US 20200156374A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2020/0156374 A1
Bandoh
(43) Pub. Date: May 21, 2020

(54) LIQUID DISCHARGE HEAD, HEAD MODULE, HEAD DEVICE, LIQUID DISCHARGE DEVICE, AND LIQUID DISCHARGE APPARATUS

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(21) Appl. No.: **16/655,476**

(22) Filed: **Oct. 17, 2019**

(30) **Foreign Application Priority Data**

Nov. 15, 2018 (JP) 2018-214373
Oct. 1, 2019 (JP) 2019-181204

Publication Classification

(51) **Int. Cl.**
B41J 2/15 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/15*** (2013.01); *B41J 2202/20* (2013.01); *B41J 2202/19* (2013.01); *B41J 2202/11* (2013.01)

(57) **ABSTRACT**

A liquid discharge head includes a plurality of nozzle arrays arranged in a first direction. The plurality of nozzle arrays each includes nozzles from which a liquid is discharged, the nozzles arranged in a second direction intersecting the first direction, and one of two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction include at least two nozzles arranged at different nozzle intervals from corresponding nozzles of another of the two nozzle arrays in the first direction.

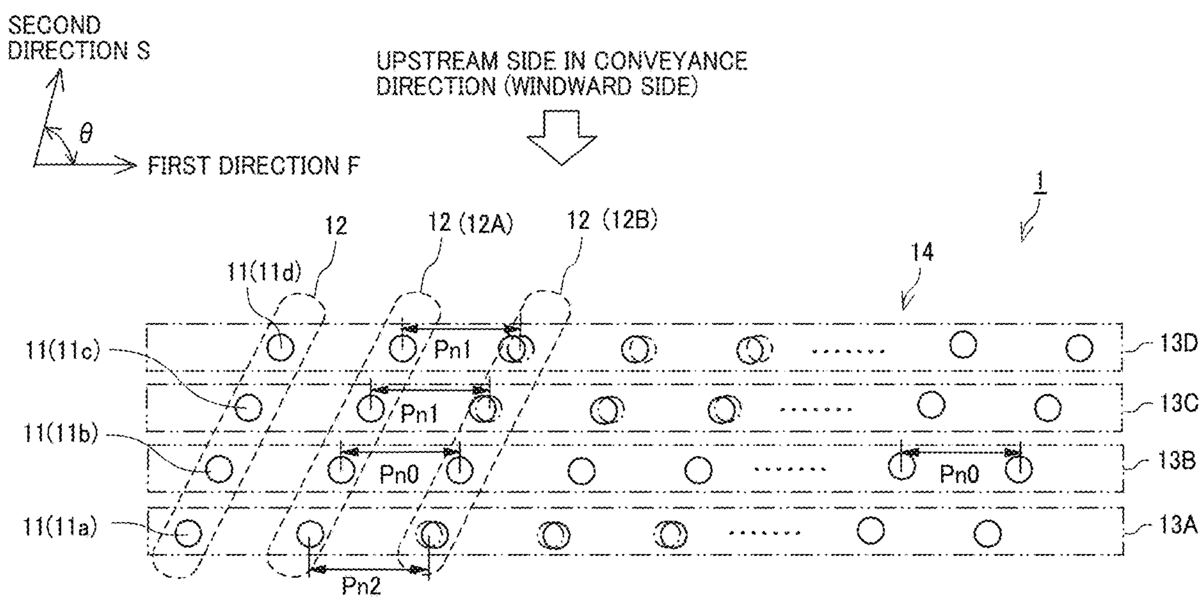


FIG. 1

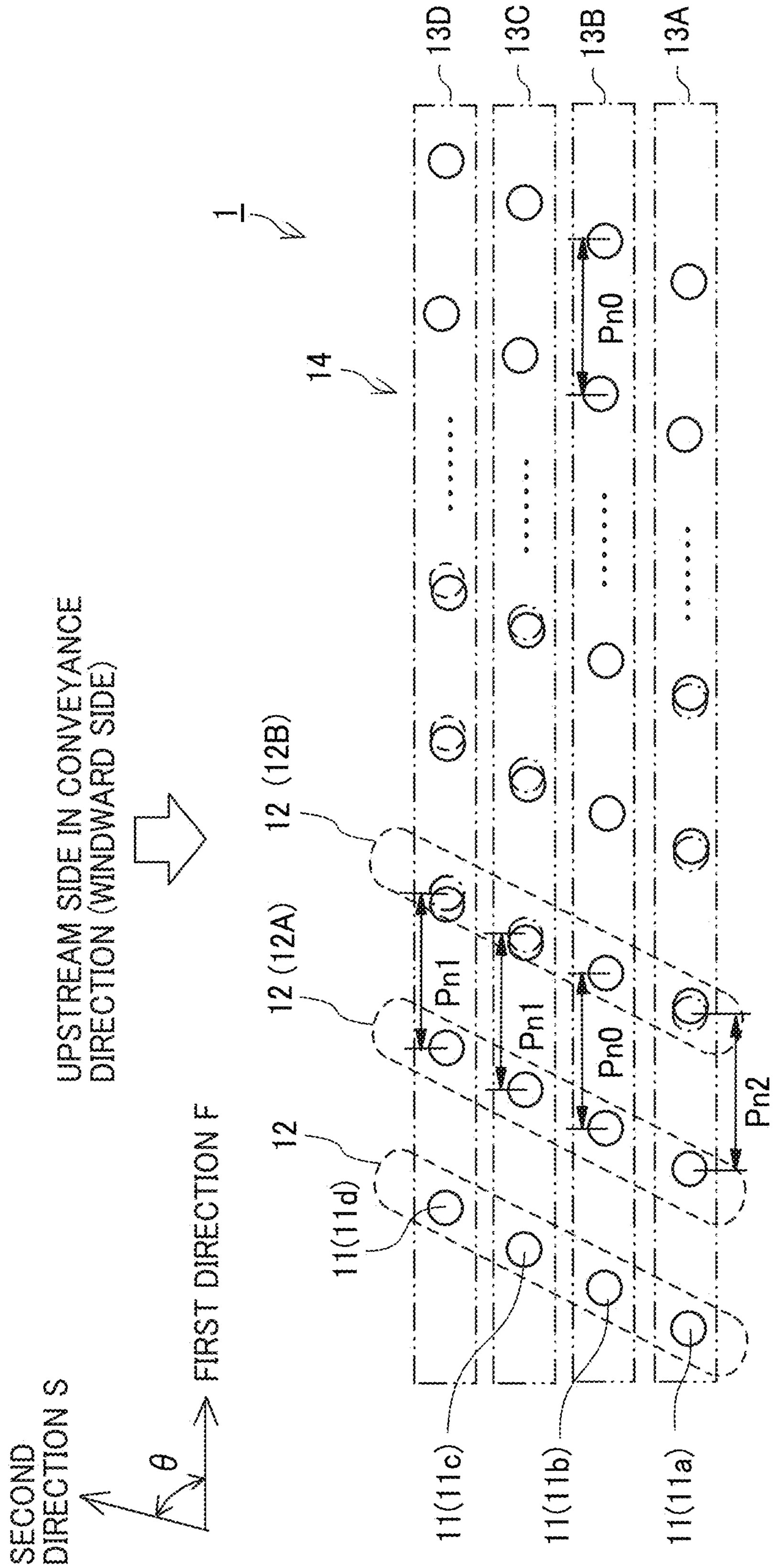

UPSTREAM SIDE IN CONVEYANCE DIRECTION (WINDWARD SIDE)
SECOND DIRECTION S
FIRST DIRECTION F
θ
1
14
13A
13B
13C
13D
12
12 (12A)
12 (12B)
11(11a)
11(11b)
11(11c)
11(11d)
Pn0
Pn1
Pn2

FIG. 2

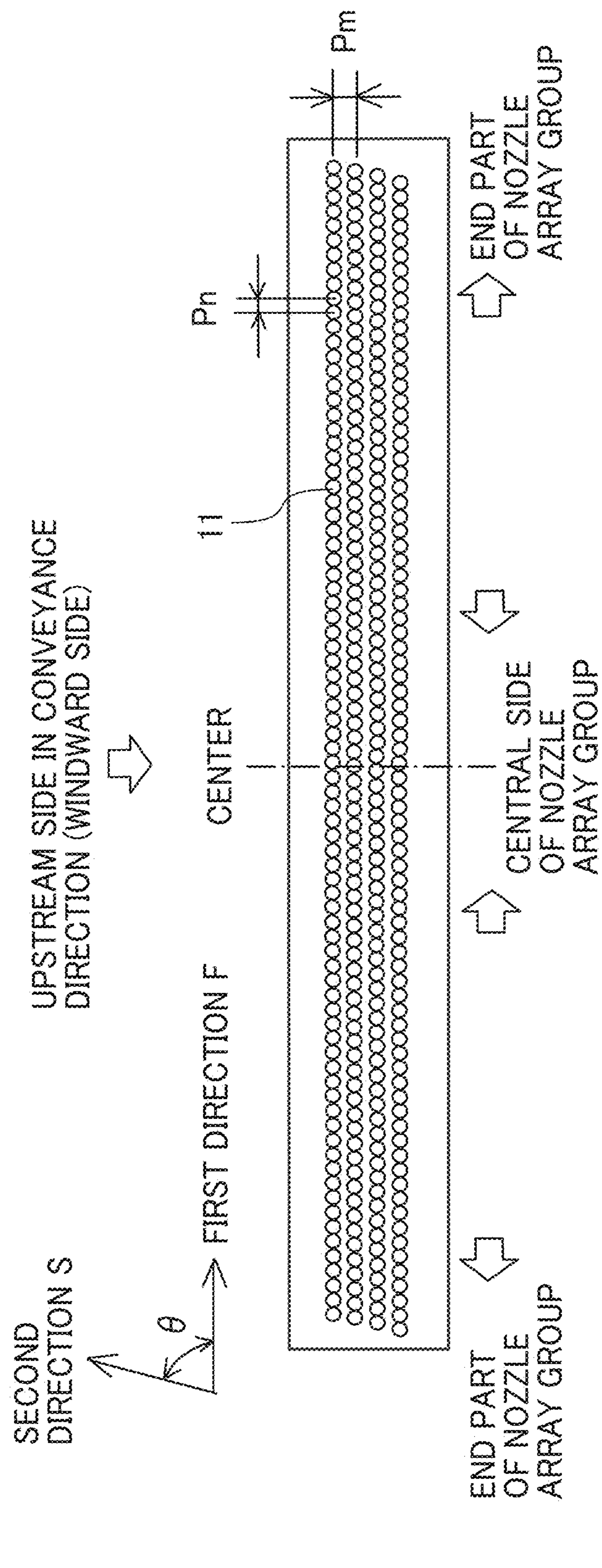

UPSTREAM SIDE IN CONVEYANCE DIRECTION (WINDWARD SIDE)
CENTER
SECOND DIRECTION S
θ
FIRST DIRECTION F
11
Pn
Pm
END PART OF NOZZLE ARRAY GROUP
CENTRAL SIDE OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP

FIG. 3

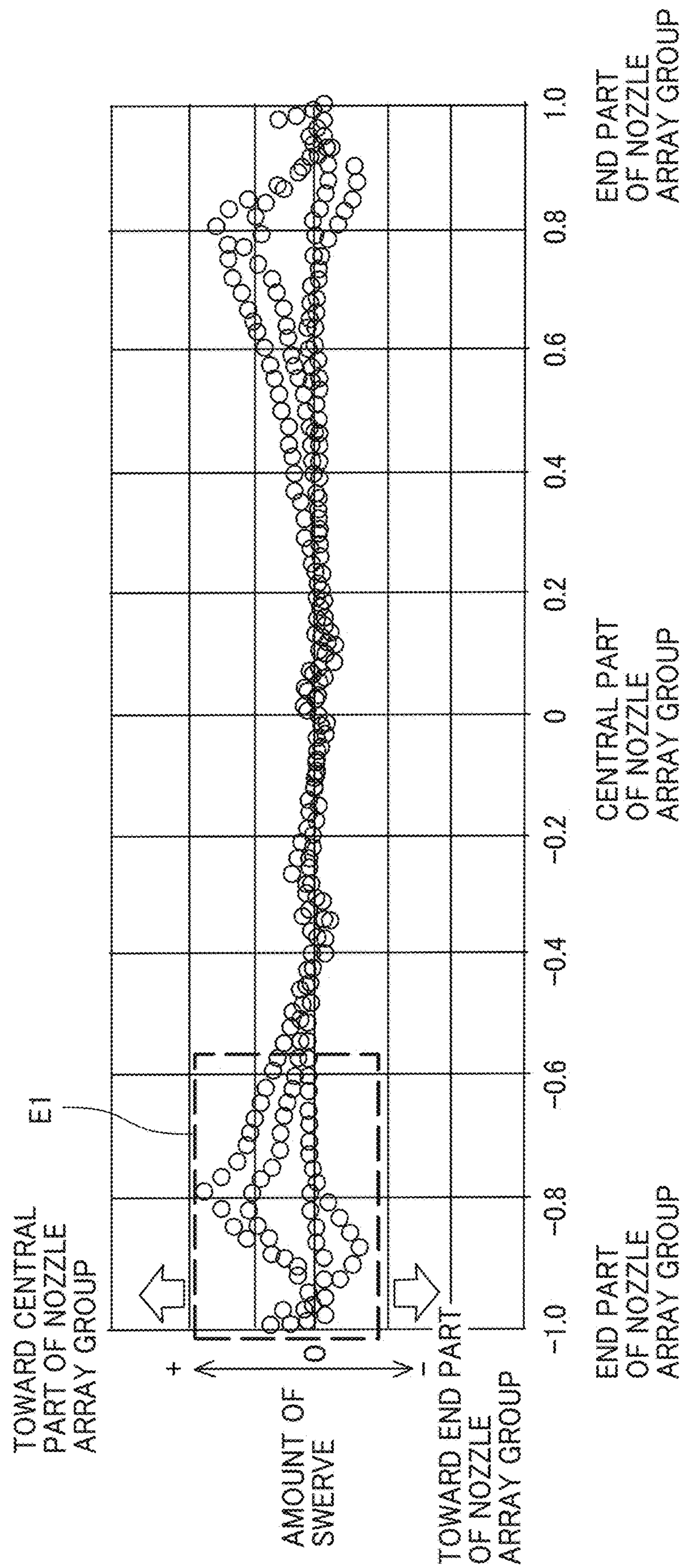
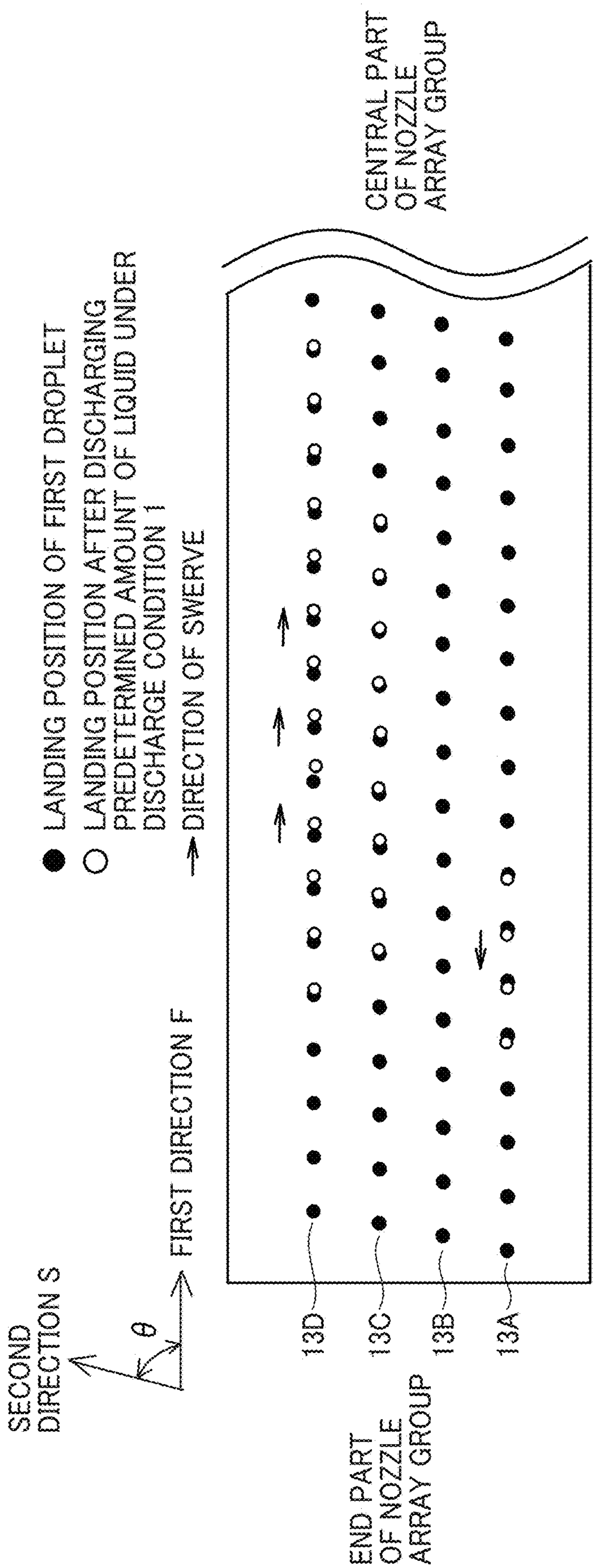

TOWARD CENTRAL PART OF NOZZLE ARRAY GROUP
AMOUNT OF SWERVE
+
0
−
TOWARD END PART OF NOZZLE ARRAY GROUP
E1
−1.0
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1.0
END PART OF NOZZLE ARRAY GROUP
CENTRAL PART OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP

FIG. 4



LANDING POSITION OF FIRST DROPLET
LANDING POSITION AFTER DISCHARGING PREDETERMINED AMOUNT OF LIQUID UNDER DISCHARGE CONDITION 1
DIRECTION OF SWERVE
CENTRAL PART OF NOZZLE ARRAY GROUP
SECOND DIRECTION S
θ
FIRST DIRECTION F
13D
13C
13B
13A
END PART OF NOZZLE ARRAY GROUP

