, the fifth open-close units 262a and 262b are opened. Such opening of the fifth open-close units 262a and 262b opens the fifth bypass channels 261a and 261b, and the supply branch channel 152 and the collection branch channel 153 communicate with each other via the fifth bypass channels 261a and 261b.

[0086] Accordingly, the liquid which has entered the supply branch channel 152 from the supply main channel 156 flows from the supply branch channel 152 to the upstream side of the collection branch channel 153 via the fifth bypass channel 261a, and then flows to the downstream side of the collection branch channel 153 via the fifth bypass channel 261b.

[0087] Herein, bubbles remaining on the downstream side within the supply branch channel 152 are discharged to the downstream side of the collection branch channel 153 via the fifth bypass channel 261a. Moreover, bubbles remaining on the upstream side within the collection branch channel 153 are transferred to the upstream side within the collection branch channel 153 by liquid that flows in from the fifth bypass channel 261a. Hence, the supply branch channel 152 and the collection branch channel 153 are reliably filled with liquid.

[0088] Then, a pressure of the liquid to be supplied to the supply main channel 156 from the supply-side tank 181 via the supply port 171 is increased, and a pressure difference between the supply main channel 156 and the collection branch channel 153 becomes a third predetermined value or more. Thus, the first open-close unit 257 is opened. Such opening of the first open-close unit 257 opens the first bypass channel 253, and the supply main channel 156 and the collection main channel 157 communicate with each other via the first bypass channel 253.

[0089] Accordingly, the liquid which have been supplied to the supply main channel 156 flows to the collection main channel 157 via the first bypass channel 253. Herein, bubbles remaining inside the supply main channel 156 are discharged to the collection main channel 157, and the supply main channel 156 is reliably filled with liquid.

[0090] Then, the bubbles which have been transferred to the collection main channel 157 are transferred to the collection-side tank 182 via the supply port 172, and the collection main channel 157 is reliably filled with liquid.

[0091] Even in the present embodiment, a fourth bypass channel 254 and a fourth open-close unit 258 can be disposed by application of the above-described example. The fourth bypass channel 254 communicates with the supply-side tank 181 and the collection-side tank 182 to connect the supply-side tank 181 and the collection-side tank 182, and the fourth open-close unit 258 opens and closes the fourth bypass channel 254.

[0092] Next, one example of a printing apparatus 1 as a discharge apparatus according to the present disclosure is described with reference to FIGS. 12 and 13. FIG. 12 is a schematic view illustrating the printing apparatus 1, and FIG. 13 is a plan view illustrating a discharge unit of the printing apparatus 1.

[0093] The printing apparatus 1 is an apparatus that discharges liquid, and includes a loading unit 10 to which sheets P are loaded, a pre-processing unit 20, a printing unit 30, a drying unit 40, and an ejection unit 50.

[0094] In the printing apparatus 1, the pre-processing unit 20 applies (coats) pre-processing liquid as necessary to a sheet P that is loaded (supplied) from the loading unit 10, and the printing unit 30 performs a required printing operation by applying liquid to the sheet P. The drying unit 40 dries the liquid adhering to the sheet P, and then the resultant sheet P is ejected to the ejection unit 50.

[0095] The loading unit 10 includes a loading tray 11 (a lower loading tray 11A and an upper loading tray 11B) in which a plurality of sheets P is stored, and a feed device 12 (a lower feed device 12A and an upper feed device 12B) that separates and feeds the sheets P one by one from the loading tray 11. The loading unit 10 supplies the sheet P to the pre-processing unit 20.

[0096] The pre-processing unit 20 includes a coating unit 21 as a processing-liquid applying unit that applies processing liquid to a print surface of the sheet P. The processing liquid has, for example, an effect of preventing ink from bleeding through the sheet P by aggregating the ink.

[0097] The printing unit 30 includes a drum 31 as a bearer (a rotator) and a liquid discharger 32. The drum 31 rotates with a circumferential surface bearing the sheet P, and the liquid discharger 32 discharges liquid toward the sheet P on the drum 31.

[0098] In addition, the printing unit 30 includes delivery drums 34 and 35. The delivery drum 34 receives the sheet P fed from the pre-processing unit 20 to deliver the sheet P toward the drum 31. The delivery drum 35 receives the sheet P conveyed by the drum 31 to deliver the sheet P to the drying unit 40.

[0099] When the sheet P is conveyed from the pre-processing unit 20 to the printing unit 30, a leading end of the sheet P is gripped by a gripper (a sheet gripper) disposed to the delivery drum 34, and the sheet P is conveyed with rotation of the delivery drum 34. The sheet P conveyed by the delivery drum 34 is delivered to the drum 31 in a position opposite the drum 31.

[0100] The drum 31 has a surface on which a gripper (a sheet gripper) is disposed, and the leading end of the sheet P is gripped by the gripper. A plurality of suction holes is dispersedly formed on the surface of the drum 31, and a suction airflow inward from a required suction hole of the drum 31 is generated by a suction unit.

[0101] Then, the leading end of the sheet P delivered from the delivery drum 34 to the drum 31 is griped by the sheet gripper, and the sheet P is conveyed with rotation of the drum 31 with the drum 31 bearing the sheet P attracted to the drum 31 by the suction airflow generated by the suction unit.

[0102] The liquid discharger 32 includes discharge units 33 (33A through 33D) as dischargers. For example, the discharge units 33A, 33B, 33C, and 33D respectively discharge cyan (C) liquid, magenta (M) liquid, yellow (Y) liquid, and black liquid (K). In addition, the liquid discharger 32 can use a discharge unit that discharges special liquid such as white liquid and gold (silver) liquid.

[0103] The discharge unit 33 is, for example, a full line head as illustrated in FIG. 13, and includes a plurality of discharge heads 100 arranged in a staggered pattern on a base member 331. Each of the discharge head 100 includes a plurality of nozzles 111 that are arranged in a two-dimensional matrix manner.

[0104] A discharge operation of each discharge unit 33 of the liquid discharger 32 is controlled based on a driving signal corresponding to print information. When the sheet P on the drum 31 passes an area opposite the liquid discharger 32, each color of liquid is discharged from the discharge unit 33, and an image corresponding to the print information is printed.

[0105] The drying unit 40 dries the liquid which has adhered to the sheet P in the printing unit 30. The use of the drying unit 40 evaporates a liquid substance such as moisture in the liquid, and a colorant contained in the liquid is fixed on the sheet P. Moreover, the use of the drying unit 40 prevents the sheet P from being curled.

[0106] A reverse unit 60 reverses a sheet P that has passed the drying unit 40 when duplex printing is performed on the sheet P. The reversed sheet P is fed backward to the upstream side relative to the delivery drum 34 via a conveyance path 61 of the printing unit 30.

[0107] The ejection unit 50 includes an ejection tray 51 on which a plurality of sheets P is to be stacked. The sheets P conveyed from the drying unit 40 via the reverse unit 60 are sequentially stacked and held on the ejection tray 51.

[0108] Liquid to be discharged by such a discharge head 100 is not particularly limited as long as liquid has surface tension and viscosity enabling the liquid to be discharged from the discharge head 100. Liquid preferably has a viscosity of 30 mPa• s or less under normal temperature and normal pressure or by heating or cooling. More particularly, examples of liquid include an emulsion, a suspension, and a solution including: a solvent such as water and an organic solvent; a colorant such as a dye and a pigment; a functionality adding material such as a polymerizable compound, a resin, and a surface-active agent; a biocompatible material such as a deoxyribonucleic acid (DNA), an amino acid, protein, and calcium; and an edible material such as a natural coloring agent. Such liquid can be used for, for example, inkjet ink, a surface treatment liquid, a liquid for forming an electronic circuit resist pattern or a component of an element such as an electronic element and a light emitting element, and a three-dimensional shaping liquid.

[0109] Herein, an example of the liquid (the three-dimension shaping liquid) to be used for formation of a three-dimensional object is a hydrogel formation material for formation of a three-dimensional structure to be used, for example, in treatment manipulation training.

[0110] The hydrogel formation material contains water and a polymerizable monomer, and preferably contains a mineral and an organic solvent. In addition, the hydrogel formation material can contain a polymerization initiator and other components as necessary. The polymerizable monomer is a compound having one or more unsaturated carbon-carbon bonds, and is preferably polymerized by activation energy rays such as ultraviolet rays and electron beams.

[0111] Examples of the polymerizable monomers include a monofunctional monomer and a multifunctional monomer. These may be used alone or in combination. Examples of the multifunctional monomers include a bifunctional monomer, a trifunctional monomer, and a tetra or higher functional monomer.

[0112] The mineral is not limited to any particular mineral. Although a mineral can be appropriately selected for each purpose, a clay mineral is preferred since a main component of the hydrogel is water. Furthermore, a layered clay mineral that is uniformly dispersible in water at a primary crystal level is preferred, and a water-swellable layered clay mineral is more preferred.

[0113] An example of the organic solvent includes a water-soluble organic solvent. Water solubility of the water-soluble organic solvent means that the organic solvent is soluble at 30% by mass or greater relative to water.