FIG. 5

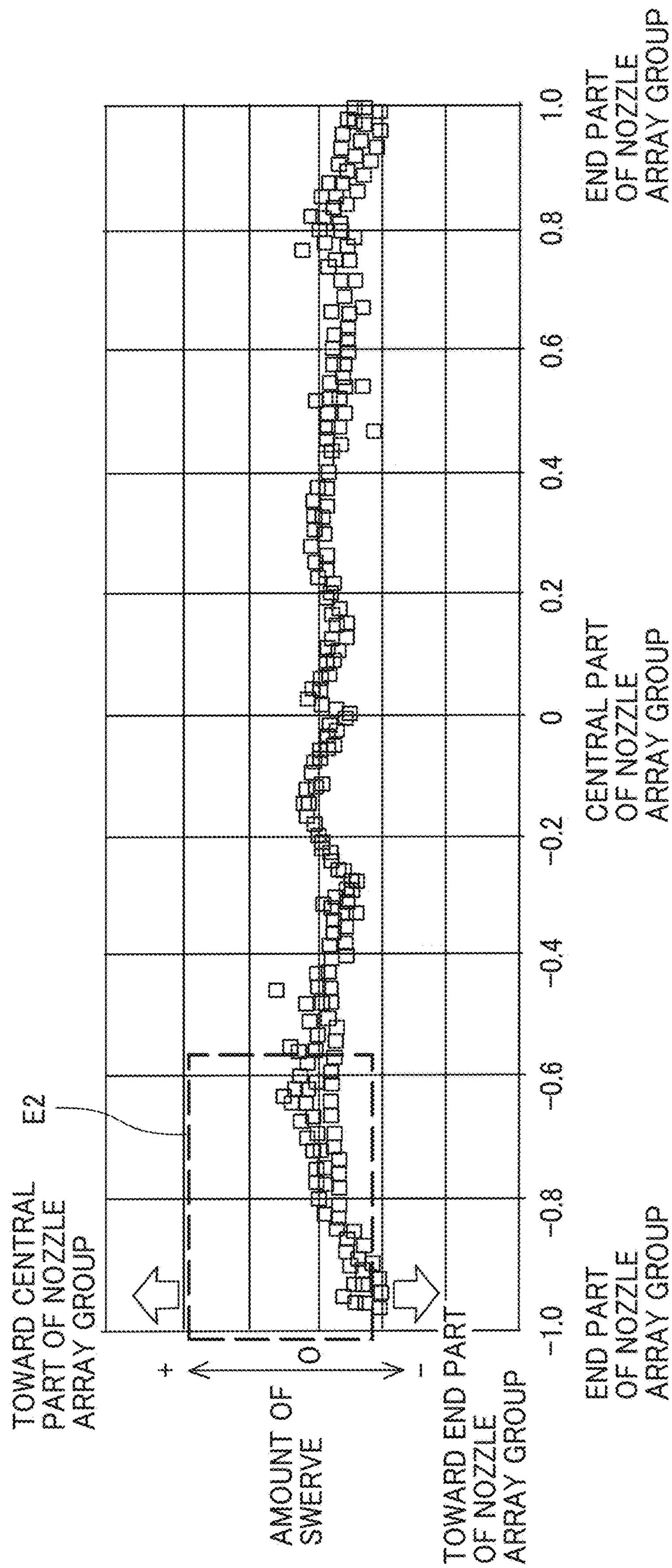

TOWARD CENTRAL PART OF NOZZLE ARRAY GROUP
AMOUNT OF SWERVE
TOWARD END PART OF NOZZLE ARRAY GROUP
+
0
−
E2
−1.0
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1.0
END PART OF NOZZLE ARRAY GROUP
CENTRAL PART OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP

FIG. 6

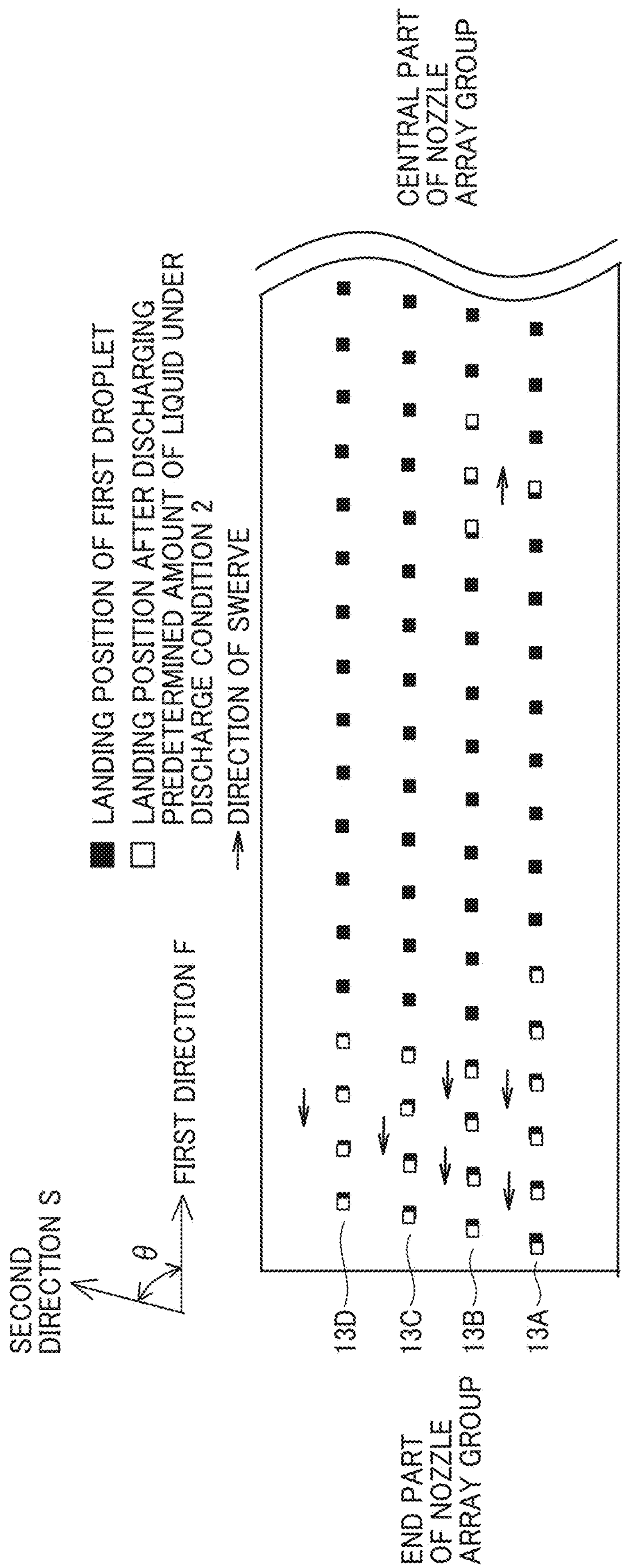
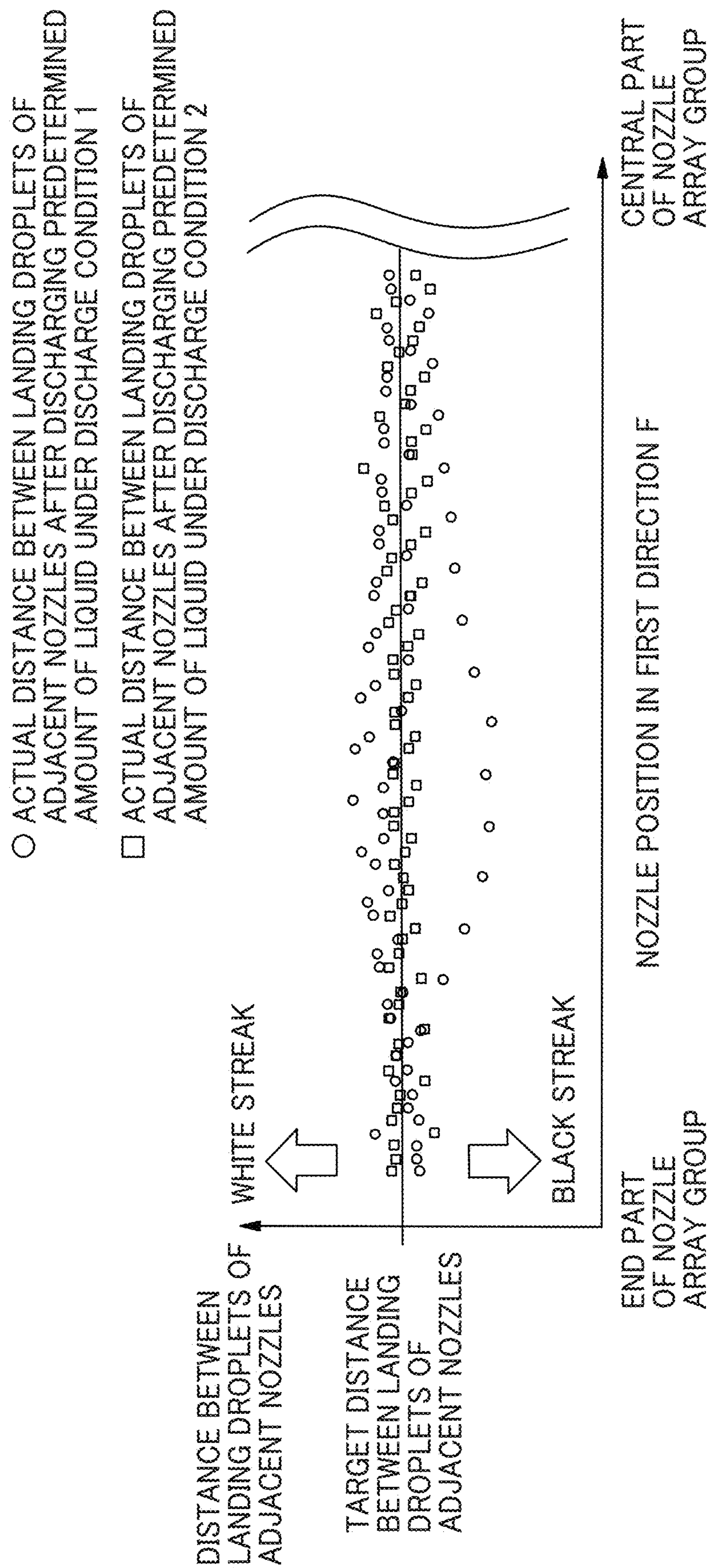
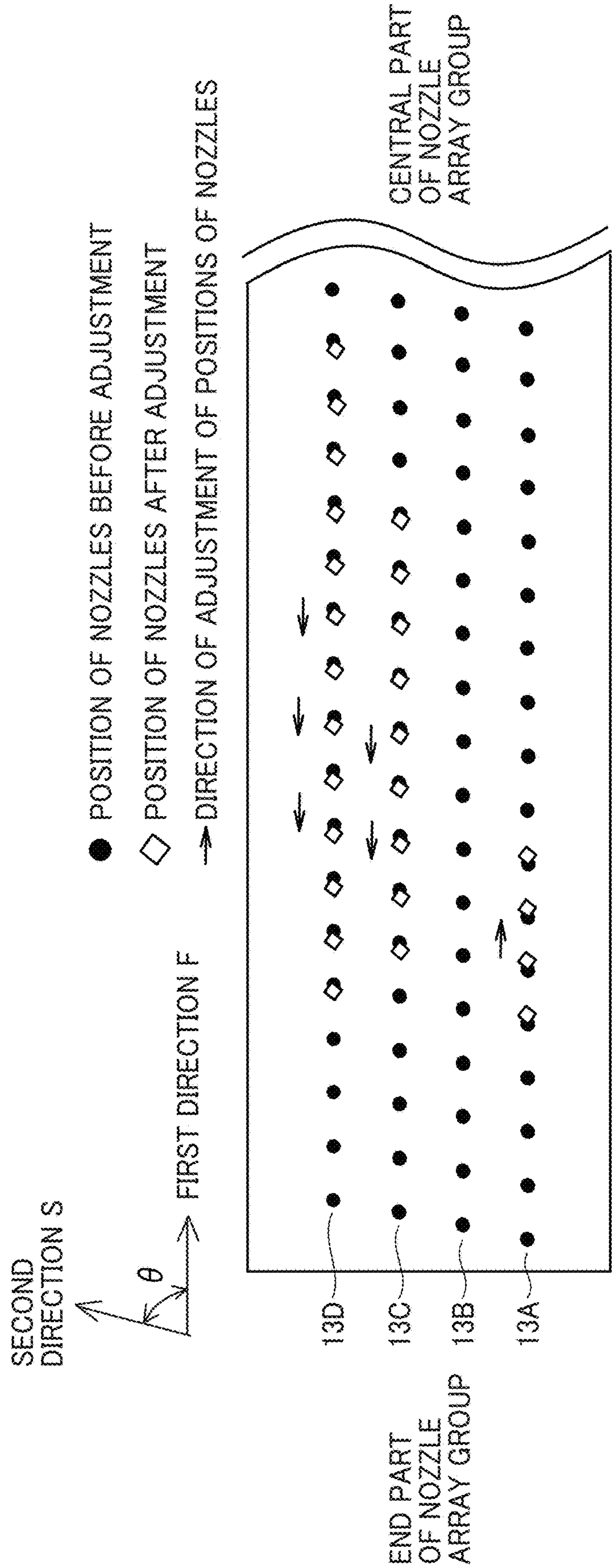

LANDING POSITION OF FIRST DROPLET
LANDING POSITION AFTER DISCHARGING PREDETERMINED AMOUNT OF LIQUID UNDER DISCHARGE CONDITION 2
DIRECTION OF SWERVE
SECOND DIRECTION S
θ
FIRST DIRECTION F
CENTRAL PART OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP
13D
13C
13B
13A

FIG. 7



○ ACTUAL DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES AFTER DISCHARGING PREDETERMINED AMOUNT OF LIQUID UNDER DISCHARGE CONDITION 1
□ ACTUAL DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES AFTER DISCHARGING PREDETERMINED AMOUNT OF LIQUID UNDER DISCHARGE CONDITION 2
DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES
WHITE STREAK
TARGET DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES
BLACK STREAK
END PART OF NOZZLE ARRAY GROUP
NOZZLE POSITION IN FIRST DIRECTION F
CENTRAL PART OF NOZZLE ARRAY GROUP

FIG. 8



● POSITION OF NOZZLES BEFORE ADJUSTMENT
◇ POSITION OF NOZZLES AFTER ADJUSTMENT
→ DIRECTION OF ADJUSTMENT OF POSITIONS OF NOZZLES
SECOND DIRECTION S
θ
FIRST DIRECTION F
CENTRAL PART OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP
13D
13C
13B
13A

FIG. 9

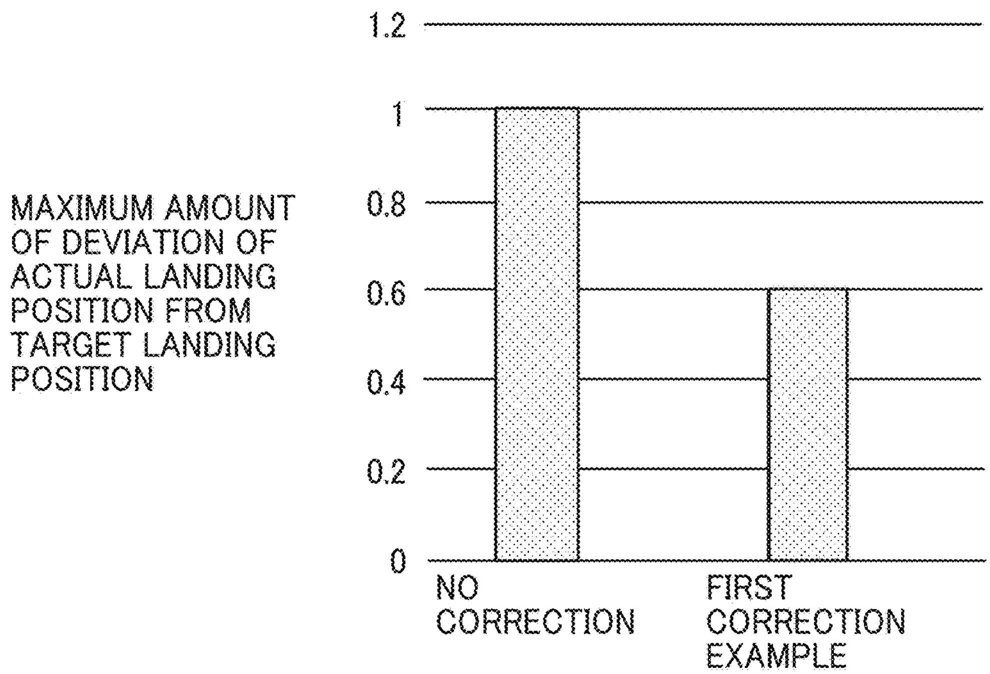

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL LANDING POSITION FROM TARGET LANDING POSITION
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
FIRST CORRECTION EXAMPLE

FIG. 10

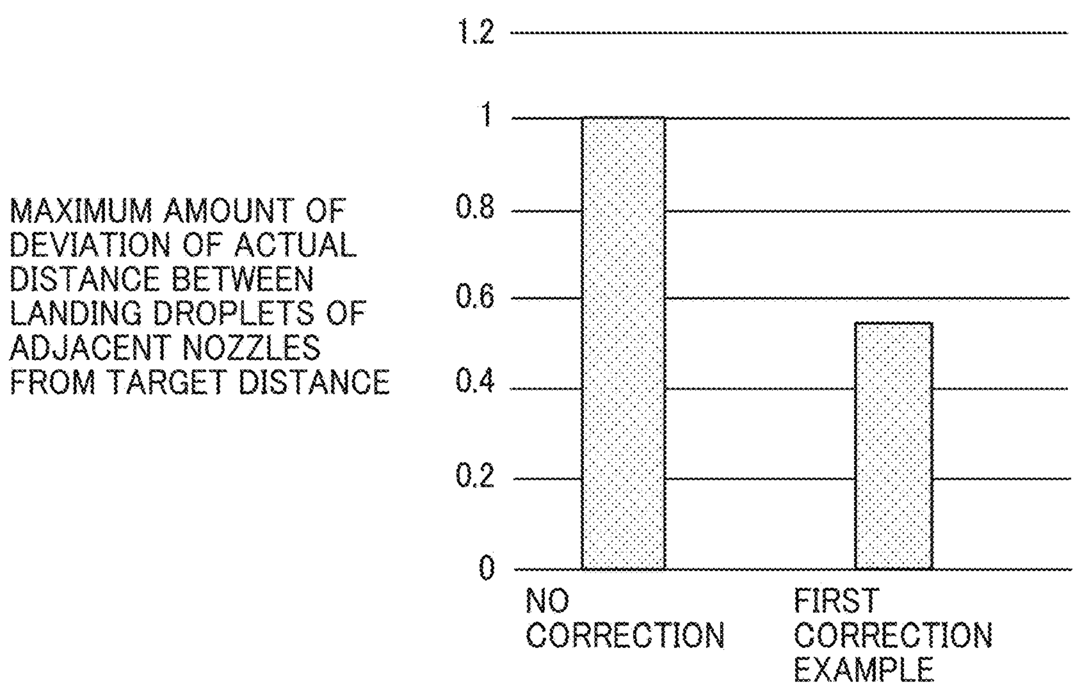

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES FROM TARGET DISTANCE
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
FIRST CORRECTION EXAMPLE

FIG. 11

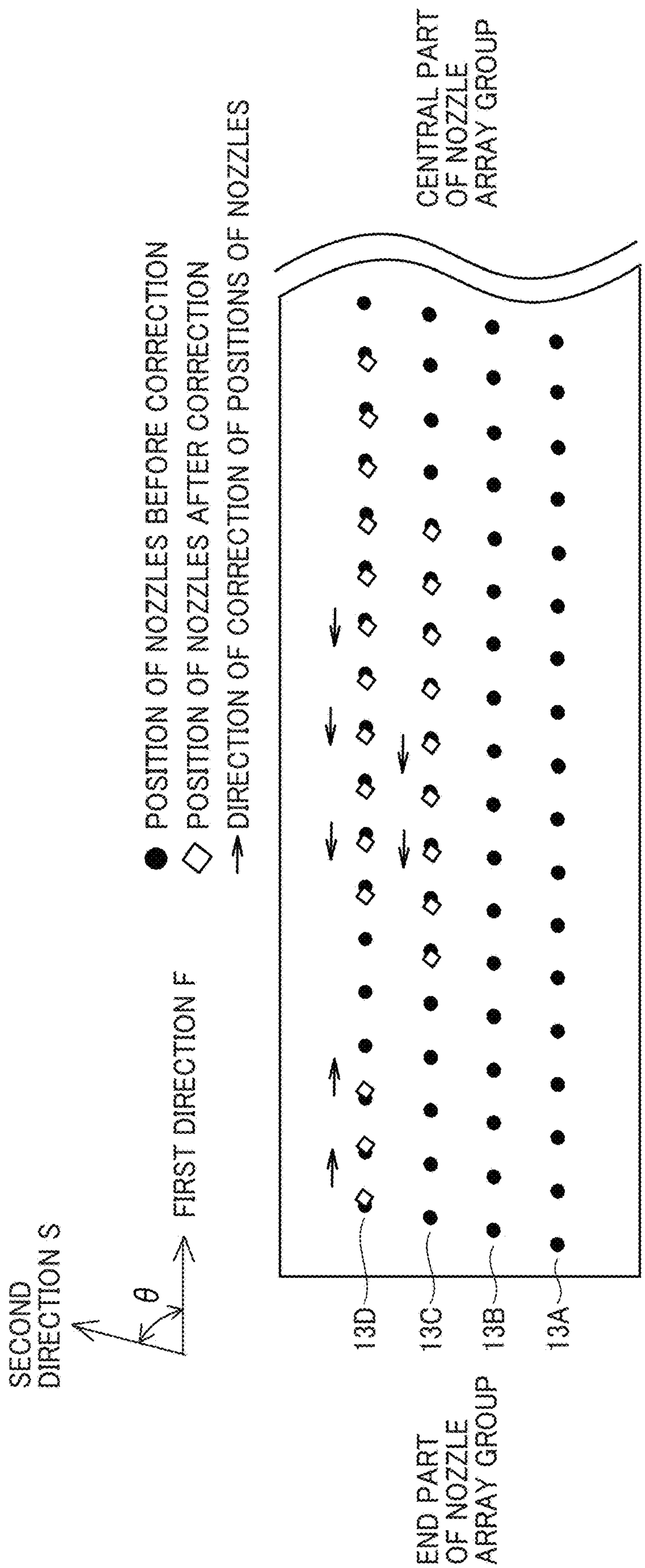

● POSITION OF NOZZLES BEFORE CORRECTION
◇ POSITION OF NOZZLES AFTER CORRECTION
→ DIRECTION OF CORRECTION OF POSITIONS OF NOZZLES
SECOND DIRECTION S
θ
FIRST DIRECTION F
CENTRAL PART OF NOZZLE ARRAY GROUP
END PART OF NOZZLE ARRAY GROUP
13D
13C
13B
13A

FIG. 12

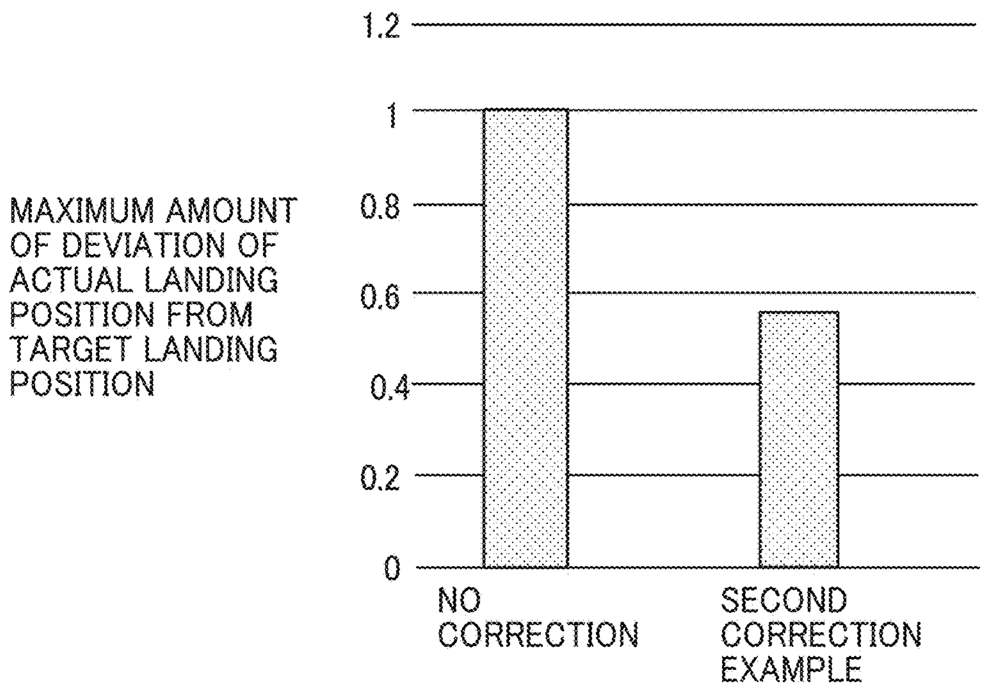

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL LANDING POSITION FROM TARGET LANDING POSITION
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
SECOND CORRECTION EXAMPLE

FIG. 13

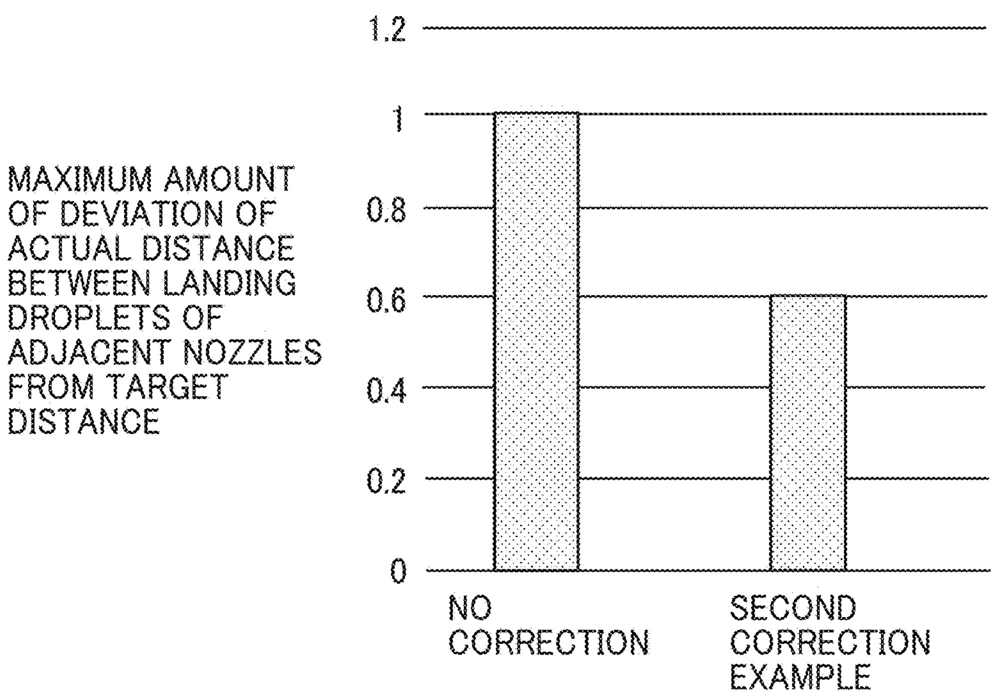

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES FROM TARGET DISTANCE
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
SECOND CORRECTION EXAMPLE

FIG. 14

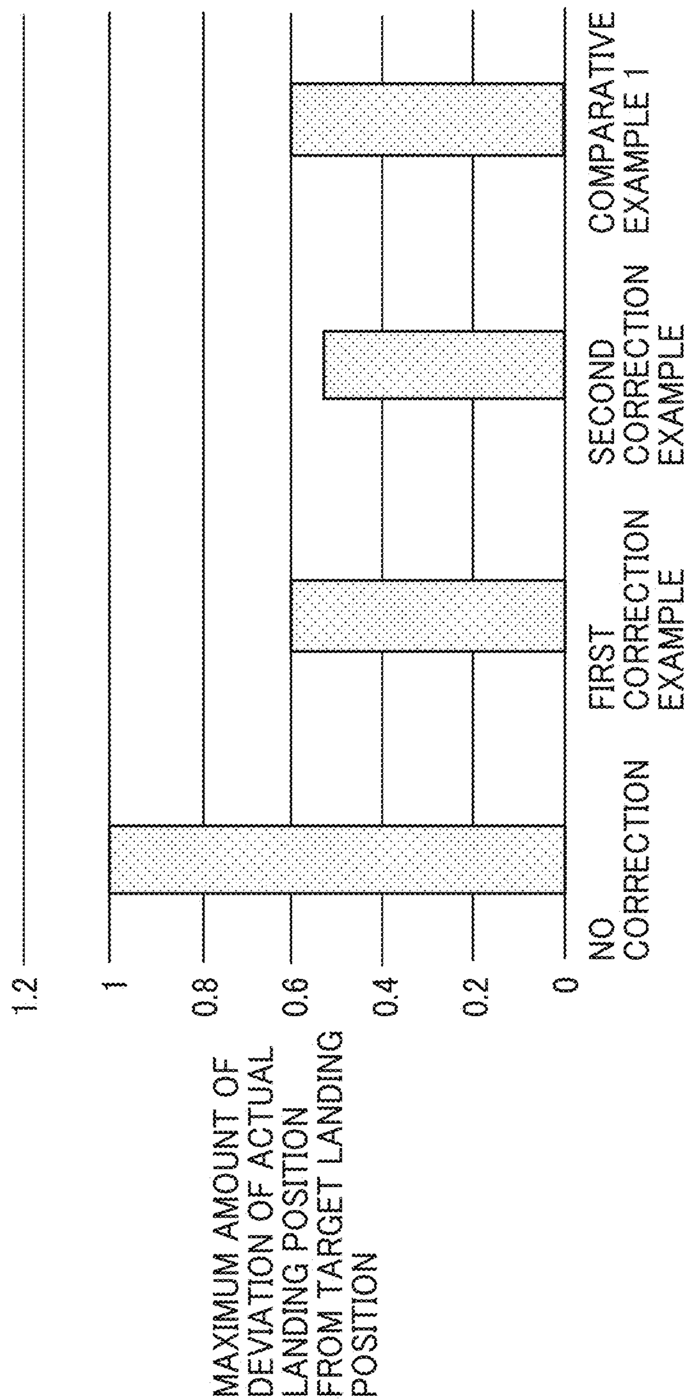

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL LANDING POSITION FROM TARGET LANDING POSITION
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
FIRST CORRECTION EXAMPLE
SECOND CORRECTION EXAMPLE
COMPARATIVE EXAMPLE 1

FIG. 15

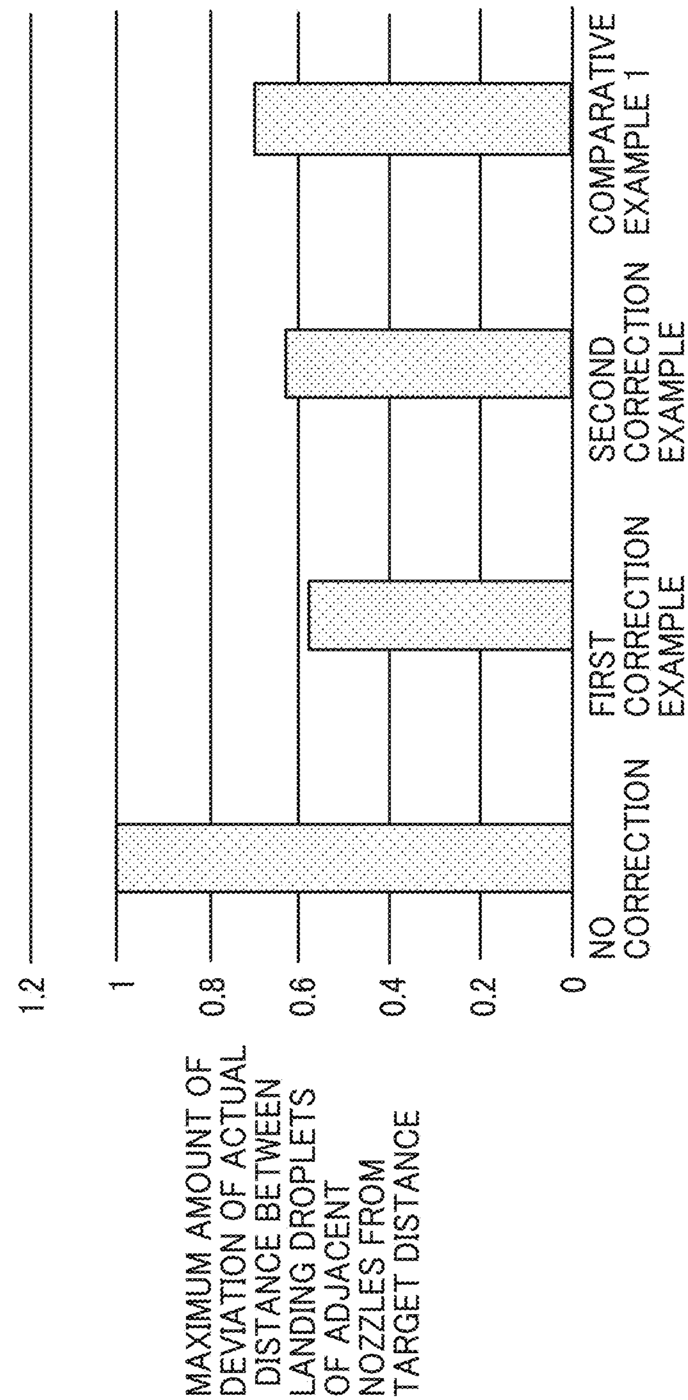

MAXIMUM AMOUNT OF DEVIATION OF ACTUAL DISTANCE BETWEEN LANDING DROPLETS OF ADJACENT NOZZLES FROM TARGET DISTANCE
1.2
1
0.8
0.6
0.4
0.2
0
NO CORRECTION
FIRST CORRECTION EXAMPLE
SECOND CORRECTION EXAMPLE
COMPARATIVE EXAMPLE 1

FIG. 16

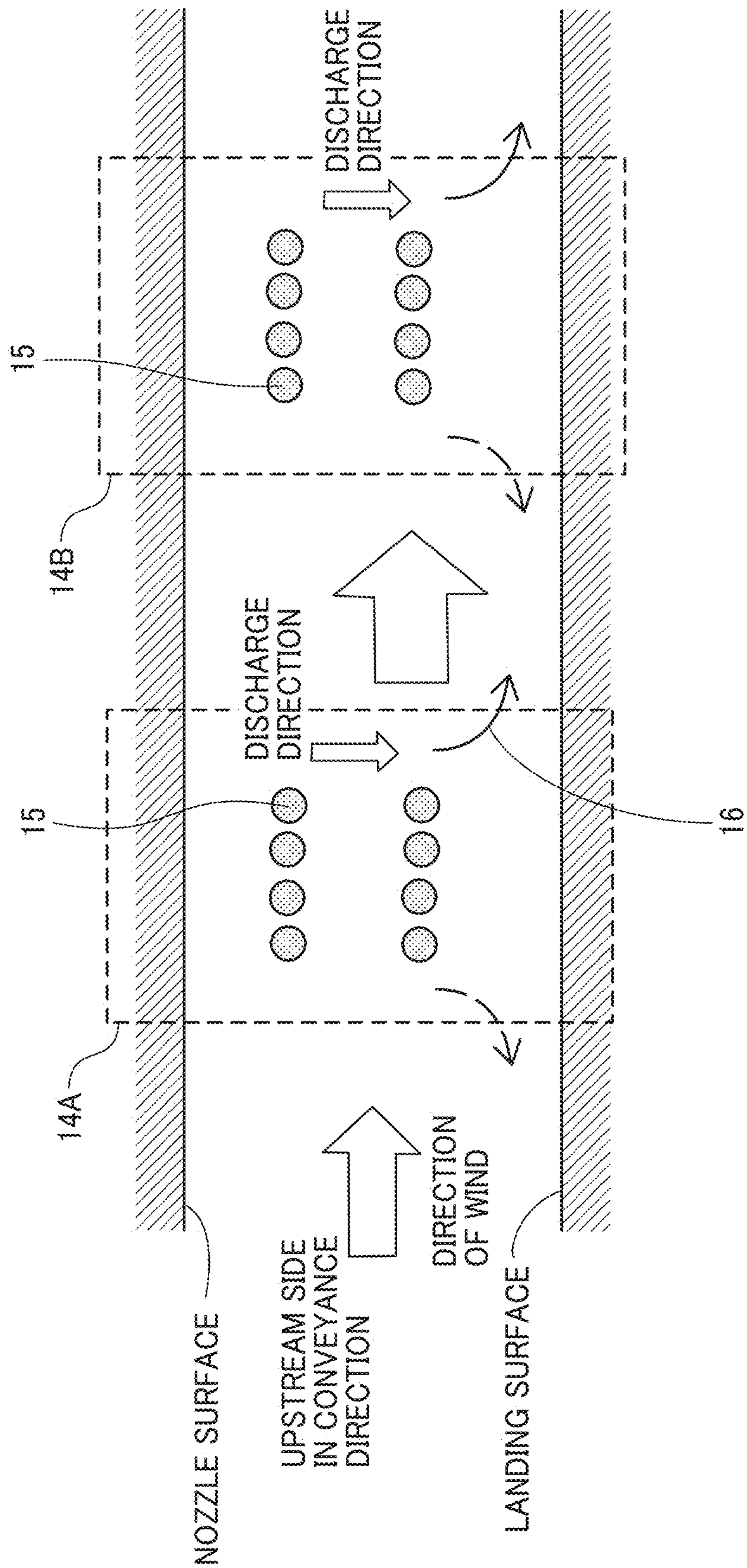

DISCHARGE DIRECTION
DISCHARGE DIRECTION
15
15
14B
14A
16
NOZZLE SURFACE
UPSTREAM SIDE IN CONVEYANCE DIRECTION
DIRECTION OF WIND
LANDING SURFACE