[0114] The water-soluble organic solvent is not particularly limited, and can be appropriately selected for each purpose. Examples of water-soluble organic solvents include: alkyl alcohols having one or more and four or less carbon atoms such as methyl alcohol, ethyl alcohol, n-propyl alcohol, isopropyl alcohol, n-butyl alcohol, sec-butyl alcohol, and tert-butyl alcohol; amides such as dimethylformamide and dimethyl acetamide; ketone or ketone alcohols such as acetone, methyl ethyl ketone, and diacetone alcohol; ethers such as tetrahydrofuran and dioxane; polyhydric alcohol such as ethylene glycol, propylene glycol, 1, 2-propanediol, 1, 2-butanediol, 1, 3-butanediol, 1, 4-butanediol, diethylene glycol, triethylene glycol, 1,2,6-hexanetriol, thioglycol, hexylene glycol, and glycerin; polyalkylene glycols such as polyethylene glycol and polypropylene glycol; lower alcohol ethers of polyhydric alcohol such as ethylene glycol monomethyl (or ethyl) ether, diethylene glycol methyl (or ethyl) ether, and triethylene glycol monomethyl (or ethyl) ether; alkanolamines such as monoethanolamine, diethanolamine, and triethanolamine; and other such as N-

Methyl-2-pyrrolidone, 2-pyrrolidone, and 1,3-dimethyl-2-imidazolidinone. These may be used alone or in combination. Among such organic solvents, polyhydric alcohol, glycerin, and propylene glycol are preferred in terms of moisture-retaining property, and glycerin and propylene glycol are more preferred.

[0115] The polymerization initiator is not particularly limited, and can be appropriately selected for each purpose. Examples of polymerization initiators include a photopolymerization initiator and a thermal polymerization initiator. As for the photopolymerization initiator, an optional material that generates a radical by using light that is emitted (particularly, an ultraviolet (UV) ray having a wavelength of 220 nm to 400 nm) can be used.

[0116] In a case where a hydrogel formation material is used to form a three-dimensional object, a UV emitting device is disposed to irradiate a discharged hydrogel formation material with UV rays, so that the hydrogel formation material is hardened, and a three-dimensional object is formed.

[Particular Example of Hydrogel Formation Material]

[0117] While agitating 120.0 parts by mass of ion exchanged water that had undergone pressure reduction and deaeration for 30 minutes, 12.0 parts by mass of synthetic hectorite (Laponite-XLG manufactured by Rockwood Inc.) having a composition of $[Mg_{5.34}Li_{0.66}Si_8O_{20}(OH)_4]Na^{-}_{0.66}$ as a layered clay mineral was added little by little and agitated. In addition, 0.6 parts by mass of etidronic acid (manufactured by Tokyo Chemical Industry Co., Ltd.) was added and agitated, so that dispersion liquid was produced.

[0118] Subsequently, 44.0 parts by mass of acryloylmorpholine (manufactured by KJ Chemicals Corporation) from which polymerization inhibitor had been removed by passing through an activated alumina column, and 0.4 parts by mass of methylenebisacrylamide (manufactured by Tokyo Chemical Industry Co., Ltd.) were added as polymerizable monomer to the dispersion liquid. Furthermore, 20.0 mass of glycerin (manufactured by Sakamoto Yakuhin Kogyo Co., Ltd.) and 0.8 parts by mass of N,N,N',N'-Tetramethylethylenediamine (manufactured by Tokyo Chemical Industry Co., Ltd.) were mixed, so that a hydrogel formation material was obtained.

[0119] The discharge head 100 according to the present disclosure, as described above, can be used for an inkjet method for optional arrangement of cells to artificially form an organism containing cells, and can discharge a cell suspension (cell ink).

[0120] The cell suspension (cell ink) at least contains cells and a cell drying inhibitor. Moreover, the cell suspension (cell ink) contains a dispersant that causes cells to be dispersed, and can contain other additive materials such as a dispersing agent and a pH adjuster as necessary.

[0121] A type of the cell is not particularly limited, and can be appropriately selected for each purpose. Every cell can be used regardless of whether, for example, a cell is taxonomically a eukaryotic cell, a procaryotic cell, a multicellular organism cell, or a unicellular organism cell. These may be used alone or in combination.

[0122] Examples of the eukaryotic cells include an animal cell, an insect cell, a plant cell, and a fungus. These may be used alone or in combination. In these examples, the animal cell is preferred. In a case where cells form a cell aggregate, an adherent cell having cell adhesiveness by which cells adhere to each other and are not isolated unless a physicochemical process is performed is more preferred.

[0123] The cell drying inhibitor has a function of covering a surface of a cell to inhibit dryness of the cell. Examples of the cell drying inhibitors include polyhydric alcohols, gel polysaccharides, and a protein selected from an extracellular matrix.

[0124] The dispersant is preferably a buffer solution or a culture medium for cell culture. The culture medium contains components necessary for formation and maintenance of a cell organism, and is a solution that prevents dryness and arranges an external environment such as an osmotic pressure. A solution or medium known as a culture medium can be appropriately selected and used. In a case where cells do not need to be constantly immersed in a culture medium, the culture medium can be appropriately removed from a cell suspension. The buffer solution adjusts pH depending on a cell or a purpose, and a known buffer solution may be appropriately selected and used.

[Particular Example of Cell Suspension (Cell Ink)]

[0125] A green fluorescent dye (Cell Tracker Green manufactured by Life Technologies Ltd.) was dissolved in dimethyl sulphoxide (DMSO) at a concentration of 10 mmol/L(mM), and the resultant solution was mixed with serum-free Dulbecco's modified Eagle medium (manufactured by Life Technologies Ltd.). Thus, a green fluorescent dye-containing serum-free medium having a concentration of 10 μmol/L(μM) was prepared.

[0126] Subsequently, 5 mL of the green fluorescent dye-containing serum-free medium was added into a dish having a cultured NIH/3T3 cells (Clone 5611, JCRB Cell Bank), and the resultant cells were cultured for 30 minutes in an incubator (KM-CC17RU2 manufactured by Panasonic Corporation, 37°C, 5 % by volume CO2 environment).

[0127] Then, a supernatant was removed using an aspirator. Five milliliters of phosphate buffered saline (hereinafter also referred to as PBS (-), manufactured by Life Technologies Ltd.) was added to the dish, and the PBS (-) was removed by suction using an aspirator to clean the surface. After cleaning with the PBS (-) was repeated twice, 2ml of trypsin-ethylene diamine tetra acetic acid (EDTA) solution (manufactured by Life Technologies Ltd.) was added per dish. The trypsin-EDTA solution added herein was 0.05% by mass of trypsin with 0.05% by mass of EDTA.

[0128] Next, the resultant solution containing the cells was heated for 5 minutes in the incubator, and the cells were exfoliated from the dish. Subsequently, 4 mL of D-MEM containing 10% by mass of a fetal bovine serum (hereafter also referred to as FBS) and 1% by mass of an antibiotic (Antibiotic-Antimycotic Mixed Stock Solution (100x), manufactured by NACALAI TESQUE, INC.) was added.

[0129] Next, a cell suspension in which trypsin had been devitalized was transferred to a single 50-mL centrifuge tube. The cell suspension in the centrifuge tube was centrifuged (at 1,200 rpm for 5 minutes at 5°C by a machine named H-19FM manufactured by KOKUSAN Co., Ltd.), and a supernatant was removed using an aspirator. After the removal, 2 mL of D-MEM containing 10% by mass of FBS and 1% by mass of antibiotic was added to the centrifuge tube, and pipetting was gently performed to disperse the cells. Hence, a cell suspension was acquired.

[0130] After 10 μL of the cell suspension was extracted into an Eppendorf tube and 70 μL of a culture medium was added into the tube, 10 μL of the resultant cell suspension was extracted into another Eppendorf tube. Then, 10 μL of a trypan blue stain solution in an amount of 0.4% by mass was added, and pipetting was performed. From the stained cell suspension, 10 μL of the suspension was removed and placed on a plastic slide made of polymethyl methacrylate (PMMA). The number of cells was counted using a counter named Countess Automated Cell Counter (manufactured by Invitrogen), so that a cell suspension containing cells the cell number of which had been counted was obtained. Moreover, a PBS (-) was used as a dispersant. Glycerin (a molecular biology grade, manufactured by Wako Pure Chemical Industries, Ltd.) as a cell drying inhibitor was dissolved in the PBS (-) so as to have a mass ratio of 0.5% by mass, and an NIH/3T3 cell suspension was dispersed in a dispersant so as to be 6 × 106 cell/mL Accordingly, a cell ink was obtained.

[0131] Moreover, a PBS (-) was used as a dispersant. Glycerin (a molecular biology grade, manufactured by Wako Pure Chemical Industries, Ltd.) as a cell drying inhibitor was dissolved in the PBS (-) so as to have a mass ratio of 0.5% by mass, and an NIH/3T3 cell suspension was dispersed in a dispersant so as to be 6 × 106 cell/mL Accordingly, a cell ink was obtained.

[0132] The present disclosure provides, for example, aspects as follows.

<Aspect 1>

[0133] A discharge head includes a plurality of nozzles, a plurality of pressure chambers, a plurality of supply branch channels, a plurality of collection branch channels, a supply main channel, a collection main channel, a first bypass channel, and a first open-close unit. The plurality of nozzles discharges liquid, and the plurality of pressure chambers communicates with the plurality of respective nozzles. The plurality of supply branch channels each communicates with two or more of the pressure chambers, and the plurality of collection branch channels each communicates with two or more of the pressure chambers. The supply main channel communicates with the plurality of supply branch channels, and the collection main channel communicates with the plurality of collection branch channels. The first bypass channel communicates with each of the supply main channel and the collection main channel to connect the supply main channel and the collection main channel. The first open-close unit opens and closes the first bypass channel. The supply branch channel is a channel that supplies the liquid to the two or more of the pressure chambers, and the collection branch channel is a channel that collects the liquid from the two or more of the pressure chambers. The supply main channel is a channel that supplies the liquid to the plurality of supply branch channels. The collection main channel is a channel that collects the liquid from the plurality of collection branch channels. The liquid to flow through the first bypass channel has a flow rate that is decreased with an increase in a pressure difference between an upstream side and a downstream side of the first open-close unit.