FIG. 17

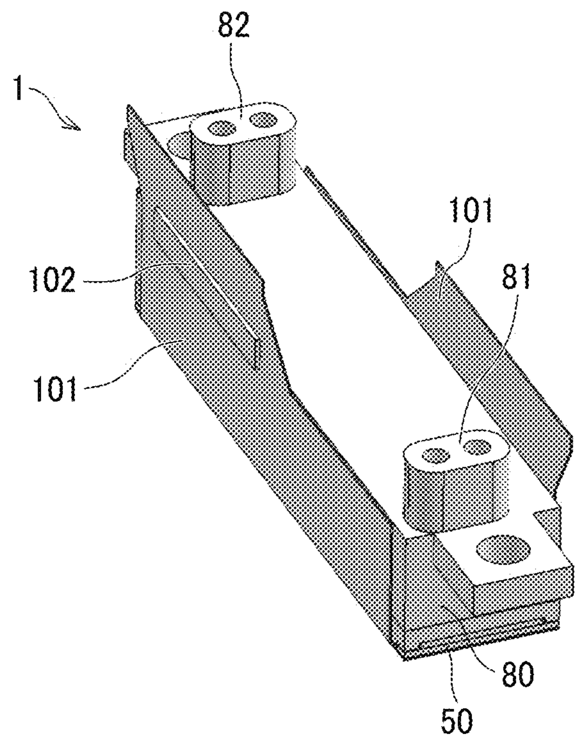


FIG. 18

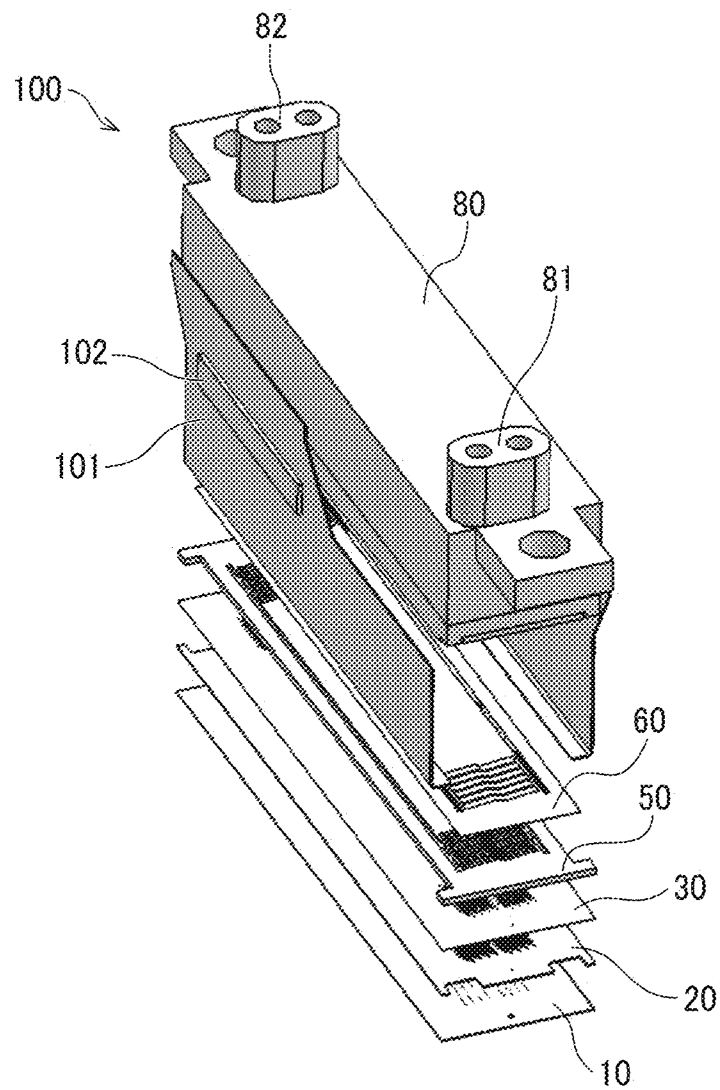


FIG. 19

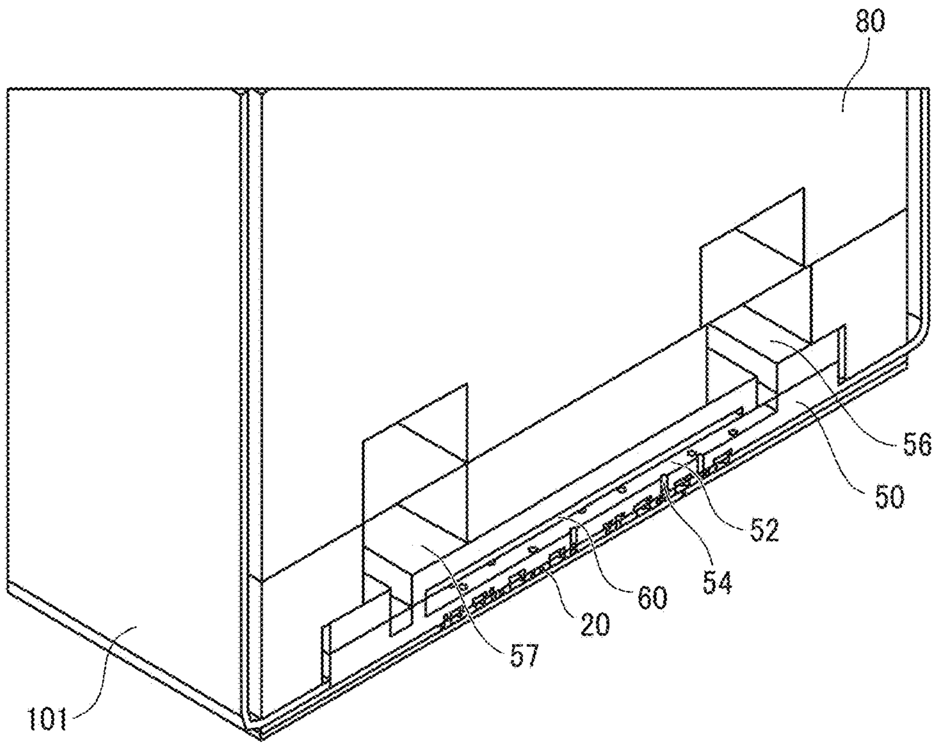


FIG. 20

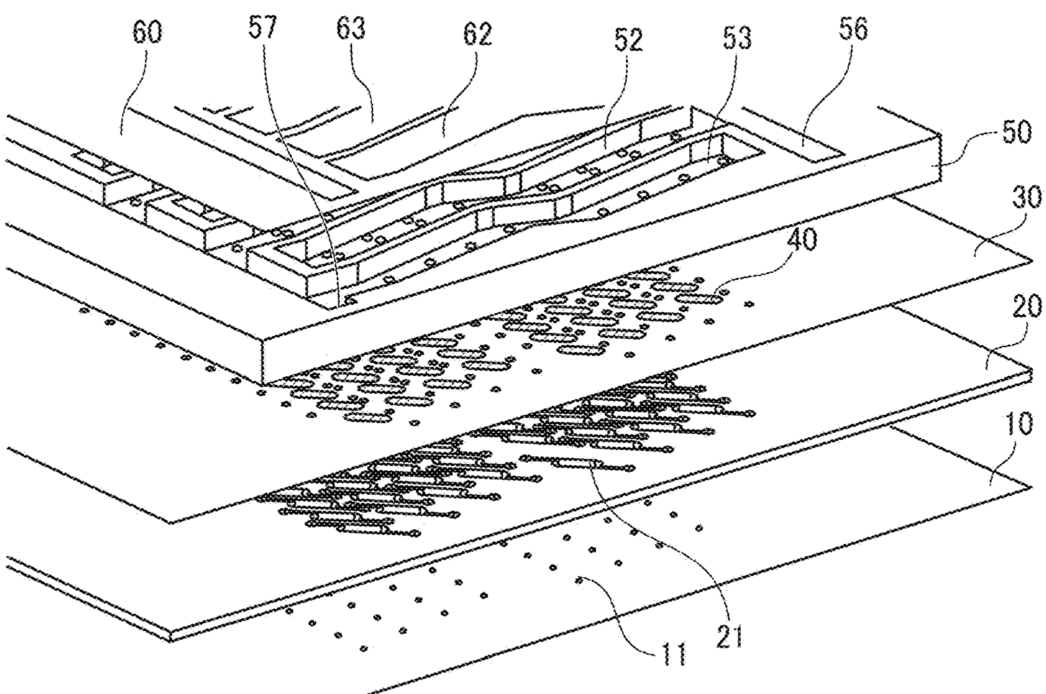
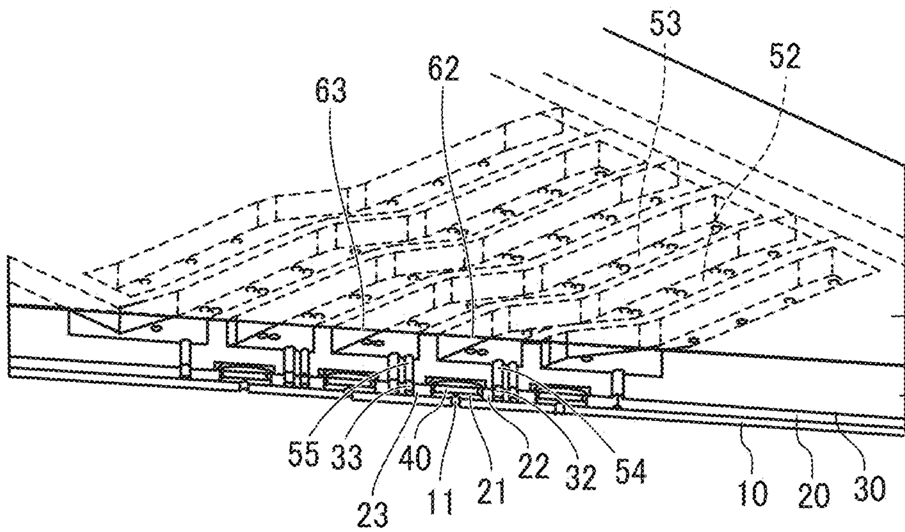
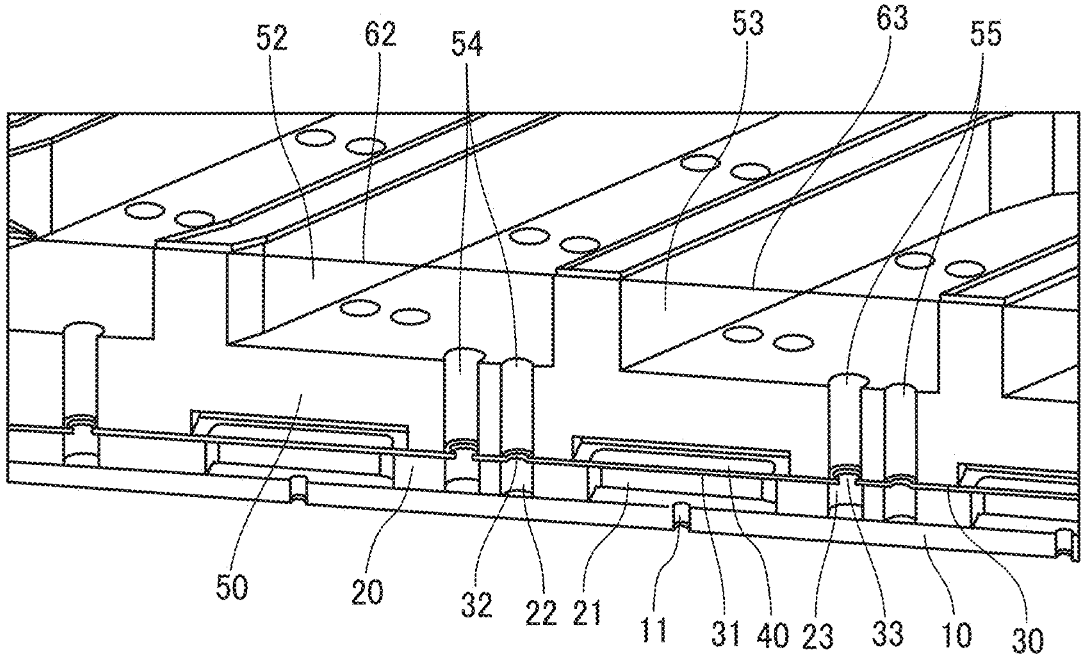