<Aspect 2>

[0134] The discharge head according to the aspect 1 further includes a second bypass channel, a third bypass channel, a second open-close unit, and a third open-close unit. The second bypass channel communicates with each of the supply branch channel and the collection main channel to connect the supply branch channel and the collection main channel. The third bypass channel communicates with each of the collection branch channel and the supply main channel to connect the collection branch channel and the supply main channel. The second open-close unit opens and closes the second bypass channel, and the third open-close unit opens and closes the third bypass channel. The second open-close unit opens and closes the second bypass channel depending on a pressure difference between an upstream side and a downstream side of the second open-close unit, whereas the third open-close unit opens and closes the third bypass channel depending on a pressure difference between an upstream side and a downstream side of the third open-close unit. Each of the second open-close unit and the third open-close unit is opened by a pressure difference that is greater than a pressure difference by which the first open-close unit is opened.

<Aspect 3>

[0135] The discharge head according to the aspect 2, the supply branch channel has an end portion in which the second bypass channel and the supply branch channel are connected.

<Aspect 4>

[0136] The discharge head according to the aspect 2 or 3, wherein the collection branch channel has an end portion in which the third bypass channel and the collection branch channel are connected.

<Aspect 5>

[0137] The discharge head according to any of the aspects 1 through 4 further includes a supply-side tank communicating with the supply main channel, a collection-side tank communicating with the collection main channel, a fourth bypass channel, and a fourth open-close unit. The fourth bypass channel communicates with each of the supply-side tank and the collection-side tank to connect the supply-side tank and the collection-side tank. The fourth open-close unit opens and closes the fourth bypass channel. The fourth open-close unit opens and closes the fourth bypass channel depending on a pressure difference between an upstream side and a downstream side of the fourth open-close unit. The first open-close unit is opened by a pressure difference that is greater than a pressure difference by which the fourth open-close unit is opened.

<Aspect 6>

[0138] The discharge head according to the aspect 5, the fourth bypass channel is disposed in an uppermost portion of the supply-side tank and the collection-side tank.

<Aspect 7>

[0139] The discharge head according to any of the aspects 1 through 6, the first open-close unit has a cantilever structure and includes a valve including a fixed end on one end side and a free end on another end side. In a case where the free end of the valve is in contact with a regulation member that is disposed in the first bypass channel to regulate the free end of the valve in a predetermined position, the first open-close unit is closed. In a case where a pressure difference between an upstream side and a downstream side of the first open-close unit is smaller than a threshold value, the free end of the valve is positioned on an upstream side of a position in which the free end of the valve contacts the regulation member in a direction in which the liquid flows.

<Aspect 8>

[0140] The discharge head according to the aspect 7, where a line connecting the fixed end and the free end of the valve is a first line and a direction in which the liquid in the first bypass channel flows is a second line, an angle between the first line and the second line changes with an increase in a pressure difference between the upstream side and the downstream side of the first open-close unit. In a case where a pressure difference between the upstream side and the downstream side of the first open-close unit exceeds a threshold value, the angle between the first line and the second line changes to an angle at which the free end of the valve contacts the regulation member.

<Aspect 9>

[0141] A discharge apparatus includes the discharge head according to any of the aspects 1 through 8.

<Aspect 10>

[0142] A discharge head (100) includes: multiple nozzles (111) from each of which a liquid is discharged; multiple pressure chambers (121) respectively communicating with the multiple nozzles (111); multiple supply branch channels (152) each communicating with two or more of the multiple pressure chambers (121) to supply the liquid to the two or more of the pressure chambers (121); multiple collection branch channels (153) each communicating with two or more of the multiple pressure chambers (121) to collect the liquid from the two or more of the pressure chambers (121); a supply main channel (156) communicating with each of the multiple supply branch channels (152) to supply the liquid to the multiple supply branch channels (152); a collection main channel (157) communicating with each of the multiple collection branch channels (153) to collect the liquid from the multiple collection branch channels (153); a first bypass channel (253) communicating with each of the supply main channel (156) and the collection main channel (157) to connect the supply main channel (156) and the collection main channel (157); and a first open-close unit (257) configured to: openably close the first bypass channel (253); and decrease a flow rate of the liquid flowing through the first bypass channel (253) with an increase in a first pressure difference between an upstream side and a downstream side of the first open-close unit (257).

<Aspect 11>

[0143] In the discharge head according to aspect 10, further includes: multiple second bypass channels (251) respectively communicating with the multiple supply branch channels (152) and the collection main channel (157); multiple third bypass channels (252) respectively communicating with the multiple collection branch channels (153) and the supply main channel (156); multiple second open-close units (255) configured to openably close the multiple second bypass channels (251), respectively; and multiple third open-close units (256) configured to openably close the multiple third bypass channels (252), respectively; wherein the multiple second open-close units are opened by a second pressure difference, between an upstream side and a downstream side of each of the second open-close unit, greater than the first pressure difference; and the multiple third open-close units are opened by a third pressure difference, between an upstream side and a downstream side of each of the multiple third open-close units, greater than the first pressure difference.

<Aspect 12>

[0144] In the discharge head according to aspect 11, the multiple supply branch channels (152) have end portions connected to the multiple second bypass channels (251), respectively.

<Aspect 13>

[0145] In the discharge head according to aspect 11 the multiple collection branch channels (153) have end portions connected to the multiple third bypass channels (252), respectively.

<Aspect 14>

[0146] The discharge head according to aspect 10, further includes: a supply-side tank (181) communicating with the supply main channel (156); a collection-side tank (182) communicating with the collection main channel (157); a fourth bypass channel (254) communicating with each of the supply-side tank and the collection-side tank to connect the supply-side tank and the collection-side tank; and a fourth open-close unit (258) configured to openably close the fourth bypass channel (254), wherein the fourth open-close unit (258) is opened by a fourth pressure difference, between an upstream side and a downstream side of the fourth open-close unit (258), smaller than the first pressure difference.

<Aspect 15>

[0147] In the discharge head according to aspect 14, the fourth bypass channel (254) is disposed in an uppermost portion of the supply-side tank and the collection-side tank.

<Aspect 16>

[0148] In the discharge head according to aspect 10, the first open-close unit (257) has a cantilever structure and includes: a valve (273) having: a fixed end (273a) on one end of the valve (273); a free end (273b) on another end of the valve (273), the free end being movable; and a regulation member (271) disposed in the first bypass channel to regulate a movement of the free end at a predetermined position in a liquid flow direction, the free end contacts the regulation member (271) at a contact position to close the first bypass channel, and the free end is positioned at an upstream of the contact position in the liquid flow direction in response to the first pressure difference being smaller than a threshold value to open the first bypass channel.

<Aspect 17>

[0149] In the discharge head according to aspect 16, an angle is formed between a first line, connecting the fixed end and the free end, and a surface of the first bypass channel on which the fixed end is provided increases with an increase in the first pressure difference, and the angle becomes the maximum at which the free end contacts the regulation member in response to the first pressure difference exceeding the threshold value.

<Aspect 18>

[0150] A discharge apparatus (1) comprising the discharge head according to any one of aspects 10 through 17.

<Aspect 19>

[0151] In the discharge head according to any one of aspects 11 to 13,
wherein the multiple second open-close units (255) are configured to decrease a flow rate of the liquid flowing through the multiple second bypass channels (251) with an increase in the second pressure difference.

<Aspect 20>

[0152] In the discharge head according to any one of aspects 11 to 13, the multiple third open-close units (256) are configured to decrease a flow rate of the liquid flowing through the multiple third bypass channels (252) with an increase in the third pressure difference.

<Aspect 21>

[0153] In the discharge head according to aspect 14 or 15, the fourth open-close units (258) is configured to decrease a flow rate of the liquid flowing through the fourth bypass channel (254) with an increase in the fourth pressure difference.

Claims

1. A discharge head (100) comprising:

multiple nozzles (111) from each of which a liquid is discharged;
multiple pressure chambers (121) respectively communicating with the multiple nozzles (111);
multiple supply branch channels (152) each communicating with two or more of the multiple

pressure chambers (121) to supply the liquid to the two or more of the pressure chambers (121);
multiple collection branch channels (153) each communicating with two or more of the multiple pressure chambers (121) to collect the liquid from the two or more of the pressure chambers (121);
a supply main channel (156) communicating with each of the multiple supply branch channels (152) to supply the liquid to the multiple supply branch channels (152);
a collection main channel (157) communicating with each of the multiple collection branch channels (153) to collect the liquid from the multiple collection branch channels (153);
a first bypass channel (253) communicating with each of the supply main channel (156) and the collection main channel (157) to connect the supply main channel (156) and the collection main channel (157); and
a first open-close unit (257) configured to:

openably close the first bypass channel (253); and
decrease a flow rate of the liquid flowing through the first bypass channel (253) with an increase in a first pressure difference between an upstream side and a downstream side of the first open-close unit (257).

2. The discharge head (100) according to claim 1, further comprising:

multiple second bypass channels (251) respectively communicating with the multiple supply branch channels (152) and the collection main channel (157);
multiple third bypass channels (252) respectively communicating with the multiple collection branch channels (153) and the supply main channel (156);
multiple second open-close units (255) configured to openably close the multiple second bypass channels (251), respectively; and
multiple third open-close units (256) configured to openably close the multiple third bypass channels (252), respectively,
wherein the multiple second open-close units are opened by a second pressure difference, between an upstream side and a downstream side of each of the second open-close unit, greater than the first pressure difference, and
the multiple third open-close units are opened by a third pressure difference, between an upstream side and a downstream side of each of the multiple third open-close units, greater than the first pressure difference.

3. The discharge head (100) according to claim 2, wherein the multiple supply branch channels (152) have end portions connected to the multiple second bypass channels (251), respectively.

4. The discharge head (100) according to claim 2, wherein the multiple collection branch channels (153) have end portions connected to the multiple third bypass channels (252), respectively.

5. The discharge head (100) according to claim 1, further comprising:

a supply-side tank (181) communicating with the supply main channel (156);
a collection-side tank (182) communicating with the collection main channel (157);
a fourth bypass channel (254) communicating with each of the supply-side tank and the collection-side tank to connect the supply-side tank and the collection-side tank; and
a fourth open-close unit (258) configured to openably close the fourth bypass channel (254),
wherein the fourth open-close unit (258) is opened by a fourth pressure difference, between an upstream side and a downstream side of the fourth open-close unit (258), smaller than the first pressure difference.

6. The discharge head (100) according to claim 5, wherein the fourth bypass channel (254) is disposed in an uppermost portion of the supply-side tank and the collection-side tank.

7. The discharge head (100) according to claim 1, wherein the first open-close unit (257) has a cantilever structure and includes:

a valve (273) having:

a fixed end (273a) on one end of the valve (273);
a free end (273b) on another end of the valve (273), the free end being movable; and

a regulation member (271) disposed in the first bypass channel to regulate a movement of the free end at a predetermined position in a liquid flow direction,
wherein the free end contacts the regulation member (271) at a contact position to close the first bypass channel, and
the free end is positioned at an upstream of the contact position in the liquid flow direction in response to the first pressure difference being smaller than a threshold value to open the first bypass channel.

8. The discharge head (100) according to claim 7,

wherein an angle is formed between a first line, connecting the fixed end and the free end, and a surface of the first bypass channel on which the fixed end is provided increases with an increase in the first pressure difference, and
the angle becomes the maximum at which the free end contacts the regulation member in response to the first pressure difference exceeding the threshold value.

9. A discharge apparatus (1) comprising the discharge head according to any one of claims 1 through 8.

10. The discharge head (100) according to any one of claims 2 to 4,
wherein the multiple second open-close units (255) are configured to decrease a flow rate of the liquid flowing through the multiple second bypass channels (251) with an increase in the second pressure difference.

11. The discharge head (100) according to any one of claims 2 to 4,
wherein the multiple third open-close units (256) are configured to decrease a flow rate of the liquid flowing through the multiple third bypass channels (252) with an increase in the third pressure difference.

12. The discharge head (100) according to claim 5 or 6, wherein the fourth open-close unit (258) is configured to decrease a flow rate of the liquid flowing through the fourth bypass channel (254) with an increase in the fourth pressure difference.