FIG. 21



53
52
63
62
60
50
55
33
40
23
11
21
22
32
54
10
20
30

FIG. 22



52
62
54
53
63
55
50
20
32
22
21
11
31
40
23
33
10
30

FIG. 23

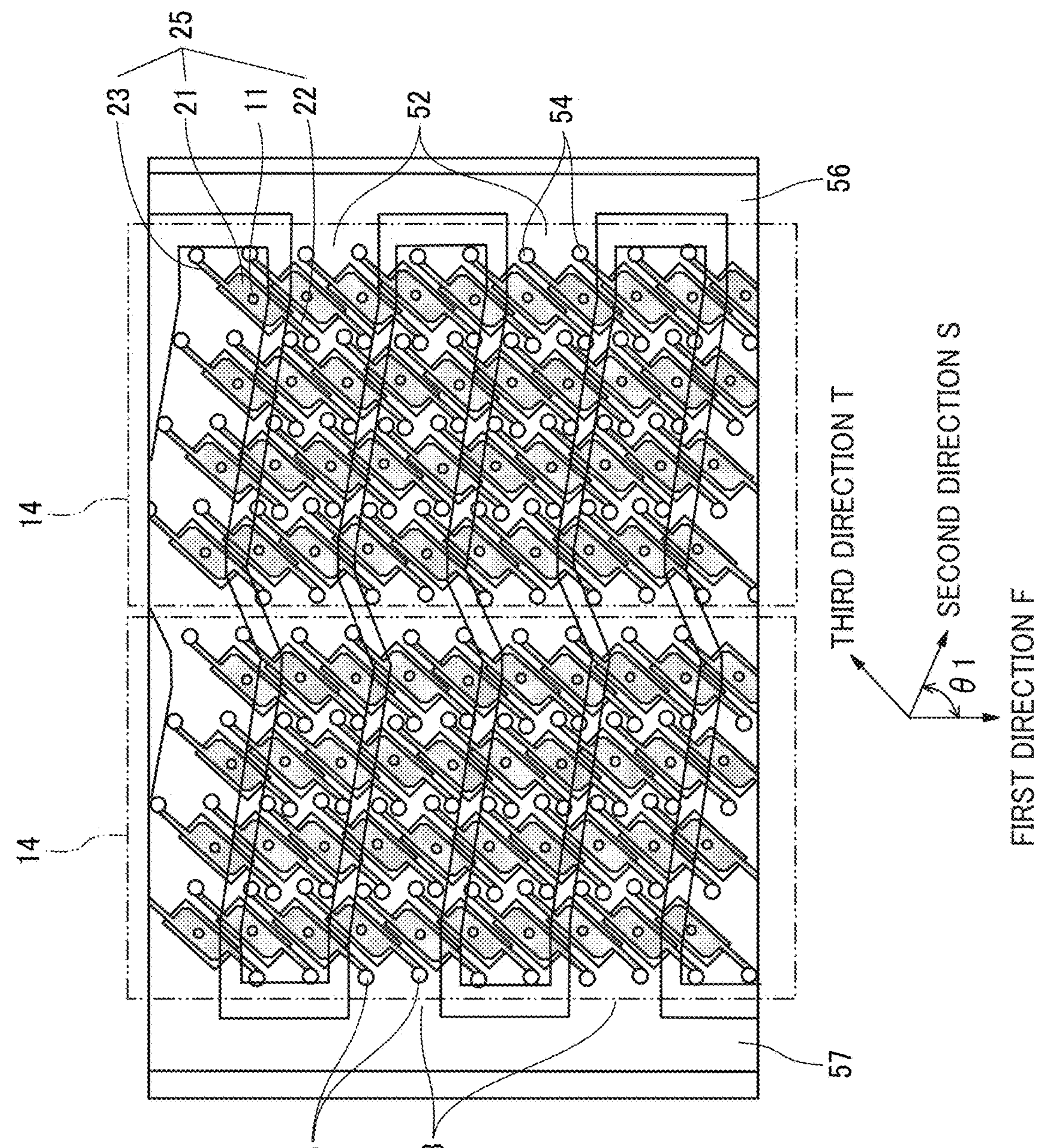

25
23
21
11
22
52
54
56
14
14
57
55
53
THIRD DIRECTION T
SECOND DIRECTION S
θ1
FIRST DIRECTION F

FIG. 24

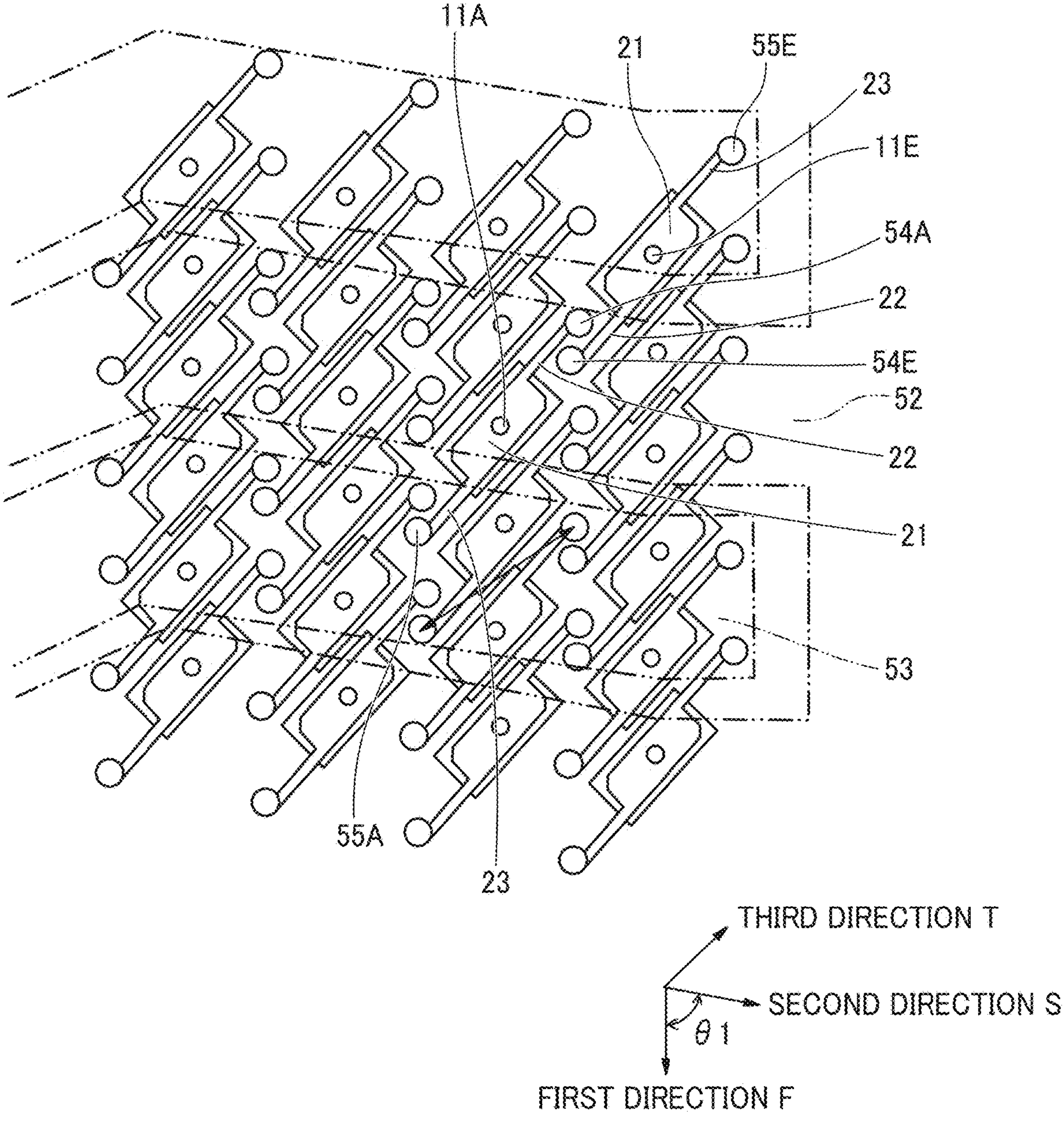

11A
21
55E
23
11E
54A
22
54E
52
22
21
53
55A
23
THIRD DIRECTION T
SECOND DIRECTION S
θ 1
FIRST DIRECTION F

FIG. 25

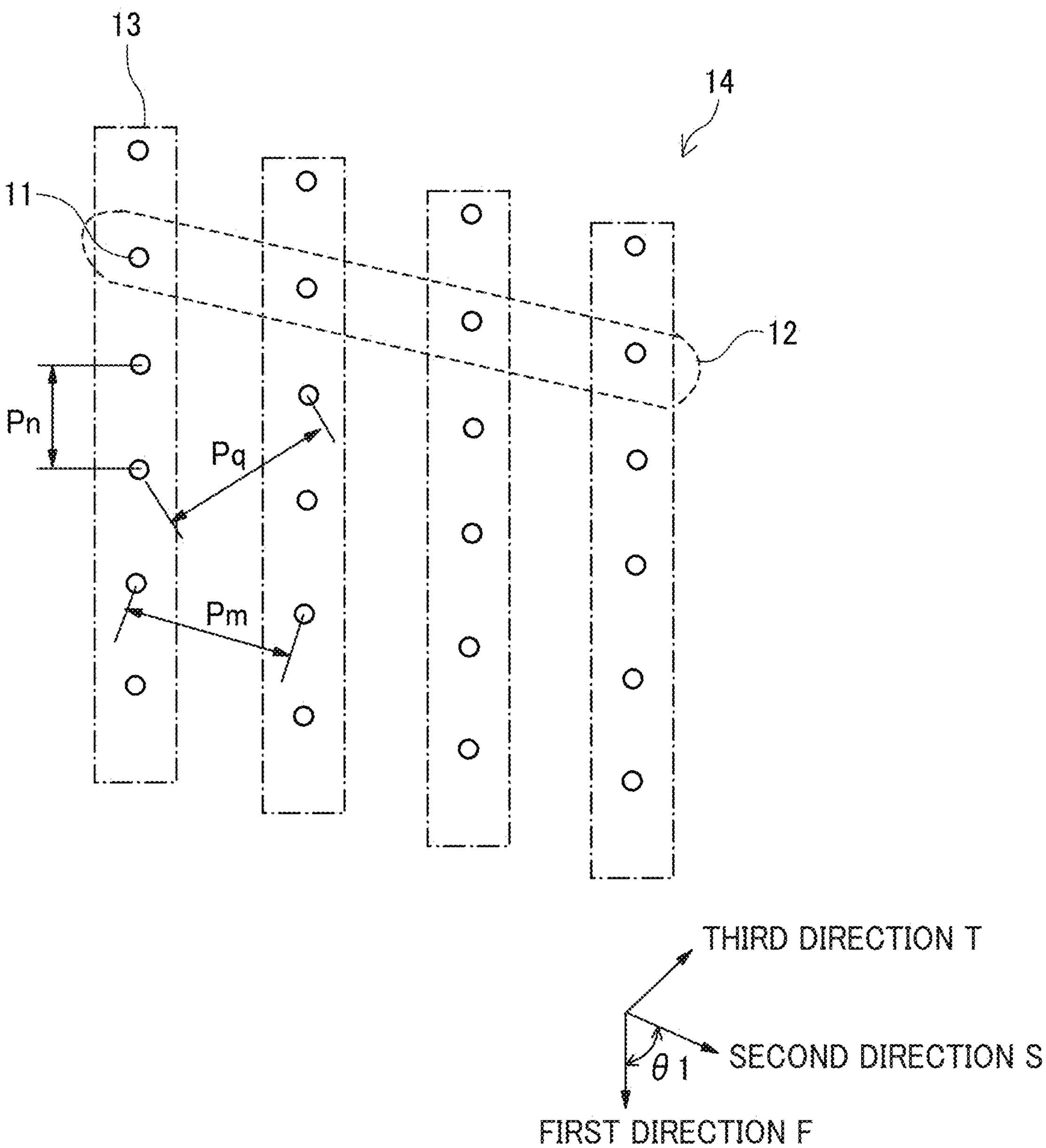

13
14
11
12
Pn
Pq
Pm
THIRD DIRECTION T
SECOND DIRECTION S
θ 1
FIRST DIRECTION F

FIG. 26

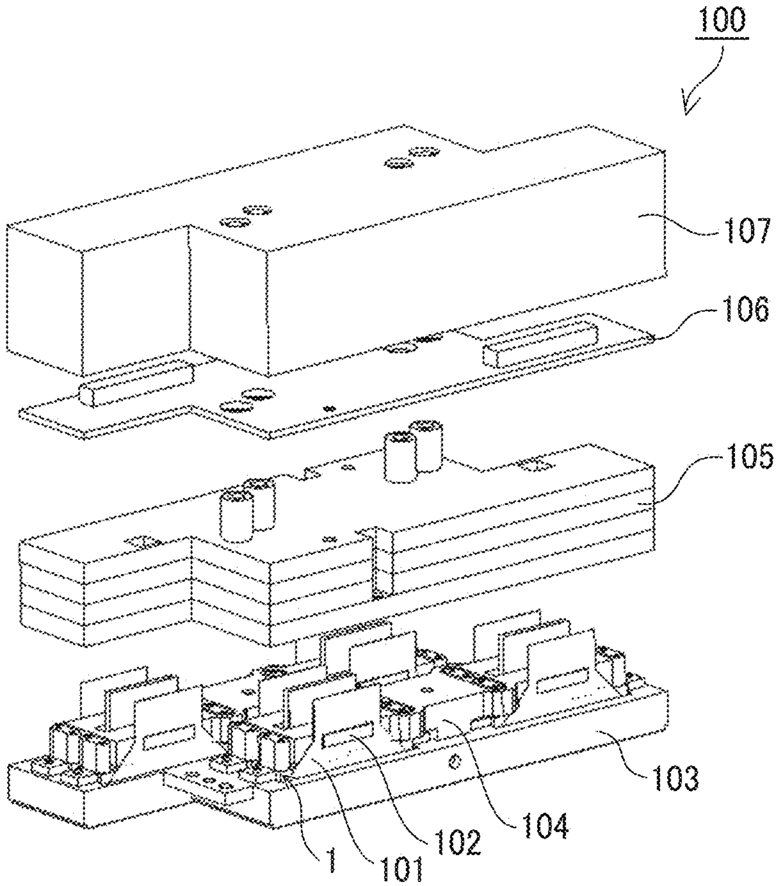


FIG. 27

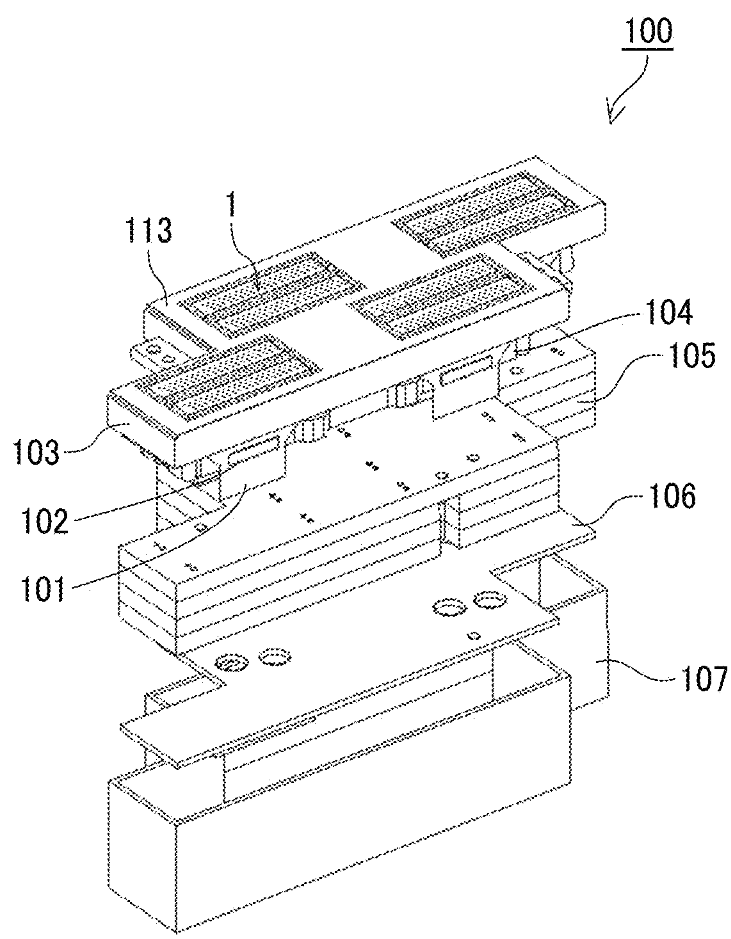


FIG. 28

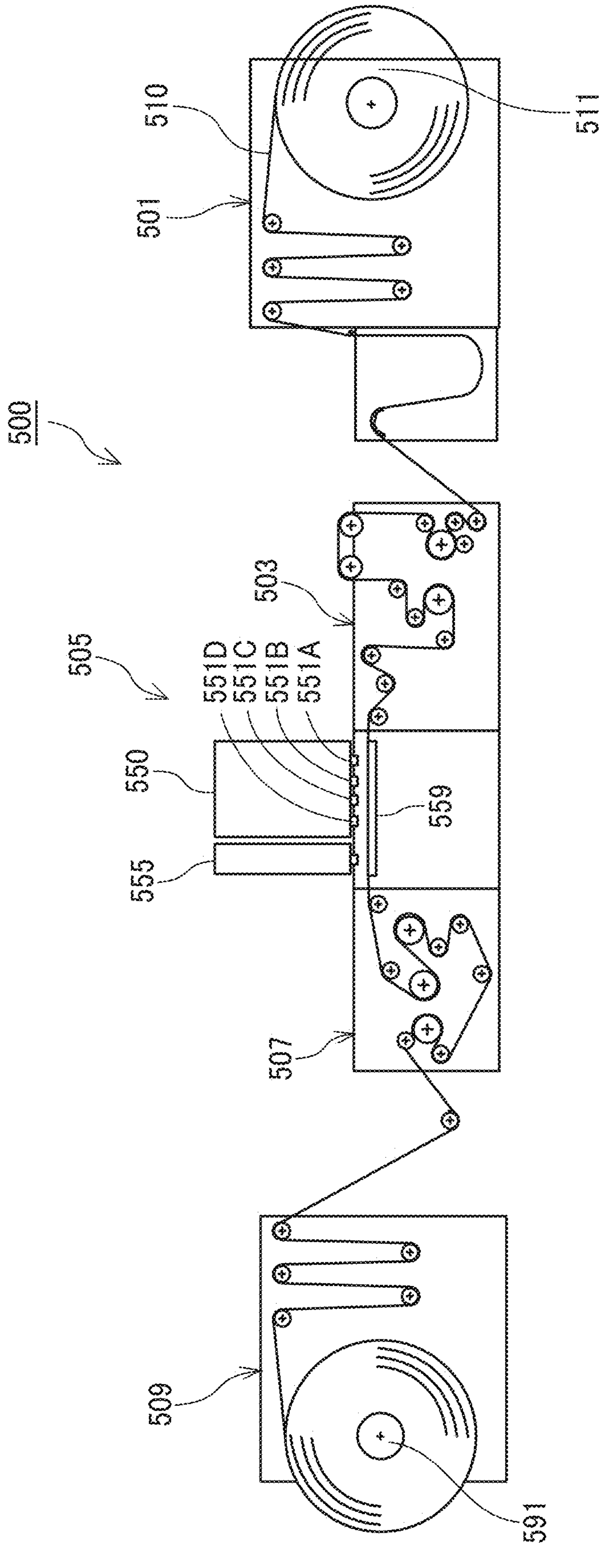

500
501
510
511
503
505
550
551A
551B
551C
551D
555
559
507
509
591

FIG. 29

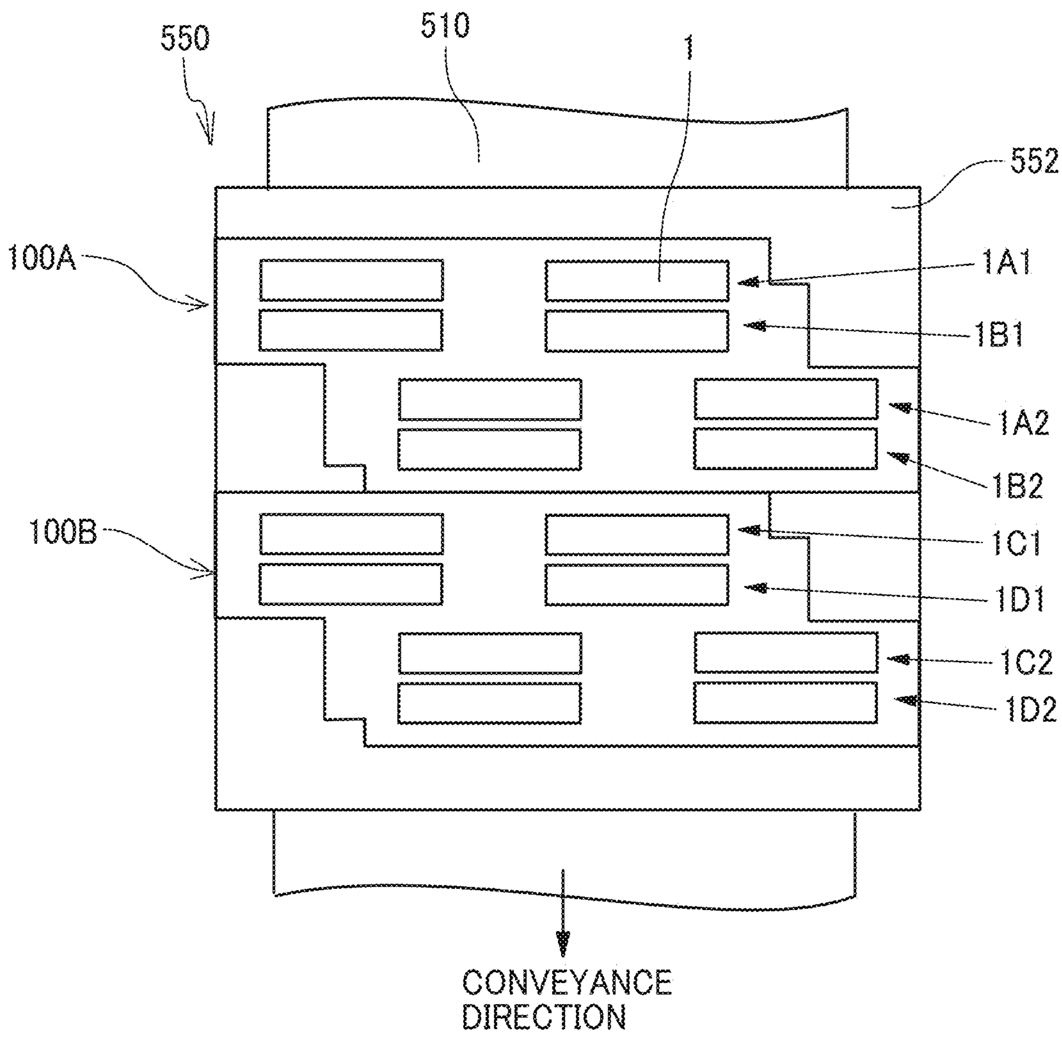

550
510
1
552
100A
1A1
1B1
1A2
1B2
100B
1C1
1D1
1C2
1D2
CONVEYANCE
DIRECTION

FIG. 30

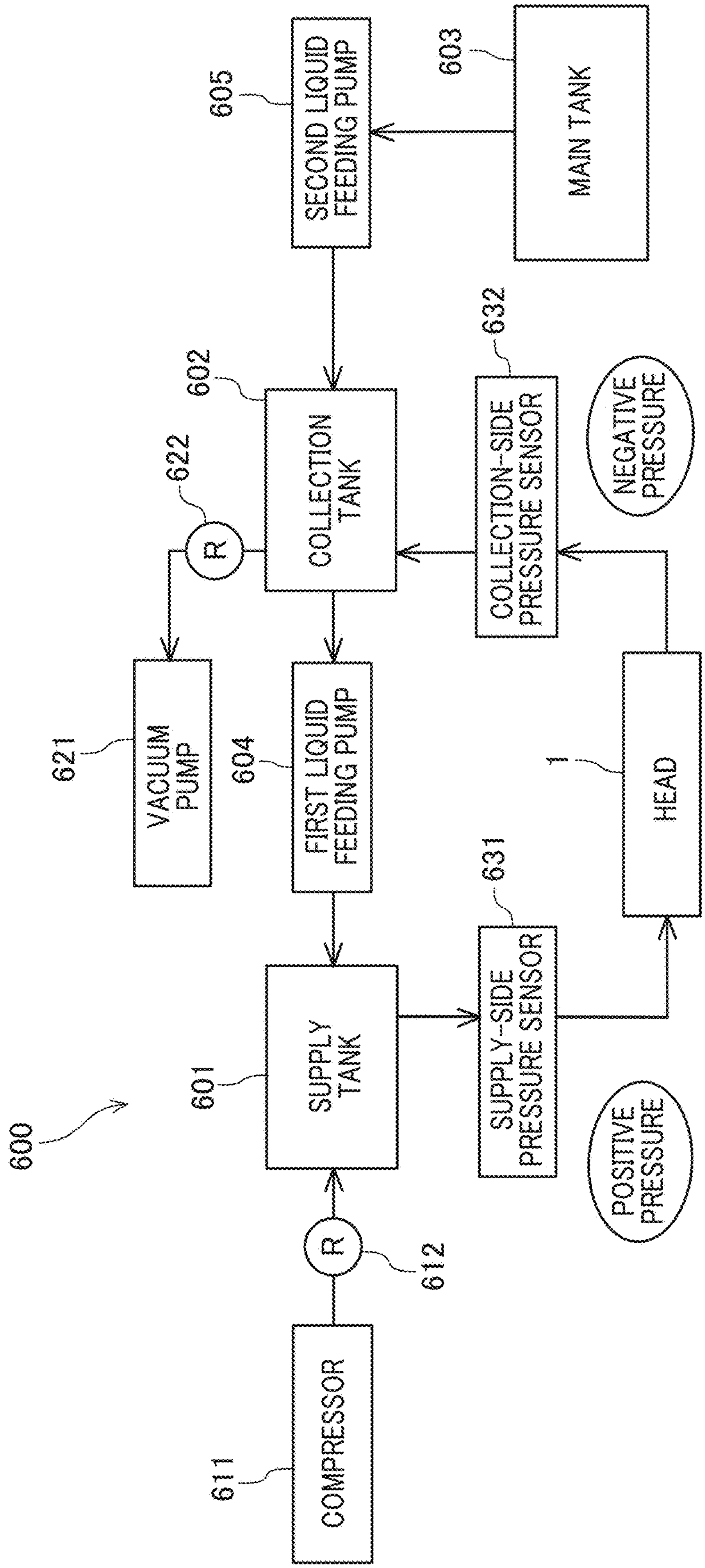
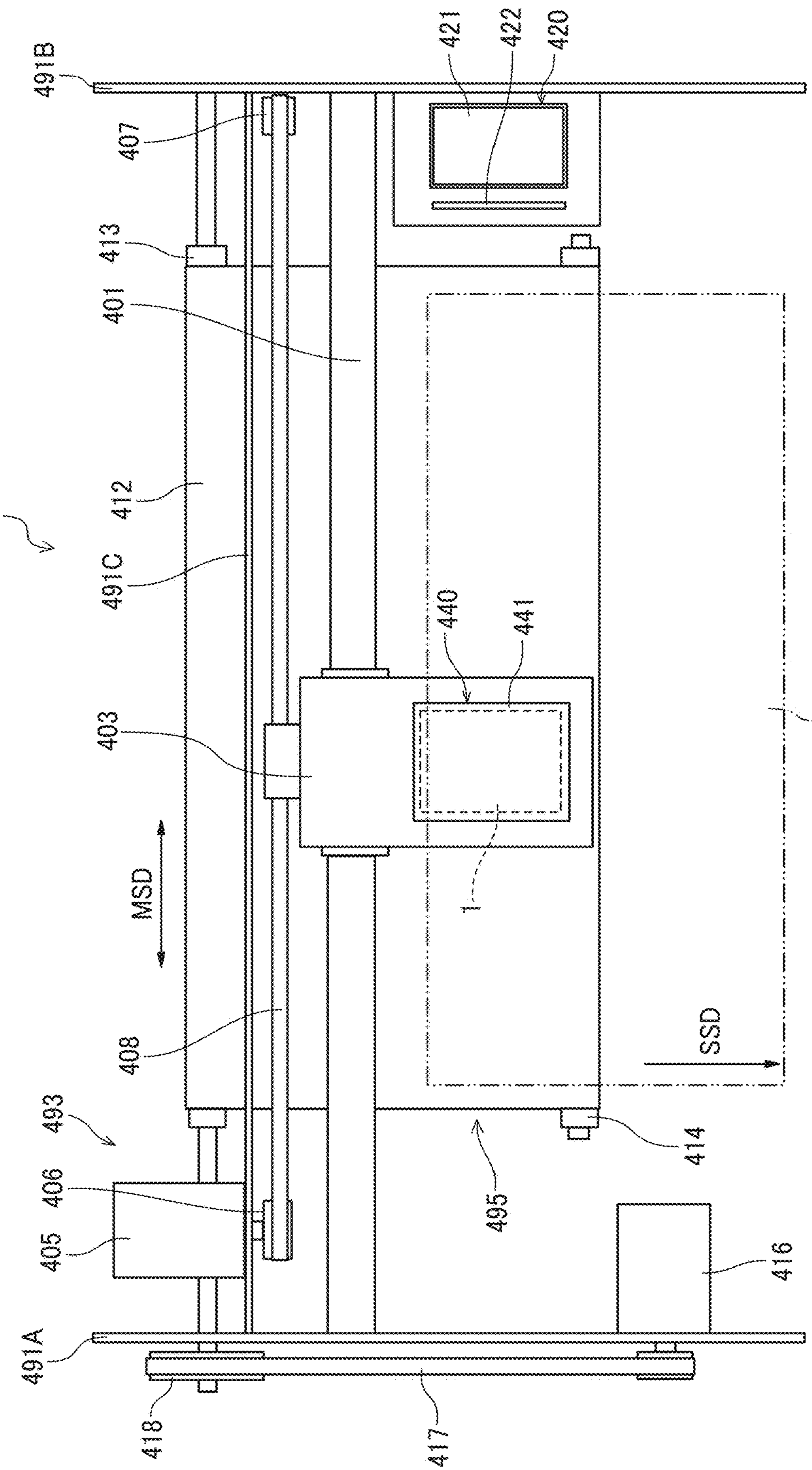

600
COMPRESSOR
611
R
612
SUPPLY TANK
601
SUPPLY-SIDE PRESSURE SENSOR
631
POSITIVE PRESSURE
VACUUM PUMP
621
FIRST LIQUID FEEDING PUMP
604
HEAD
1
R
622
COLLECTION TANK
602
COLLECTION-SIDE PRESSURE SENSOR
632
NEGATIVE PRESSURE
SECOND LIQUID FEEDING PUMP
605
MAIN TANK
603

FIG. 31



500
491B
421
422
420
407
413
401
412
491C
440
441
403
MSD
1
410
408
SSD
493
406
405
414
495
416
491A
418
417

FIG. 32

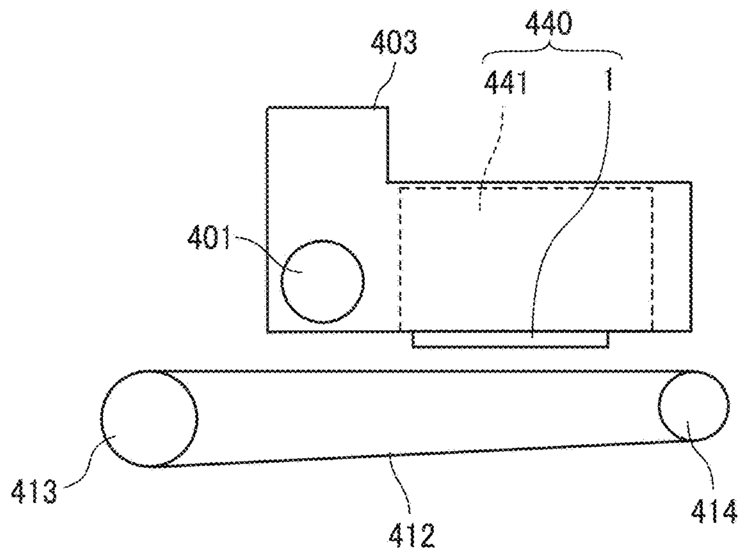

440
403
441
1
401
413
412
414

FIG. 33

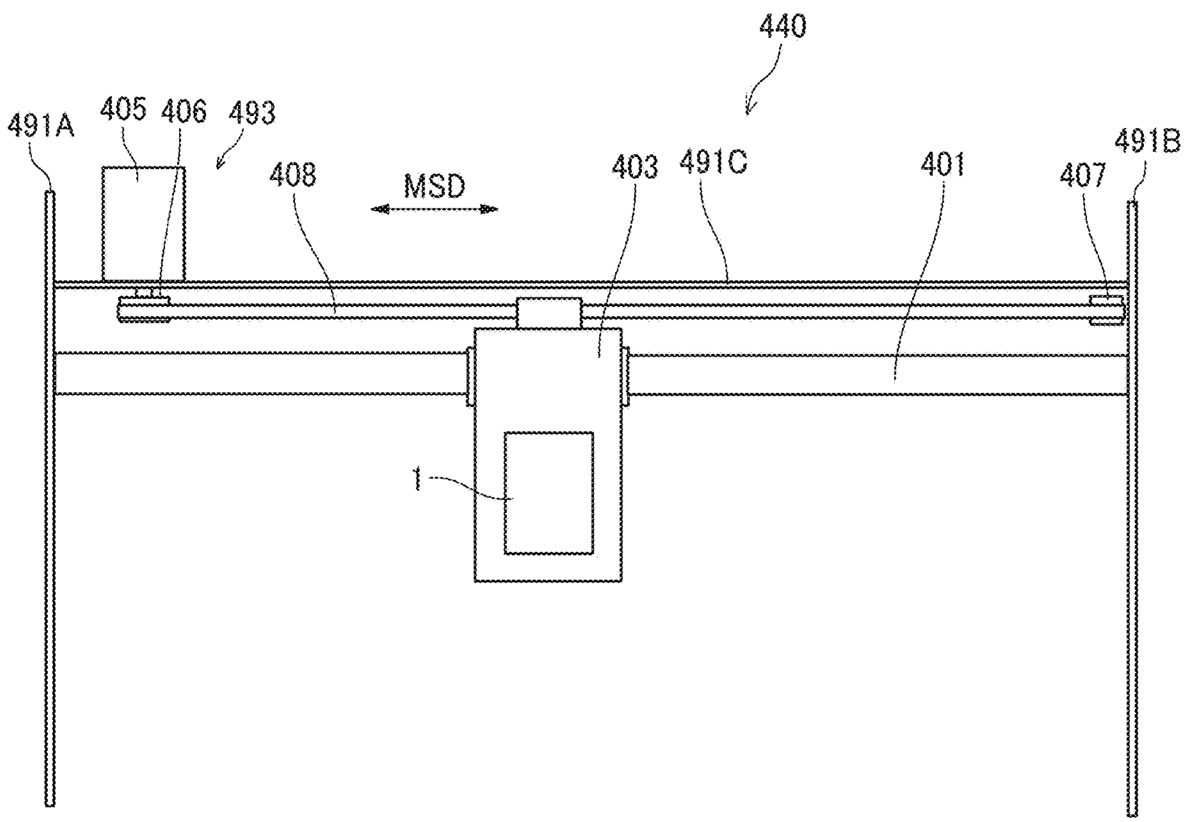
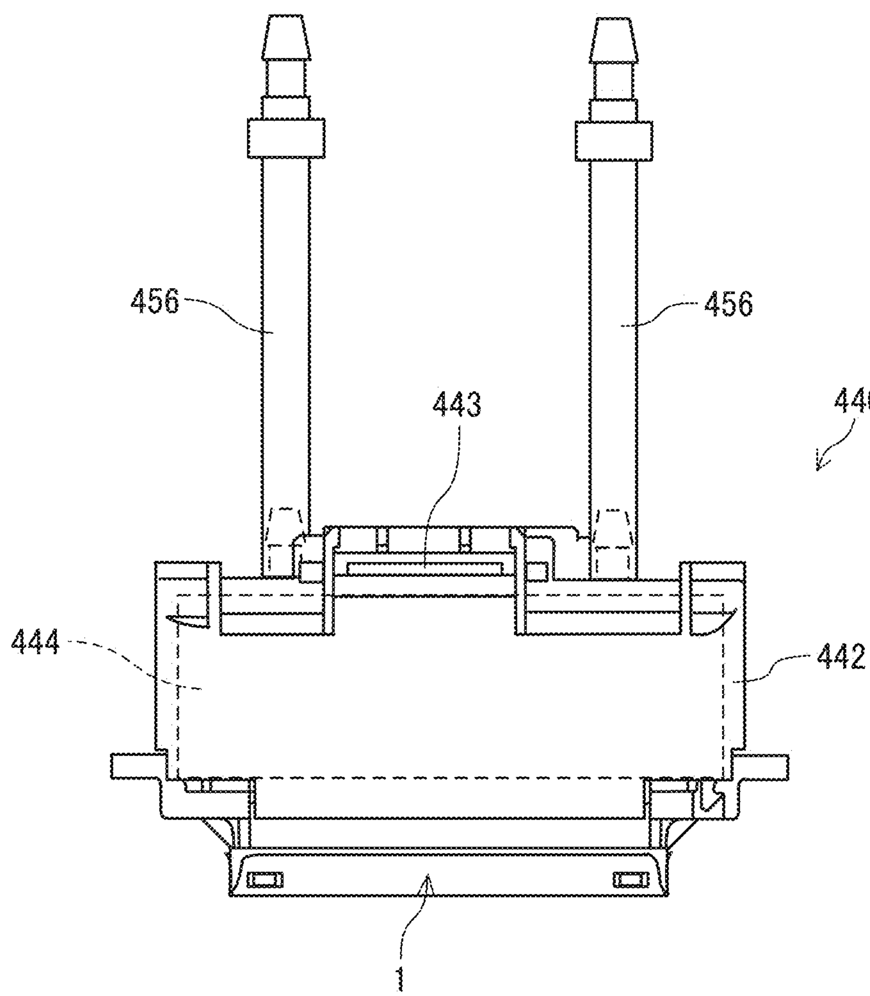

440
491A
405
406
493
408
MSD
403
491C
401
407
491B
1

FIG. 34



LIQUID DISCHARGE HEAD, HEAD MODULE, HEAD DEVICE, LIQUID DISCHARGE DEVICE, AND LIQUID DISCHARGE APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is based on and claims priority pursuant to 35 U.S.C. § 119(a) to Japanese Patent Application No. 2018-214373, filed on Nov. 15, 2018, and Japanese Patent Application No. 2019-181204, filed on Oct. 1, 2019, in the Japan Patent Office, the entire disclosure of each of which is hereby incorporated by reference herein.