FIG. 1A

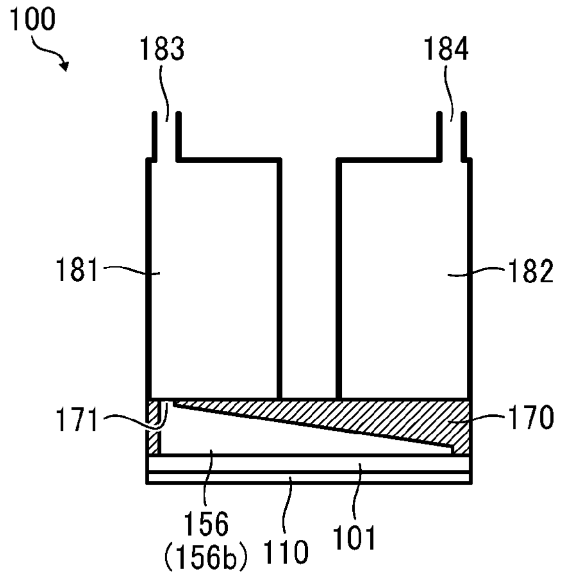


FIG. 1B

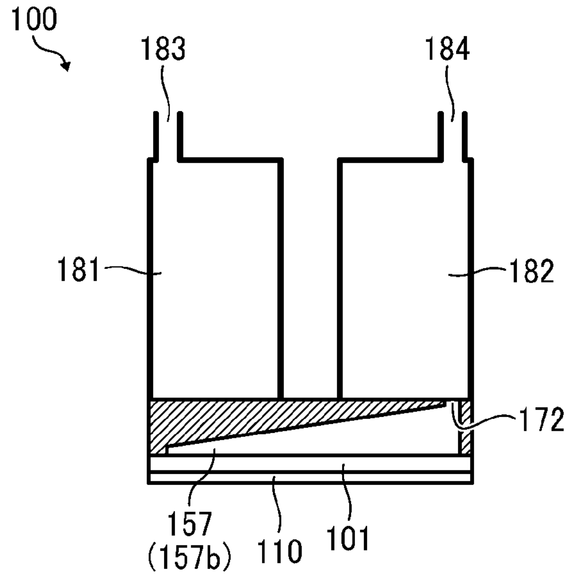


FIG. 2

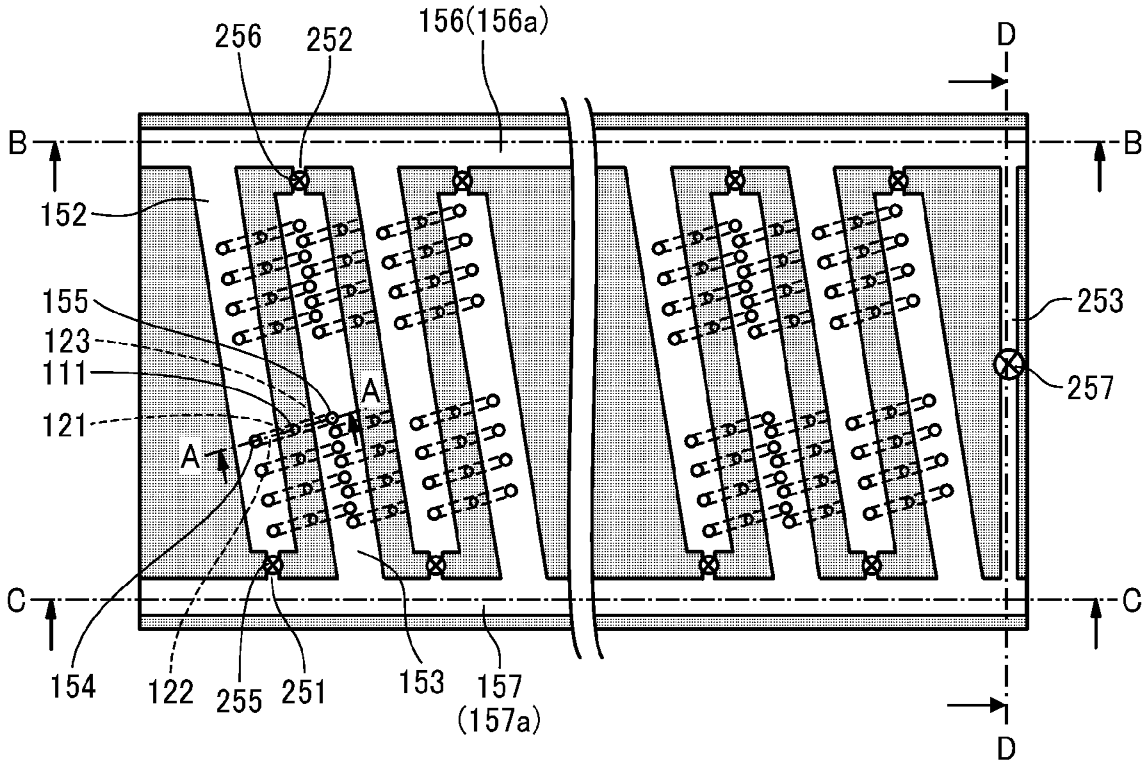


FIG. 3

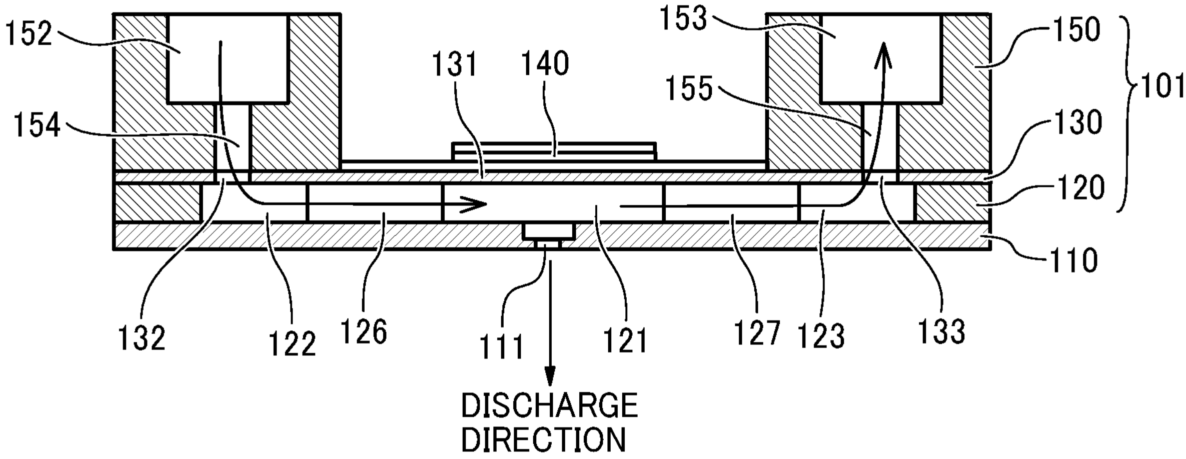
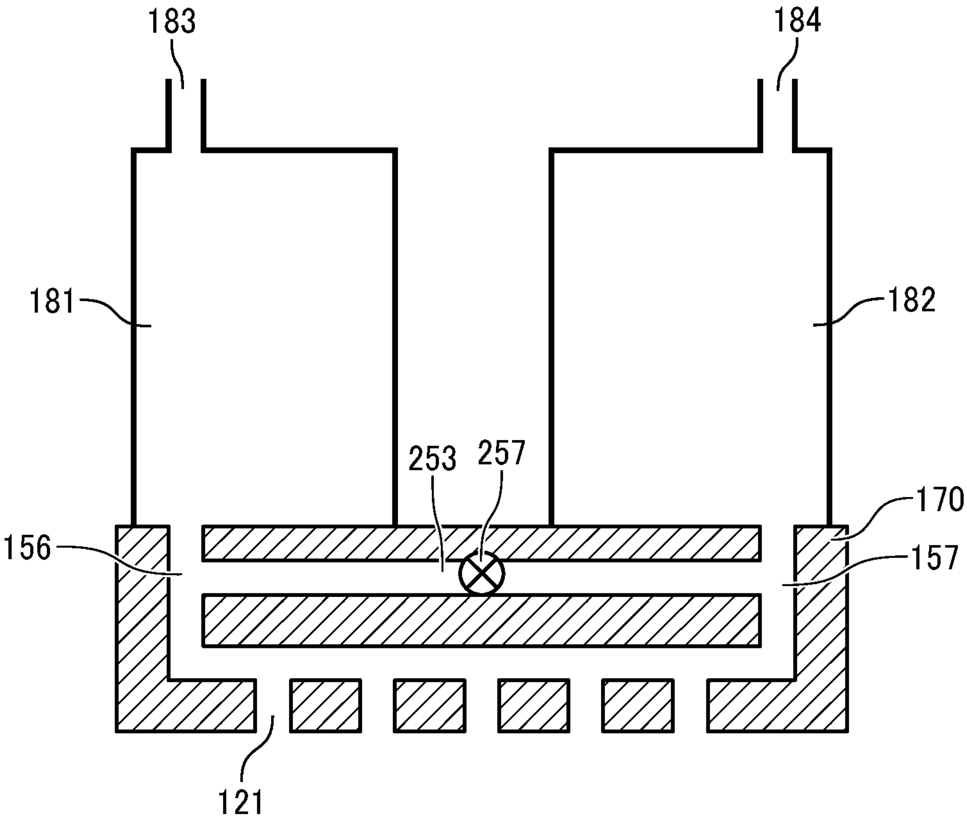
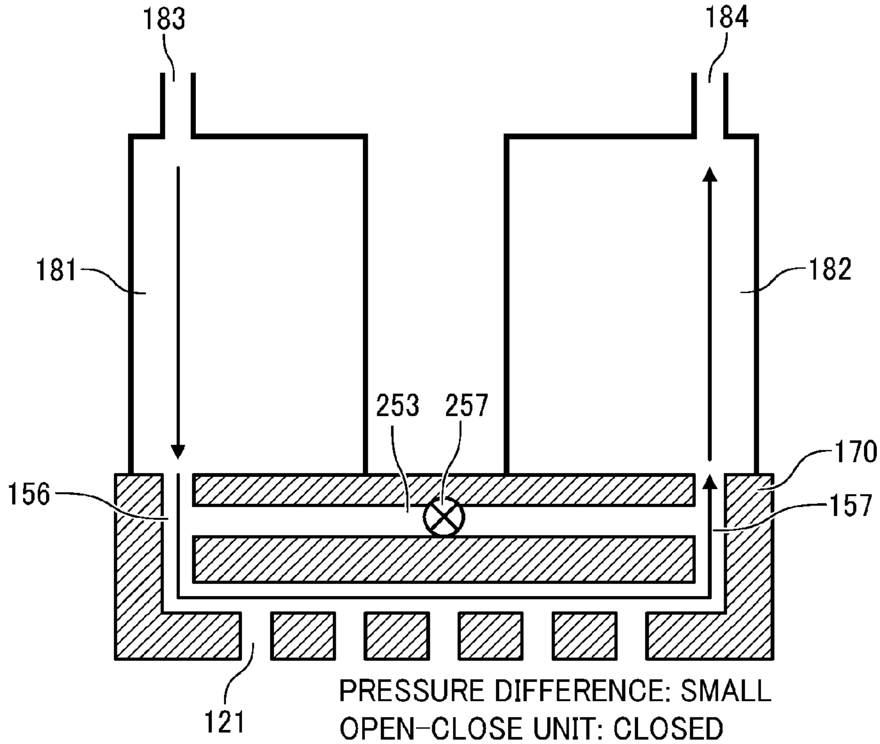

152
153
150
101
131
140
155
154
130
120
110
132
122
126
111
121
127
123
133
DISCHARGE
DIRECTION

FIG. 4


183
184
181
182
253
257
170
156
157
121

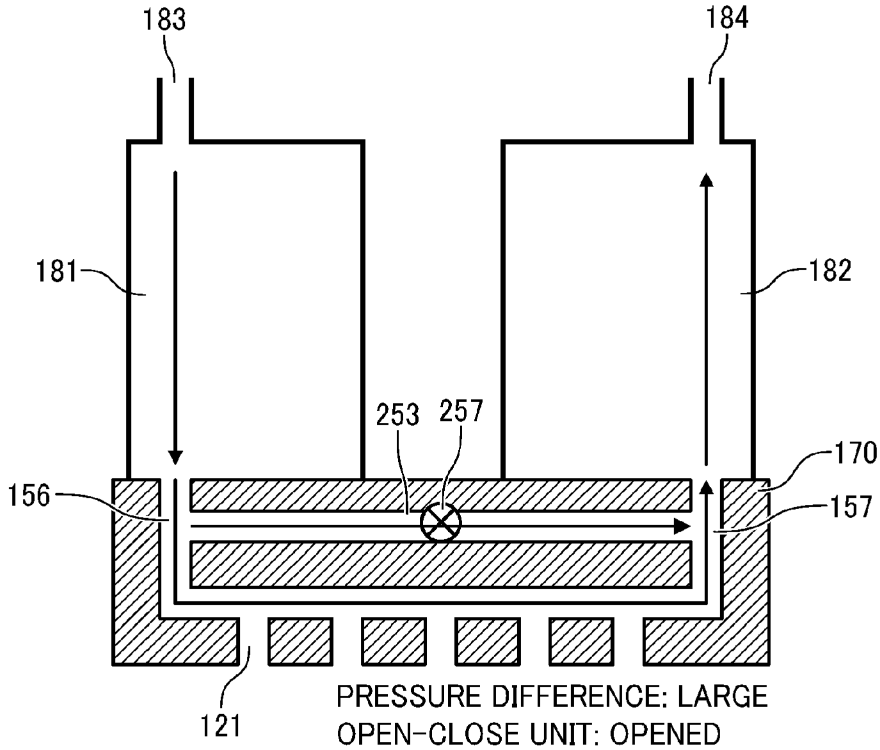
COMPAREATIVE EXAMPLE

FIG. 5A



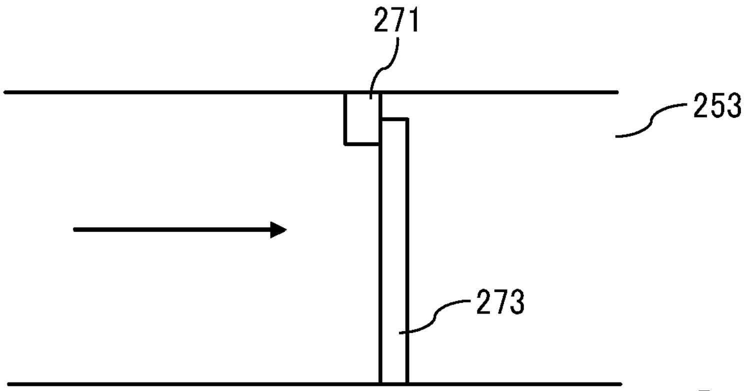
COMPAREATIVE EXAMPLE

FIG. 5B



COMPAREATIVE EXAMPLE

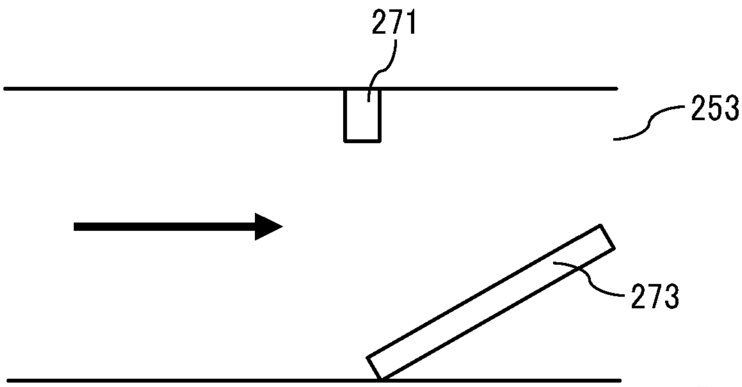
FIG. 6A



PRESSURE DIFFERENCE: SMALL
OPEN-CLOSE UNIT: CLOSED

COMPAREATIVE EXAMPLE

FIG. 6B



PRESSURE DIFFERENCE: LARGE
OPEN-CLOSE UNIT: OPENED

FIG. 7A

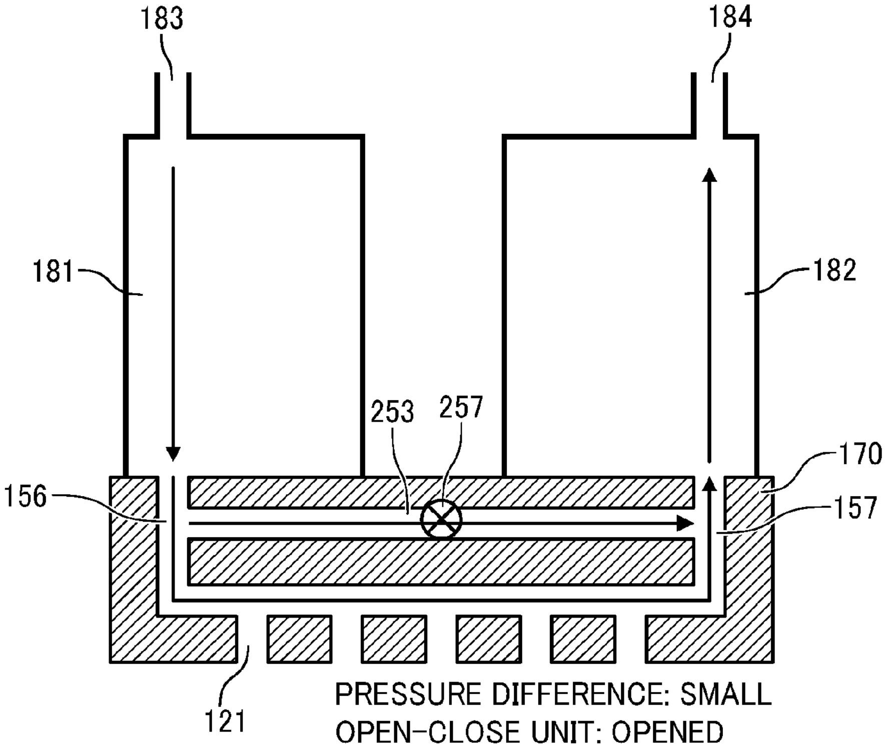
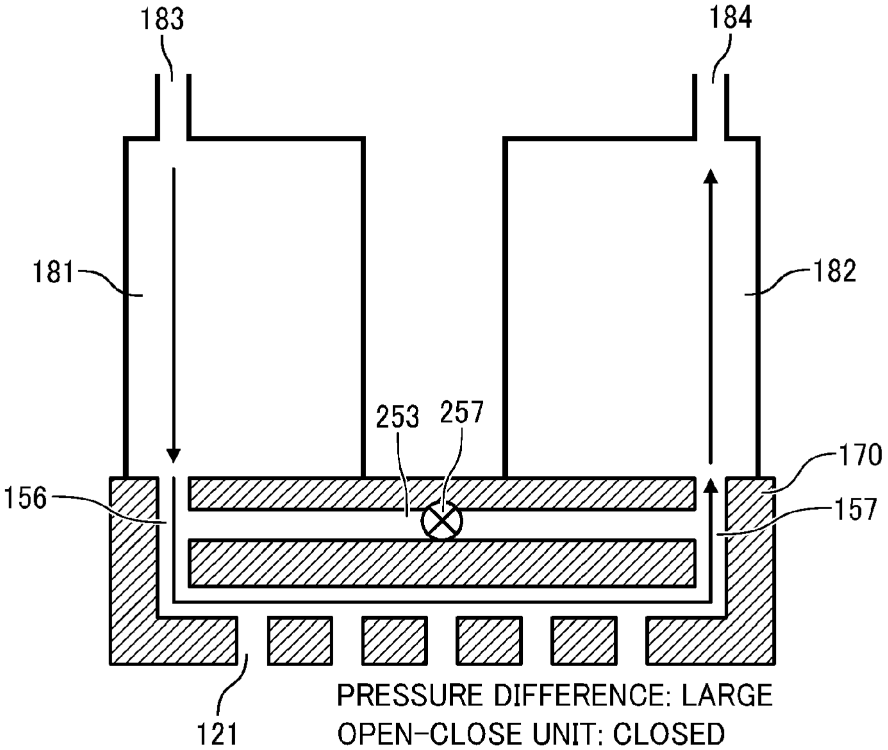

183
184
181
182
253
257
170
156
157
121
PRESSURE DIFFERENCE: SMALL
OPEN-CLOSE UNIT: OPENED

FIG. 7B


183
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182
253
257
170
156
157
121
PRESSURE DIFFERENCE: LARGE
OPEN-CLOSE UNIT: CLOSED