BACKGROUND

Technical Field

[0002] An aspect of the present disclosure relates to a liquid discharge head, a head module, a head device, a liquid discharge device, and a liquid discharge apparatus.

Related Art

[0003] A liquid discharge head includes a plurality of nozzles from which a liquid is discharged. The plurality of nozzles is arrayed in a nozzle array direction. When the liquid discharge head discharges liquid droplets with high-density (with high-frequency) from a large number of nozzles as in a solid image, a landing position of a discharged droplet may be deviated from a target landing position due to an interference between a self-airflow generated by the discharged liquid droplet, or an interference between the self-airflow and an airflow accompanied with a conveyance of a medium on which the liquid is applied. Hereinafter, "the medium on which the liquid is applied" is simply referred to as "the medium". The deviation of the landing position of the liquid droplet from the target landing position may cause an abnormal image such as wind ripples or edge distortion.

[0004] Thus, the liquid discharge head includes nozzles arranged so that an interval between adjacent nozzles at an end portion of the liquid discharge head is made wider than an interval between adjacent nozzles at a central portion of the liquid discharge head in the nozzle array direction.

SUMMARY

[0005] In an aspect of this disclosure, a liquid discharge head includes a plurality of nozzle arrays arranged in a first direction. The plurality of nozzle arrays each includes nozzles from which a liquid is discharged, the nozzles arranged in a second direction intersecting the first direction, and one of two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction include at least two nozzles arranged at different nozzle intervals from corresponding nozzles of another of the two nozzle arrays in the first direction.