FIG. 8A

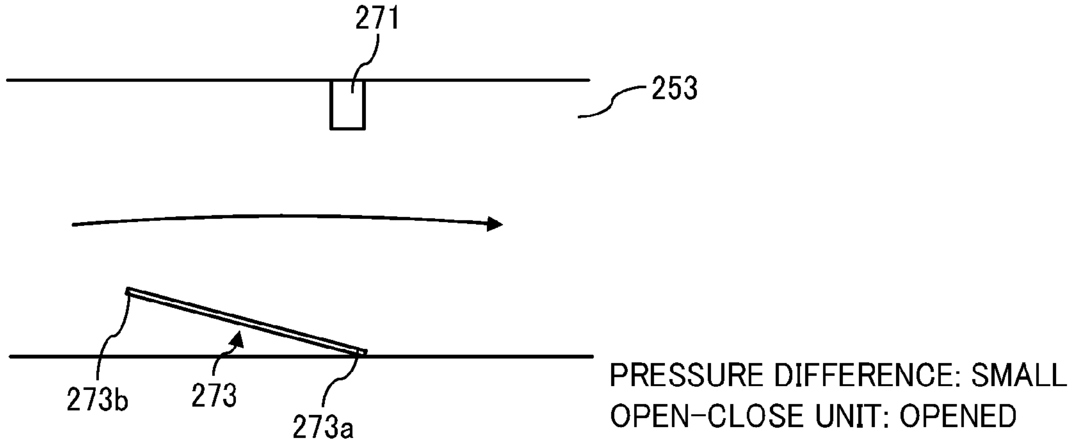


FIG. 8B

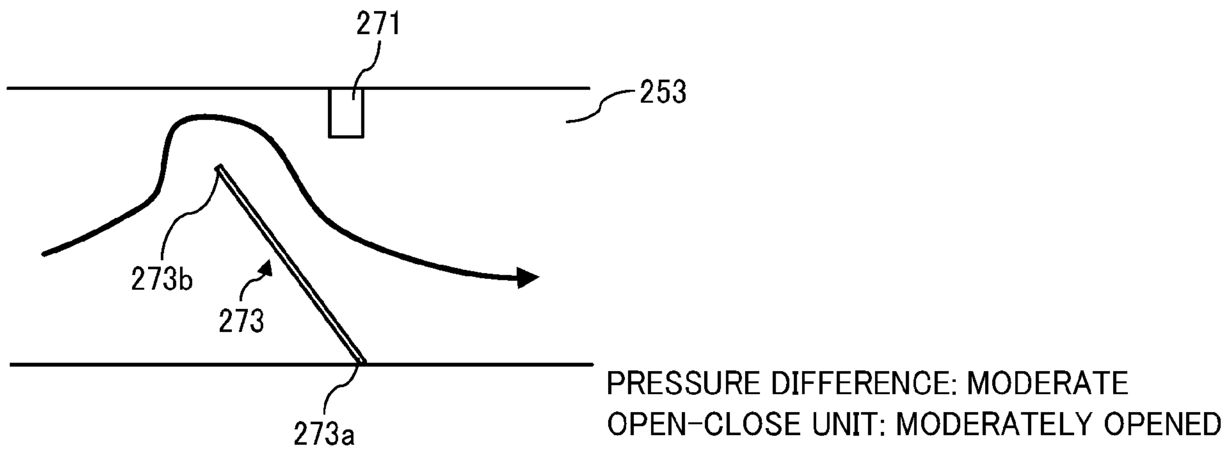


FIG. 8C

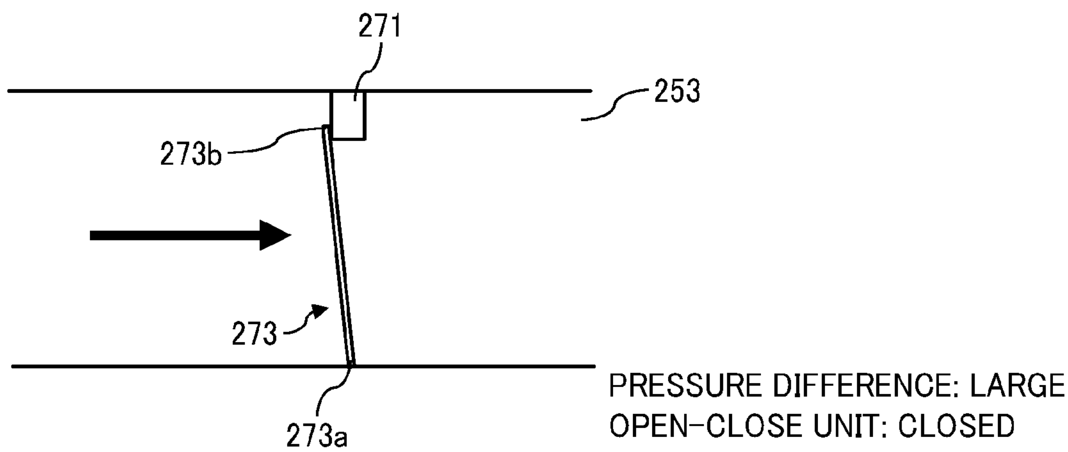


FIG. 9A

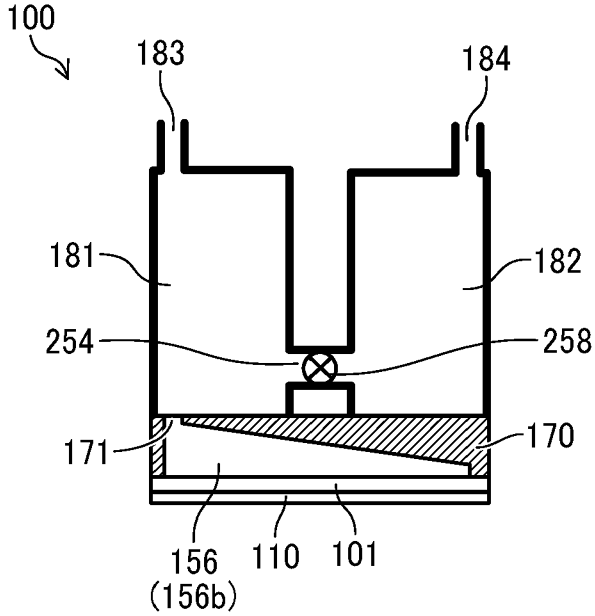

100
183
184
181
182
254
258
171
170
156
(156b)
110
101

FIG. 9B

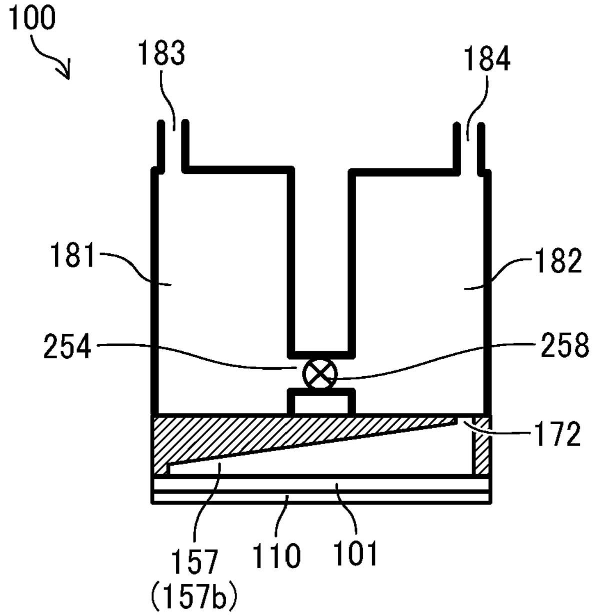

100
183
184
181
182
254
258
172
157
(157b)
110
101

FIG. 10A

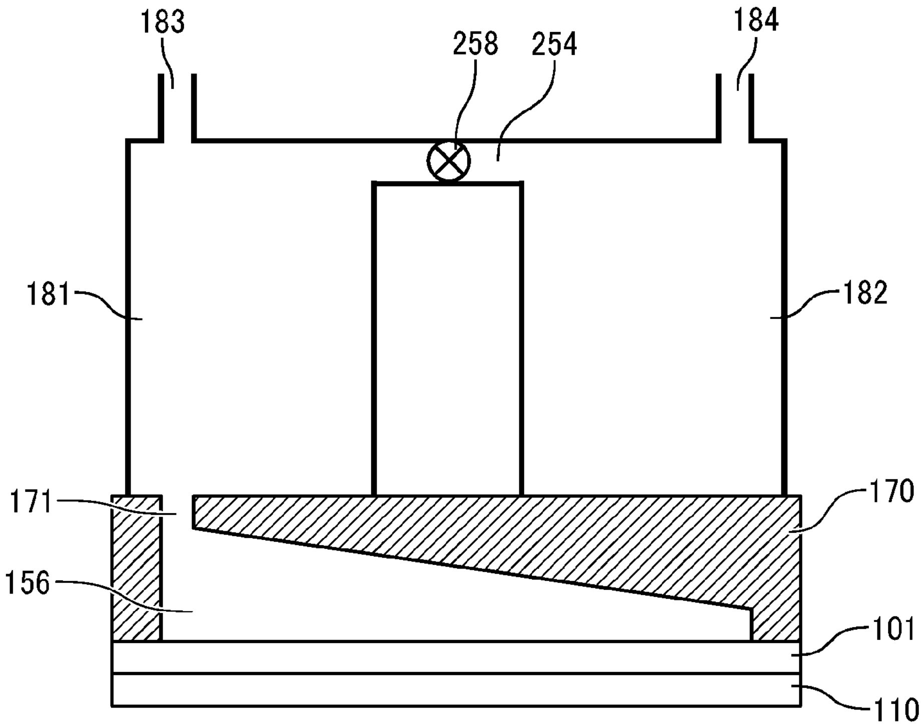


FIG. 10B

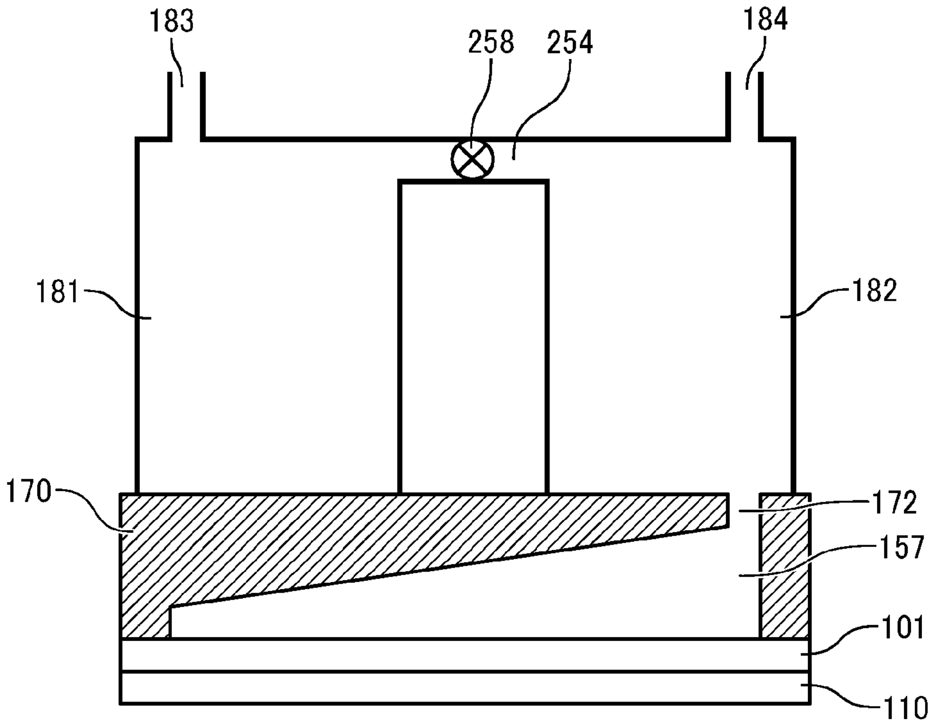


FIG. 11

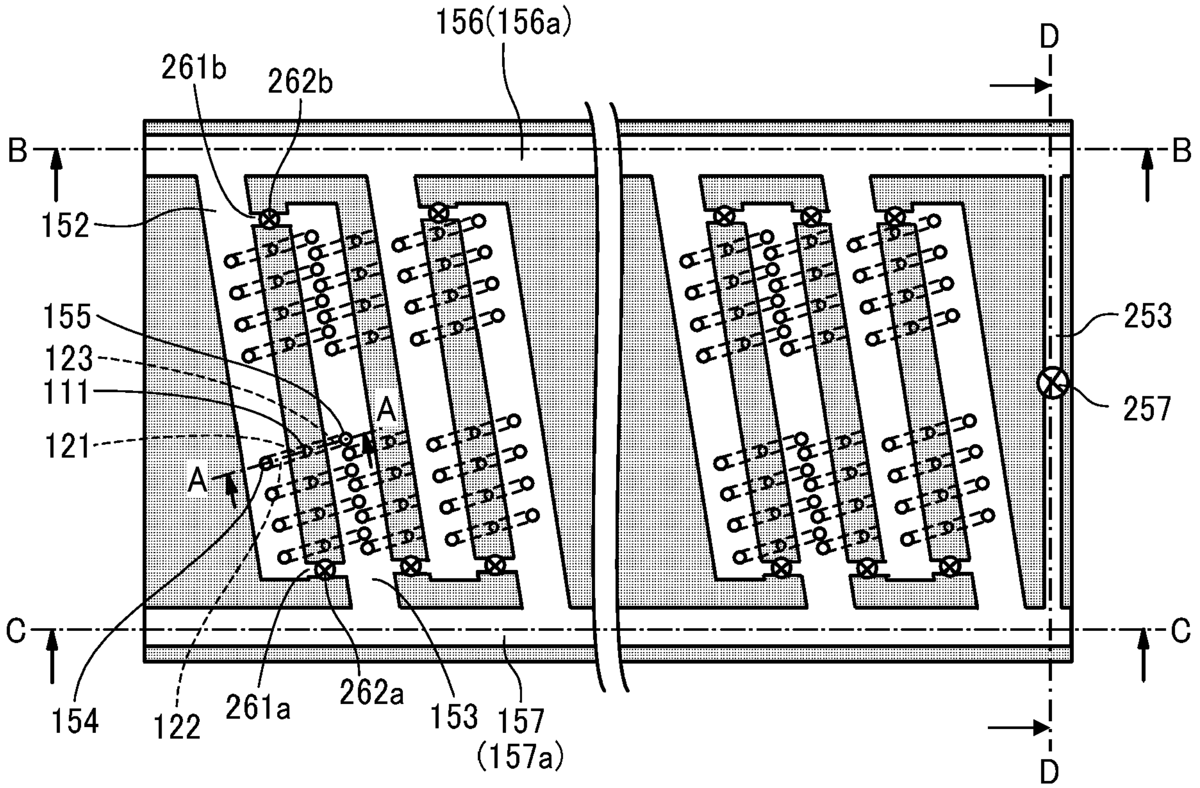
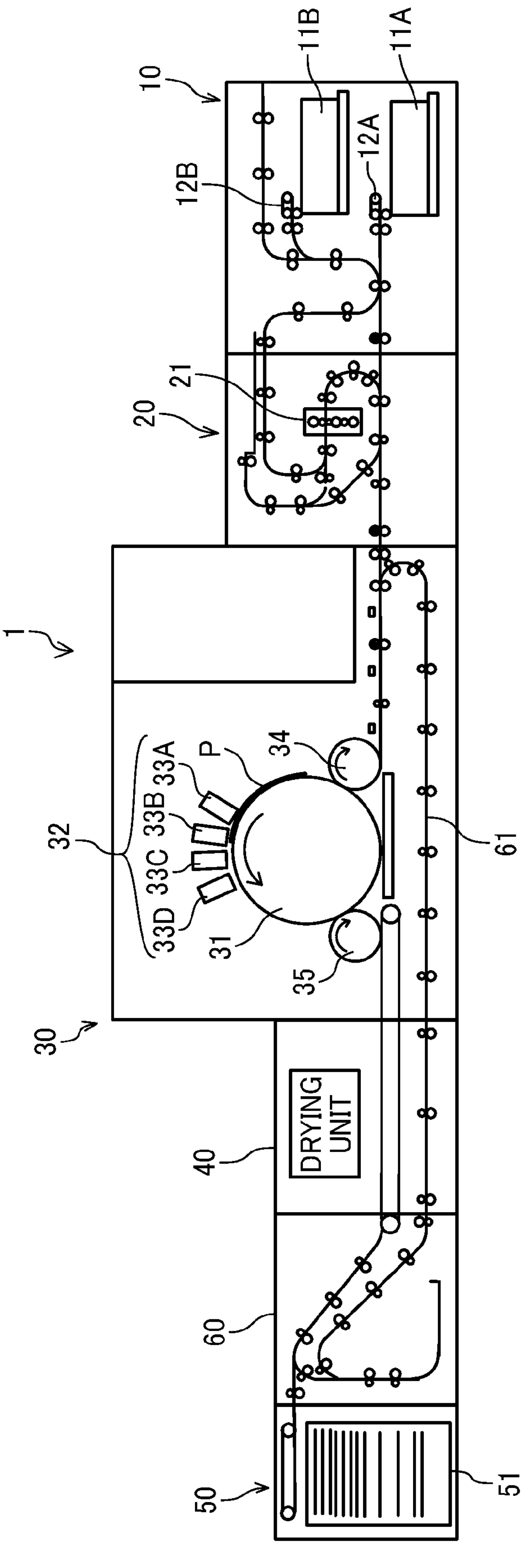

156(156a)
D
261b
262b
B
B
152
155
253
123
111
257
121
A
A
C
C
154
122
261a
262a
153
157
(157a)
D

FIG. 12


1
10
11B
11A
12B
12A
20
21
30
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33B
33C
33D
P
34
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61
40
DRYING UNIT
60
50
51

FIG. 13

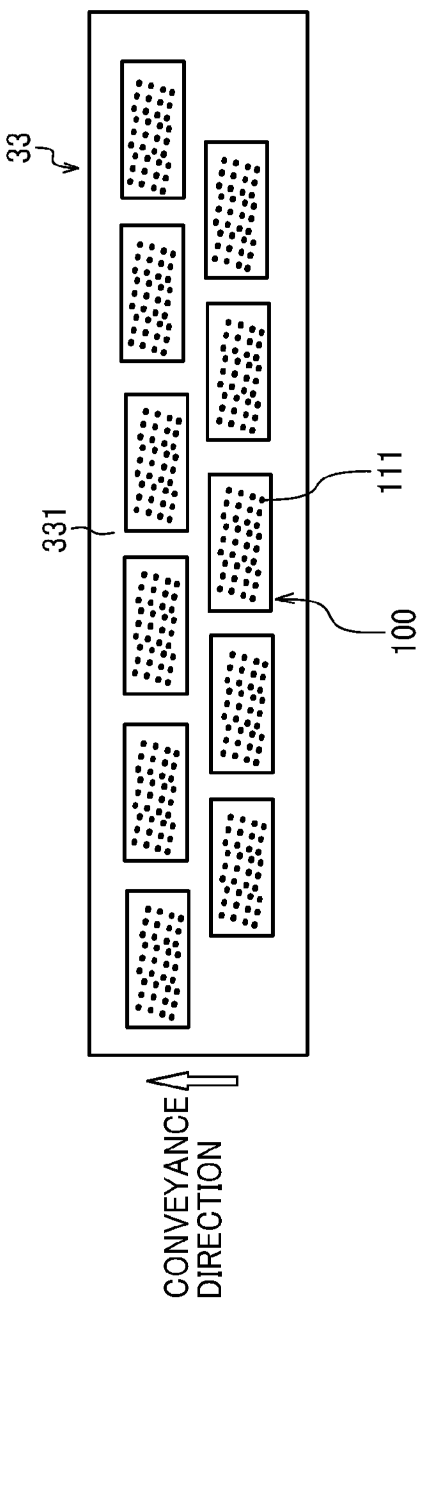
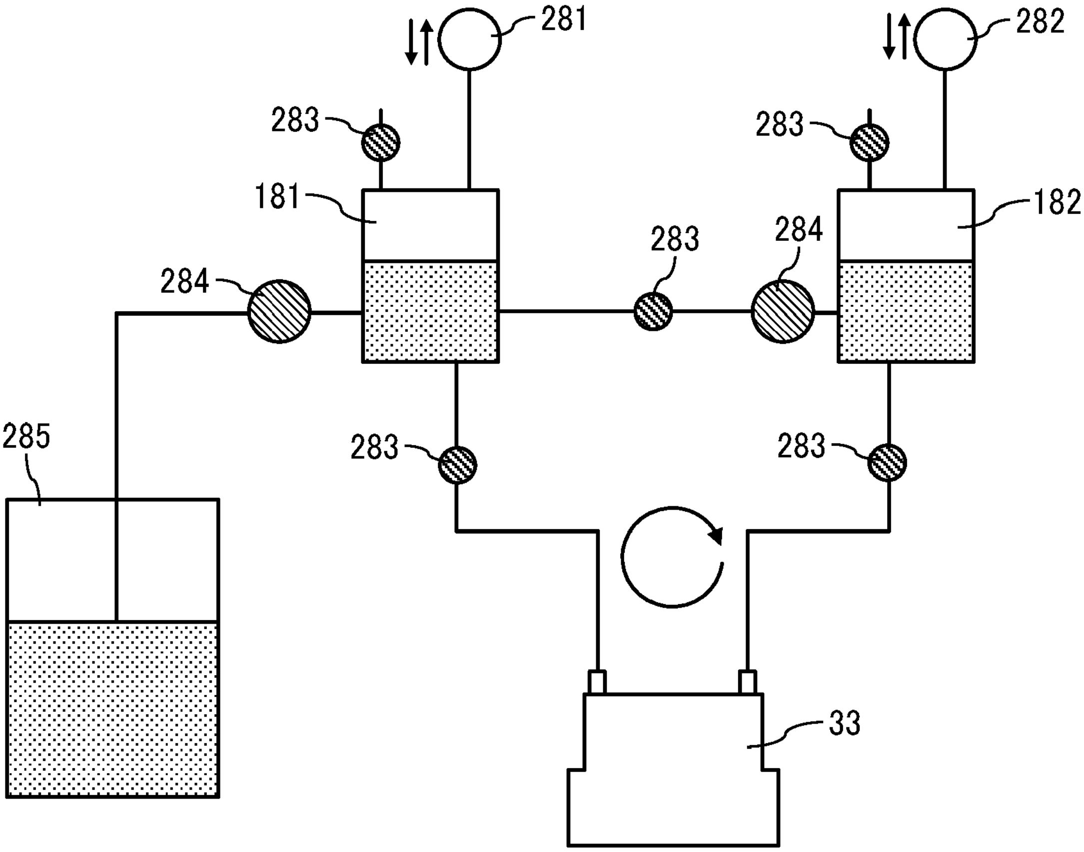

33
331
111
100
CONVEYANCE DIRECTION

FIG. 14



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EUROPEAN SEARCH REPORT

Application Number
EP 23 17 7969

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	JP 2017 159561 A (RICOH CO LTD) 14 September 2017 (2017-09-14) * paragraphs [0050] - [0052]; figures 1-15 *	1-12	INV. B41J2/18 B41J2/19 B41J2/14
A	US 2010/079511 A1 (MURAKAMI ATSUSHI [JP] ET AL) 1 April 2010 (2010-04-01) * figures 1-20 *	1-12	

TECHNICAL FIELDS SEARCHED (IPC)

B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 November 2023	Cavia Del Olmo, D

CATEGORY OF CITED DOCUMENTS

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EP 23 17 7969

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20-11-2023

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JP 2017159561 A	14-09-2017	NONE	
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		US 2010169456 A1	01-07-2010

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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Patent documents cited in the description

- JP 2017159561 A **[0003]**
- JP 2019209595 A **[0004]**