[0006] In another aspect of this disclosure, a liquid discharge apparatus includes a liquid discharge head configured to discharge a liquid, and a conveyor configured to convey a medium, onto which the liquid discharged from the liquid discharge head is applied, in a conveyance direction. The liquid discharge head includes a plurality of nozzle arrays arranged in a first direction perpendicular to the conveyance direction, the plurality of nozzle arrays each includes nozzles from which the liquid is discharged, the nozzles arranged in a second direction intersecting the first direction, and one of two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction includes at least two nozzles arranged at different nozzle intervals from corresponding nozzles of another of the two nozzle arrays in the first direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The aforementioned and other aspects, features, and advantages of the present disclosure will be better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0008] FIG. **1** is a schematic plan view of a nozzle arrangement of a liquid discharge head according to a first embodiment;

[0009] FIG. **2** is a plan view of a portion of the nozzle arrangement of the liquid discharge head illustrated;

[0010] FIG. **3** is a graph illustrating a first example of a deviation of the landing position of the discharged droplets (amount and direction of swerve) in the first direction F when the liquid discharge head includes the nozzle array arranged at a constant nozzle interval Pn;

[0011] FIG. **4** is a schematic plan view of a portion of the nozzle arrangement of the liquid discharge head illustrating the deviation of the landing position of the discharged droplets (amount and direction of swerve) in the first direction F;

[0012] FIG. **5** is a graph illustrating a second example of a deviation of the landing position of the discharged droplets (amount and direction of swerve) in the first direction F when the liquid discharge head includes the nozzle array arranged at a constant nozzle interval Pn;

[0013] FIG. **6** is a schematic plan view of the portion of the nozzle arrangement of the liquid discharge head in the second example illustrating the deviation of the landing position of the discharged droplets (amount and direction of swerve) in the first direction F;

[0014] FIG. **7** is a graph illustrating a distance between adjacent landing droplets in the first example and the second example;

[0015] FIG. **8** is a plan view of the portion of the nozzle arrangement of the liquid discharge head illustrating a first correction;

[0016] FIG. **9** is a graph illustrating a maximum amount of deviation of the actual landing position from the target landing position in the first direction F in the first correction;

[0017] FIG. **10** is a graph illustrating a maximum amount of deviation of an actual distance between the landing droplets of adjacent nozzles from a target distance between the landing droplets of adjacent nozzles **11** in the first direction F in the first correction;

[0018] FIG. **11** is a plan view of the portion of the nozzle arrangement of the liquid discharge head illustrating a second correction;

[0019] FIG. **12** is a graph illustrating a maximum amount of deviation of the actual landing position from the target landing position in the first direction F in the second correction;

[0020] FIG. **13** is a graph illustrating a maximum amount of deviation of an actual distance between the landing droplets of adjacent nozzles from a target distance between the landing droplets of adjacent nozzles in the first direction F in the second correction;

[0021] FIG. **14** is a graph illustrating a maximum amount of deviation of the actual landing position from the target landing position in the first direction F in the first correction, second correction, and a comparative example 1;

[0022] FIG. **15** is a graph illustrating a maximum amount of deviation of the actual distance between the landing droplets of adjacent nozzles from the target distance between the landing droplets of adjacent nozzles in the first direction F in the first correction, second correction, and the comparative example 1;

[0023] FIG. **16** is an enlarged plan view of a nozzle arrangement of a liquid discharge head according to a second embodiment of the present disclosure;

[0024] FIG. **17** is an external perspective view of a liquid discharge head according to a third embodiment of the present disclosure;

[0025] FIG. **18** is an exploded perspective view of the liquid discharge head in the third embodiment,

[0026] FIG. **19** is an explanatory cross-sectional perspective view of the liquid discharge head in the third embodiment,

[0027] FIG. **20** is an exploded perspective view of the liquid discharge head without a frame in the third embodiment;

[0028] FIG. **21** is a cross-sectional perspective view of channels in the liquid discharge head in the third embodiment;

[0029] FIG. **22** is an enlarged cross-sectional perspective view of the channels in the third embodiment;

[0030] FIG. **23** is a plan view of the channels of the liquid discharge head in the third embodiment;

[0031] FIG. **24** is an enlarged plan view of a portion of the liquid discharge head in the third embodiment in FIG. **23**;

[0032] FIG. **25** is a plan view of a of the nozzle arrangement illustrated in **23**;

[0033] FIG. **26** is an exploded perspective view of a head module according to the present disclosure;

[0034] FIG. **27** is an exploded perspective view of the head module viewed from a nozzle surface side of the head module;

[0035] FIG. **28** is a schematic side view of a liquid discharge apparatus according to the present disclosure;

[0036] FIG. **29** is a plan view of a head unit of the liquid discharge apparatus of FIG. **28**;

[0037] FIG. **30** is a circuit diagram illustrating an example of a liquid circulation device according to the present disclosure;

[0038] FIG. **31** is a plan view of a portion of a printer as a liquid discharge apparatus according to the present disclosure;

[0039] FIG. **32** is a schematic side view of a main portion of the liquid discharge apparatus;

[0040] FIG. **33** is a plan view of a portion of another example of a liquid discharge device; and

[0041] FIG. **34** is a front view of the liquid discharge device according to still another embodiment of the present disclosure.

[0042] 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.

DETAILED DESCRIPTION

[0043] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this patent 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 the same function, operate in an analogous manner, and achieve similar results.

[0044] Although the embodiments are described with technical limitations with reference to the attached drawings, such description is not intended to limit the scope of the disclosure and all the components or elements described in the embodiments of this disclosure are not necessarily indispensable. 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.

[0045] Embodiments of the present disclosure are described below with reference to the attached drawings. FIG. **1** illustrates a first embodiment of the present disclosure. FIG. **1** is a schematic plan view of a nozzle arrangement of a liquid discharge head according to the first embodiment.

[0046] The liquid discharge head **1** has a plurality of nozzle arrays **12** in which a plurality of nozzles **11** (**11***a* to **11***d*) are arrayed in a second direction S. The plurality of nozzle arrays **12** are arranged side by side in a first direction F that intersects the second direction S. Hereinafter, the “liquid discharge head” is simply referred to as the “head”.

[0047] Here, the second direction S is a direction that obliquely intersects the first direction F at an angle θ. A group of nozzles **11** arranged in the first direction F is referred to as a stage **13**, and a group of stages **13**A to **13**D is referred to as a nozzle array group **14**. The stage **13**A is a group of nozzles **11***a* of each nozzle array **12**. Similarly, the stage **13**B is a group of nozzles **11***b* of each nozzle array **12**, the stage **13**C is a group of nozzles **11***c* of each nozzle array **12**, and the stage **13**D is a group of nozzles **11***d* of each nozzle array **12**.

[0048] Two nozzle arrays **12**A and **12**B are adjacent with each other in the first direction F. A “nozzle interval Pn” is an interval between the nozzle **11** of one of the nozzle array **12**A and the nozzle **11** of another nozzle array **12**B arranged adjacent in the first direction F in the head **1**.

[0049] Further, the nozzle interval Pn includes a nozzle interval Pn**1** that is wider than a preset nozzle interval Pn**0** and a nozzle interval Pn**2** that is narrower than the nozzle interval Pn**0** (Pn**1**>Pn**0**>Pn**2**).

[0050] At least one nozzle array **12** among the plurality of nozzle arrays **12** includes at least two nozzles **11** arranged at different nozzle intervals Pn.

[0051] Thus, as illustrated in FIG. **1**, the head **1** includes a plurality of nozzle arrays **12** arranged in a first direction F. The plurality of nozzle arrays **12** each includes nozzles **11** from which a liquid is discharged, the nozzles **11** arranged in a second direction S intersecting the first direction F. One of two nozzle arrays **12** of the plurality of nozzle arrays **12** adjacent to each other in the first direction F include at least two nozzles **11***a* to **11***d* arranged at different nozzle intervals (Pn**0**, Pn**1**, and Pn**2**) from corresponding nozzles **11** of another of the two nozzle arrays **12** in the first direction F.

[0052] Further, two nozzle arrays **12** of the plurality of nozzle arrays **12** arranged at an end part of the head **1** in the first direction F. The two nozzle arrays **12** includes first nozzles **11***d* arranged at a first nozzle interval (Pn**1**) wider than a nozzle interval (Pn**0**) of the nozzles **11***b* arranged at a central part of the head **1** in the first direction F and second nozzles **11***a* arranged at a second nozzle interval (Pn**2**) narrower than the nozzle interval (Pn**0**) of the nozzles **11***b* arranged at the central part of the head **1** in the first direction F.

[0053] Further, two nozzle arrays **12** of the plurality of nozzle arrays **12** adjacent to each other in the first direction F include the nozzles **11***c* and **11***d* arranged at a constant nozzle interval (Pn**1**) in the first direction F.

[0054] FIG. **1** illustrates a nozzle position of the nozzle **11** by a solid line when the discharged droplet lands on a target landing position without causing a swerve of the discharged droplet. Further, FIG. **1** illustrates a nozzle position of the nozzle **11** by a broken line when the nozzle position of the nozzle **11** is corrected so that an actual landing position of the discharged droplet approaches the target landing position when the swerve of the discharged droplet is occurred.

[0055] In FIG. **1**, the liquid discharged from the nozzle **11***a* of the nozzle array **12**B is assumed to swerve in a direction away from the nozzle array **12**A with respect to the target landing position. In FIG. **1**, the liquid discharged from the nozzle **11***b* of the nozzle array **12**B is assumed not to swerve from the target landing position. In FIG. **1**, the liquid discharged from the nozzles **11***c* and **11***d* of the nozzle array **12**B is assumed to swerve in a direction approaching the nozzle array **12**A with respect to the target landing position.

[0056] Thus, the nozzle **11***a* of the nozzle array **12**B is shifted to approach the nozzle **11***a* of the nozzle array **12**A in the first direction F to reduce an amount of deviation between the target landing position and the actual landing position of the discharge droplets. The nozzles **11** before shifting are indicated by circles with a solid line, and the nozzles **11** after the shifting are indicated by circles with a broken line in FIG. **1**. Further, the nozzles **11***c* and **11***d* of the nozzle array **12**B are shifted away from the nozzles **11***c* and **11***d* of the nozzle array **12**A in the first direction F. As described above, the nozzles **11** before the shifting are indicated by circles with a solid line, and the nozzles **11** after the shifting are indicated by circles with a broken line in FIG. **1**. Thus, an amount of deviation between the target landing position of the discharged droplet and the actual landing position decreases.

[0057] Thus, each of the nozzles **11***a* to **11***d* in the nozzle array **12**A and **12**B includes the nozzles **11***a* having a nozzle interval of Pn**2**, the nozzle **11***b* having a nozzle interval of Pn**0**, and the nozzles **11***c* and **11***d* having a nozzle interval of Pn**1**.

[0058] That is, at least one nozzle array **12** of the plurality of nozzle arrays **12** (nozzle arrays **12** constituting the stage **13**) includes at least two nozzles **11** arranged to have at least two different nozzle intervals (at least two of Pn**0**, Pn**1**, and Pn**2**).

[0059] Thus, the head **1** includes the nozzles **11** arranged so that the actual landing position of the nozzle approaches the target landing position according to a direction of swerve of the discharged droplets in the first direction F instead of uniformly widening or narrowing the nozzle interval Pn between the adjacent nozzle arrays **12** with respect to the target nozzle interval Pn**0**. Thus, the head **1** according to the present disclosure changes a nozzle interval to increase an accuracy of the landing position of the liquid droplet on a medium **410** (see FIG. **31**).

[0060] Specific example of changing the nozzle interval is described below.

[0061] FIG. **2** is a plan view of a nozzle arrangement of the head **1**. In FIG. **2**, a center of an arrangement of the nozzles **11** forming the stage **13** is referred to as "central side (part) of nozzle array group", and both ends of the arrangement of the nozzles **11** are referred to as "end part (side) of nozzle array group" in the first direction F. Further, a direction of conveyance of the medium **410** onto which the liquid (discharged droplets) is discharged from the head **1** is indicated by a vertical arrow directed downward in FIG. **2**. Hereinafter, "the direction of conveyance of the medium" is simply referred to as "the medium conveyance direction". The stage **13**D among four stages **13**A to **13**D (see FIG. **1**) of the head **1** is arranged most windward side (upstream side) in the medium conveyance direction.

[0062] The head **1** has a total nozzle number of 320 nozzles. The nozzle interval Pm of the head **1** is 300 nozzles/inch in a direction perpendicular to the first direction F. A preset nozzle interval Pn**0** of the head **1** is 75 nozzles/inch in the first direction F.

[0063] FIGS. **3** and **4** illustrate a first example of a deviation of the landing position of the discharged droplets in the first direction F when the head **1** includes the nozzle array **12** arranged at a constant nozzle interval Pn, for example, an equal interval such as the preset nozzle interval Pn**0**.

[0064] The first example in FIGS. **3** and **4** illustrates an amount of deviation (amount of swerve) and a direction of swerve of the landing position of the n-th droplet ($n>1$) in the first direction F after a predetermined numbers of droplets are discharged with respect to a landing position of a first droplet when a predetermined numbers of the droplets is discharged at a high frequency such as a solid image under a preset discharge condition **1**, a conveyance speed of the medium **410** of which is set to T**1**.

[0065] In FIG. **3**, a horizontal axis indicates a position of nozzle **11** in the first direction F, and a vertical axis indicates an amount of swerve and a direction of swerve of the discharged droplets. The direction of swerve is positive (+) when the discharged droplet is swerved toward the center part of the nozzle array group **14** and negative (−) when the discharged droplet is swerved toward the end part of the nozzle array group **14**. Further, a central position of the nozzle array group **14** (stage **13**) is set to "0", and positions at each ends of the nozzle array group **14** (stage **13**) is set to "+1" and "−1", respectively in the position of nozzles in the first direction F in FIG. **3**. As illustrated in FIG. **3**, the swerve of the discharged droplets from the nozzle **11** disposed at a position around ±0.8 is large.

[0066] FIG. **4** is a plan view of a portion of the nozzle arrangement of the head **1** near the end E**1** of the nozzle array group **14** of FIG. **3**. In FIG. **4**, a landing position of the first droplet is indicated by a black circle. Further, a landing position of the n-th ($n>1$) droplet after discharging the liquid for a predetermined amount under the discharge condition **1** from the nozzle **11** is indicated by a white circle. In FIG. **4**, an amount of swerve of the discharged droplets from the nozzles **11** belonging to the stages **13**C and **13**D disposed upstream in the medium conveyance direction is large, and a direction of swerve is directed toward the center (inward direction) of the nozzle array group **14** under the discharge condition **1**.

[0067] FIGS. **5** and **6** illustrate a second example of a deviation of the landing position of the discharged droplets in the first direction F when the head **1** includes the nozzle array **12** arranged at a constant nozzle interval Pn, for example, an equal interval such as the preset nozzle interval Pn**0**.

[0068] The second example in FIGS. **5** and **6** illustrates an amount of deviation (amount of swerve) and a direction of swerve of the landing position of the n-th droplet (n>1) in the first direction F after a predetermined numbers of droplets are discharged with respect to a landing position of a first droplet when a predetermined numbers of the droplets is discharged at a high frequency such as a solid image under a preset discharge condition **2**. A conveyance speed T**2** of the medium **410** under the discharge condition **2** is set to be higher than the conveyance speed T**1** of the medium **410** under the discharge condition **1**.

[0069] In FIG. **5**, a horizontal axis indicates a position of nozzle **11** in the first direction F, and a vertical axis indicates an amount of swerve and a direction of swerve of the discharged droplets. The direction of swerve is positive (+) when the discharged droplet is swerved toward the center part of the nozzle array group **14** (stage **13**) and negative (−) when the discharged droplet is swerved toward the end part of the nozzle array group **14**. Further, a central position of the nozzle array group **14** (stage **14**) is set to "0", and positions at each ends of the nozzle array group **14** (stage **13**) is set to "+1" and "−1", respectively in the position of nozzles in the first direction F in FIG. **3**. As illustrated in FIG. **5**, the swerve of the discharged droplets from the nozzle **11** disposed at a position around ±1.0 is large.

[0070] FIG. **6** is a plan view of a portion of the nozzle arrangement of the head **1** near the end E2 of the nozzle array group **14** of FIG. **5**. In FIG. **6**, a landing position of the first droplet is indicated by a black square. Further, a landing position of the n-th (n>1) droplet after discharging the liquid for a predetermined amount under the discharge condition **2** from the nozzle **11** is indicated by a white square. In FIG. **6**, an amount of swerve of the discharged droplets from the nozzles **11** belonging to the stages **13**A and **13**B disposed downstream in the medium conveyance direction is large, and a direction of swerve is directed toward the end part (outward direction) of the nozzle array group **14** under the discharge condition **2**.

[0071] As in the first and second examples described above, with discharge of a predetermined numbers of droplets, the landing position of the discharged droplet is shifted in the first direction. An interval (distance) between landing droplets discharged from the adjacent nozzles **11** in the first direction F becomes wider or narrower than a target distance. Hereinafter, "the landing droplets discharged from the adjacent nozzles **11**" is simply referred to as "landing droplets of adjacent nozzles **11**".

[0072] Widening of the interval between the landing droplets of adjacent nozzles **11** causes a white streaks with increase in the interval between the landing droplets, and narrowing of the interval between the landing droplets of adjacent nozzles **11** causes a black streak with decrease in the interval between the landing droplets. The white streaks and black streaks cause an abnormal image.

[0073] FIG. **7** illustrates an example of the interval (distance) between the landing droplets of adjacent nozzles **11** after a predetermined number of droplets is discharged under the discharge conditions **1** and **2** from the nozzles **11** of the nozzle arrays **12** adjacent in the first direction F. A horizontal axis in FIG. **7** indicates the nozzle position in the first direction F, and a vertical axis indicates a distance between the landing droplets of adjacent nozzles **11** in the first direction F. When the actual distance between the landing droplets of adjacent nozzles **11** is wider (larger) than a target distance between the landing droplets of adjacent nozzles **11**, the actual distance is indicated in a region above the horizontal axis. The "target distance between the landing droplets of adjacent nozzles **11**" is indicated by a horizontal line **150** illustrated above the horizontal axis in FIG. **7**. The actual distance larger (wider) than the target distance indicated above the horizontal line **150** causes the white streaks in the image. When the actual distance between the landing droplets of adjacent nozzles **11** is smaller (narrower) than the target distance, the distance is indicated in a region below the horizontal line **150**. The actual distance smaller (narrower) than the target distance indicated above the horizontal line **150** causes the black streaks in the image. As illustrated in FIG. **7**, there are places in which the landing positions of adjacent nozzles **11** become wider or narrower in the positions of the nozzles **11** in the first direction F (in the horizontal axis in FIG. **7**). Thus, the positions of the nozzles **11** (nozzle position) in the first direction F are corrected to reduce the deviation of an actual interval (distance) between the landing droplets of adjacent nozzles **11** from the target interval (distance) between the landing droplets of adjacent nozzles **11**.

[0074] FIG. **8** illustrates an example of a first correction of positions of the nozzles **11** when there is variation in the interval (distance) between the landing droplets of adjacent nozzles **11** as illustrated in FIG. **7**.

[0075] In the example of the first correction example in FIG. **8**, the position of the nozzle **11** before correction is indicated by a black circle, and the position of the nozzle **11** after correction is indicated by a white rhombus at the end part in the nozzle array group **14** in the first direction F.

[0076] The position of the nozzles **11** before correction is the position when the nozzles **11** are arranged at the nozzle interval Pn**0**, and the actual landing position may deviate from the target landing position due to the swerve of the discharged droplets in the first direction F. The position of the nozzles **11** after correction is the position in which the amount of deviation is smaller than the amount of deviation between the actual landing position and the target landing position of the discharged droplets when the liquid droplet is discharged from the nozzle **11** disposed at the position before correction.

[0077] The position of nozzles **11** with the first correction reduces the amount of swerve in the first direction F with respect to the position of the nozzle **11** before correction under the discharge conditions **1** and **2** when the stage **13**D is arranged on the upstream in the medium conveyance direction, the nozzle position after correction is set in the first direction F relative to the nozzle position before correction

[0078] The first correction shifts the positions of a part of nozzles **11** in the stages **13**C and **13**D toward the end part of the nozzle array group **14** and shifts the positions of a part of nozzles **11** in the stage **13**A toward the center part of the nozzle array group **14** as indicated by arrows in FIG. **8**.

[0079] Shifting the position of the nozzle **11** (nozzle position) toward the center part of the nozzle array group **14** or toward the end part of the nozzle array group **14** changes the nozzle interval Pn between the nozzles **11** of adjacent nozzle arrays **12** in the nozzles **11** constituting the nozzle array **12**. Thus, a plurality of nozzles **11** in the nozzle array **12** includes pairs of the nozzles **11** arranged at least two different nozzle intervals Pn as illustrated in the nozzle intervals Pn**0**, Pn**1**, and Pn**2** in FIG. **1**.

[0080] Thus, as illustrated in FIG. **8**, two nozzle arrays **12** of the plurality of nozzle arrays **12** are arranged at an end part of the head **1** in the first direction F. The two nozzle arrays **12** of the plurality of nozzle arrays **12** includes first nozzles **11***d* arranged at an upstream in the medium conveyance direction, the first nozzles **11***d* arranged at a first nozzle interval Pn**1** wider than a nozzle interval Pn**0** of the nozzles **11***b* arranged at a central part of the head **1** in the first direction F, and second nozzles **11***a* arranged at a downstream of the first nozzles **11***d* in the medium conveyance direction, the second nozzles **11***a* arranged at a second nozzle interval Pn**2** narrower than a nozzle interval Pn**0** of the nozzles **11***b* arranged at the central part of the head **1** in the first direction F.

[0081] A number of the plurality of nozzle arrays **12** including the first nozzles **11***d* is larger than a number of the plurality of nozzle arrays **12** including the second nozzles **11***a* as illustrated in FIG. **8**.

[0082] FIG. **9** is a graph illustrating a maximum amount of deviation of the actual landing position from the target landing position in the first direction F in the first correction. FIG. **10** is a graph illustrating a maximum amount of deviation of an actual distance between the landing droplets of adjacent nozzles **11** from the target distance between the landing droplets of adjacent nozzles **11** in the first direction F in the first correction.

[0083] Here, the maximum amount of deviation of the actual landing position from the target landing position is the maximum amount of deviation in the amount of deviation of the actual landing position from the target landing position in the nozzle array group **14**. Further, the maximum amount of deviation of distance is the maximum amount of deviation of actual distance between the landing droplets of adjacent nozzles **11** from the target distance. Thus, with decrease in the maximum amount of deviation of the actual landing position from the target landing position, the amount of deviation of the actual landing position from the target landing position decreases in FIG. **9**. Thus, with decrease in the maximum amount of deviation of the actual distance between the landing droplets of adjacent nozzles **11** from the target distance, the white streaks and the black streaks becomes incognizable.

[0084] The nozzle position is corrected for the nozzles **11** disposed at the nozzle position of ±0.5 or more (near the end part of the nozzle array group **14**) in FIGS. **3** and **5** described above. The position of the nozzles **11** may be corrected regardless of the nozzle position of the nozzles **11**. However, a sufficient effect can be obtained by correcting only the nozzle position of the nozzles **11** in the vicinity of a region having a large amount of deviation in the landing position since the maximum amount of deviation in the landing position is affected by the nozzle **11** having a large amount of deviation in the landing position.

[0085] From the results illustrated in FIGS. **9** and **10**, the nozzle position of the nozzles **11** is corrected to be shifted toward a direction opposite to the direction of swerve in the first direction F. Thus, the head **1** can reduce both of the maximum amount of deviation of the actual landing position from the target landing position and the maximum amount of deviation of the actual distance between the landing droplets of adjacent nozzles **11** from the target distance. Thus, the deviation in the landing position of the discharged droplet becomes incognizable as an image abnormality even if the landing position is deviated.

[0086] FIG. **11** is a plan view of the arrangement of the nozzles **11** illustrating an example of a second correction of the nozzle position having variation in the distance (interval) of landing droplets of adjacent nozzles **11** as illustrated in FIG. **7**.

[0087] The second correction corrects the nozzle position of the nozzles **11** in the stage **13**C so that the second correction shifts the positions of part of the nozzles **11** arranged at an end part of the nozzle array group **14** in the stage **13**C toward the central part of the nozzle array group **14** in the first direction F. The second correction further shifts the positions of part of the nozzles **11** arranged at a central part of the nozzle array group **14** toward the end part of the nozzle array group **14** in the first direction F. Further, the second correction shifts the positions of part of nozzles **11** arranged at central part of the nozzle array group **14** in the stage **13**C toward the end part of the nozzle array group **14** in the first direction F.

[0088] Shifting the position of the nozzle **11** (nozzle position) toward the central part of the nozzle array group **14** or toward the end part of the nozzle array group **14** changes the nozzle interval Pn between adjacent nozzles **11** in adjacent nozzle arrays **12** in the first direction F in the nozzles **11** that configures the nozzle array **12**. Thus, a plurality of nozzles **11** in the nozzle array **12** includes pairs of the nozzles **11** arranged at least two different nozzle intervals Pn as illustrated in the nozzle intervals Pn**0**, Pn**1**, and Pn**2** in FIG. **1**.

[0089] The stage **13**D of the head **1** in the second correction is disposed upstream in the medium conveyance direction under the discharge condition **1**. FIGS. **12** and **13** respectively illustrate the results of the maximum amount of deviation of the actual landing position from the target landing position in the first direction F and the maximum amount of deviation of the actual distance from the target distance in the first direction F when the stage **13** of the head **1** is disposed upstream in the medium conveyance direction under the discharge condition **2**.

[0090] Thus, as illustrated in FIG. **11**, the nozzles **11** disposed at the same stage **13**D in the second direction S in each of the plurality of nozzle arrays **12** arranged in the first direction F includes first nozzles **11** arranged at an upstream in the medium conveyance direction, the first nozzles **11** arranged at a first nozzle interval Pn**1** wider than a nozzle interval Pn**0** of the nozzles **11** in the plurality of nozzle arrays **12** arranged at a central part of the head **1** in the first direction F, and second nozzles **11** arranged at a downstream in the medium conveyance direction of the first nozzles **11**, the second nozzles **11** arranged at a second nozzle interval Pn**2** narrower than a nozzle interval Pn**0** of the nozzles **11** in the plurality of nozzle arrays **12** arranged at the central part of the head **1** in the first direction F.

[0091] A number of the plurality of nozzle arrays **12** including the first nozzles **11** is larger than a number of the plurality of nozzle arrays **12** including the second nozzles **11**.

[0092] As illustrated in FIGS. **12** and **13**, the second correction corrects the nozzle positions to reduce the maximum amount of deviation of the landing position and the maximum amount of deviation of the distance to be smaller than the maximum amount of deviation of the landing position and the maximum amount of deviation of the distance, respectively, when the nozzle positions of the nozzles **11** are not corrected. Thus, the head **1** according to the present disclosure can reduce the deviation of the landing position to the extent that the deviation is not recognized as an image abnormality even if the deviation in the landing position occurs.

[0093] The above-described examples of the first and second corrections may specify and correct the nozzles **11** disposed upstream in the medium conveyance direction (such as stages **13**C and **13**D) during discharge operation of the liquid droplet. The first and second corrections may correct the nozzle position of the nozzles **11** so that amount of correction of the nozzle position becomes substantially identical when the nozzle array group **14** is viewed from each sides in a direction perpendicular to the first direction (in the medium conveyance direction). Thus, the first and second corrections may correct the nozzle position of the nozzles **11** so that arrangement of the interval (distance) of the nozzles **11** becomes identical when the nozzle array group **14** is viewed from each sides in a direction perpendicular to the first direction (in the medium conveyance direction).

[0094] The above-described correction can obtain the same effect even when any side of the stage **13** of the nozzle array **12** is arranged on the upstream in the medium conveyance direction. Thus, the above-described correction can obtain the same effect regardless of the direction of printing when the head **1** is used in a serial-type printing apparatus.

[0095] In a head **1** of a Comparative Example 1, an interval (distance) of nozzles **11** arranged at the end part of the nozzle array group **14** in the first direction F is larger (wider) than an interval (distance) of nozzles **11** arranged at the central part of the nozzle array group **14** in the first direction F. FIGS. **14** and **15** respectively illustrate the results of comparison of the maximum amount of deviation of the actual landing position from the target landing position in the first direction F and the maximum amount of deviation of the actual distance from the target distance in the first direction F among the heads **1** of no-correction, the first correction, the second correction, and the Comparative Example 1.

[0096] As illustrated in FIG. **14**, the maximum amount of deviation of the landing position of the head **1** corrected by the second correction becomes smaller than the maximum amount of deviation of the landing position of the head **1** of the Comparative Example 1. Further, as illustrated in FIG. **15**, each of the maximum amount of deviations of the distance of the head **1** corrected by the first and second corrections becomes smaller than the maximum amount of deviation of the distance of the head **1** of the Comparative Example 1.

[0097] In the first and second corrections, the swerve of the droplets discharged from the nozzles **11** disposed around ±0.8 (see FIG. **5**) under the discharge condition **1** and from the nozzles **11** disposed around ±1.0 (see FIG. **5**) under the discharge condition **2** becomes large. However, the positions of the nozzles **11** that cause the swerve varies according to the nozzle arrangement, the discharge conditions, and the like. Thus, the nozzle position is preferably corrected according to the nozzle arrangement or the like.

[0098] Next, a second embodiment of the present disclosure is described with reference to FIG. **16**. FIG. **16** is an enlarged plan view of a nozzle arrangement of the head **1** according to the second embodiment of the present disclosure.

[0099] The head **1** in the second embodiment includes a plurality of, for example, two nozzle array groups **14**A and **14**B (see FIG. **23** described below). The nozzle array group **14**A is arranged on the upstream in the medium conveyance direction, and the nozzle array group **14**B is arranged on the downstream in the medium conveyance direction. A gap is provided between the nozzle array group **14**A and the nozzle array group **14**B in the medium conveyance direction.

[0100] In FIG. **16**, an airflow generated by conveyance of the medium **410** in addition to an airflow **16** generated by droplets **15** discharged from the nozzles **11** influence the nozzle array group **14**B disposed downstream in the medium conveyance direction.

[0101] The droplets **15** are discharged from the nozzle array group **14**A disposed upstream of the nozzle array group **14**B in the medium conveyance direction and generates airflow in the downstream in the medium conveyance direction. Thus, the discharge condition of the nozzle array group **14**B is different from the discharge condition of the nozzle array group **14**A such that a conveyance speed of the medium **410** at the nozzle array group **14**B is higher than the conveyance speed of the medium **410** at the nozzle array group **14**A. Thus, even if the nozzle array group **14**A disposed upstream in the medium conveyance direction is in the discharge condition **1**, the nozzle array group **14**B disposed downstream in the medium conveyance direction is in the discharge condition **2**.

[0102] Thus, the head **1** includes a plurality of nozzle array groups **14**A and **14**B each including the plurality of nozzle arrays **12**. The nozzle intervals Pn of the nozzles **11** are different between the plurality of nozzle array groups **14**A and **14**B.

[0103] Thus, the head **1** according to the second embodiment corrects the nozzle position according to the amount and direction of swerve of the discharged droplets. Thus, the head **1** according to the second embodiment can improve the accuracy of the landing position as compared to the Comparative Example 1. The Comparative Example 1 has a configuration in which the nozzle interval (distance) between the nozzles **11** located at both ends of the nozzle array group **14** in the first direction F is set to be uniformly wider than the nozzle interval (distance) between the nozzles **11** located at the central part of the nozzle array group **14**.

[0104] Next, a third embodiment of the present disclosure is described with reference to FIGS. **17** to **23**. FIG. **17** is an outer perspective view of the head **1** according to the third embodiment. FIG. **18** is an exploded perspective view of the head **1**. FIG. **19** is a cross-sectional perspective view of the head **1**. FIG. **20** is an exploded perspective view of the head **1** excluding a frame. FIG. **21** is a cross-sectional perspective view of channels of the head **1**. FIG. **22** is an enlarged cross-sectional perspective view of the channels of the head **1**. FIG. **23** is a plan view of the channels of the head **1**.

[0105] The liquid discharge head **1** includes a nozzle plate **10**, a channel plate (individual channel member **20**), a diaphragm member **30**, a common channel member **50**, a damper **60**, a frame **80**, and a substrate **101** mounting a drive circuit **102** (flexible wiring substrate).

[0106] The nozzle plate **10** includes a plurality of nozzles **11** to discharge liquid. As illustrated in FIG. **23**, the plurality of nozzles **11** are arranged two-dimensionally in a matrix and are arranged side by side in three directions of a first direction F, a second direction S and a third direction T.

[0107] The individual channel member **20** includes a plurality of pressure chambers **21** (individual chambers) respectively communicating with the plurality of nozzles **11**, a plurality of individual supply channels **22** respectively communicating with the plurality of pressure chambers **21**, and a plurality of individual collection channels **23** respectively communicating with the plurality of pressure chambers **21**. A combination of one pressure chamber **21**, one individual supply channel **22** communicating with one pressure chamber **21**, and one individual collection channel **23** communicating with one pressure chamber **21** is collectively referred to as an individual channel **25**.

[0108] The diaphragm member **30** forms a diaphragm **31** serving as a deformable wall of the pressure chamber **21**, and the piezoelectric element **40** is formed on the diaphragm **31** to form a single body. Further, a supply-side opening **32** communicating with the individual supply channel **22** and a collection-side opening **33** communicating with the individual collection channel **23** are formed on the diaphragm member **30**. The piezoelectric element **40** is a pressure generator to deform the diaphragm **31** to pressurize the liquid in the pressure chamber **21**.

[0109] Note that the individual channel member **20** and the diaphragm member **30** are not limited to be separate members. For example, an identical member such as a Silicon on Insulator (SOI) substrate may be used to form the individual channel member **20** and the diaphragm member **30** in a single body. That is, an SOI substrate formed by sequentially forming a silicon oxide film, a silicon layer, and a silicon oxide film on a silicon substrate is used.

[0110] The SOI substrate on the silicon substrate forms the individual channel member **20**, and the silicon oxide film, the silicon layer, and the silicon oxide film in the SOI substrate form the diaphragm **31**. In the above-described configuration, the layer structure of the silicon oxide film, the silicon layer, and the silicon oxide film in the SOI substrate forms the diaphragm member **30**. As described above, the diaphragm member **30** includes a member made of the material that is film-formed on a surface of the individual channel member **20**.

[0111] The common channel member **50** includes a plurality of common-supply branch channel **52** communicating with two or more individual supply channels **22** and a plurality of common-collection branch channel **53** communicating with two or more individual collection channels **23**. The plurality of common-supply branch channel **52** and the plurality of common-collection branch channel **53** are alternately formed adjacent to each other in the second direction S of the nozzle **11** (see FIG. **23**).

[0112] As illustrated in FIG. **22**, the common channel member **50** includes a through hole serving as a supply port **54** that connects the supply-side opening **32** of the individual supply channel **22** and the common-supply branch channel **52** and a through hole serving as a collection port **55** that connects the collection-side opening **33** of the individual collection channel **23** and the common-collection branch channel **53**.

[0113] Further, as illustrated in FIGS. **19** to **23**, the common channel member **50** includes one or more common-supply main channel **56** communicating with the plurality of common-supply branch channels **52** and one or more common-collection main channel **57** communicating with the plurality of common-collection branch channels **53**.

[0114] The damper **60** includes a supply-side damper **62** that faces (opposes) the supply port **54** of the common-supply branch channel **52** and a collection-side damper **63** that faces (opposes) the collection port **55** of the common-collection branch channel **53**.

[0115] As illustrated in FIGS. **20** to **22**, the common-supply branch channel **52** and the common-collection branch channel **53** are formed by sealing grooves with the supply-side damper **62** or the collection-side damper **63** of the damper **60**. The grooves are alternately arranged in the common channel member **50** in which both of the common-supply branch channel **52** and the common-collection branch channel **53** are formed. As a material of the damper **60**, it is preferable to use a metal thin film or an inorganic thin film resistant to an organic solvent. A thickness of the supply-side damper **62** and the collection-side damper **63** of the damper **60** is preferably 10 μm or less.

[0116] Next, an arrangement of nozzles **11** and the channels in the present disclosure is described with reference also to FIGS. **23** to **25**. FIG. **24** is an enlarged plan view of a portion of the head **1**. FIG. **25** is a plan view of a of the nozzle arrangement illustrated in **23**. In FIG. **24**, branch channels such as the common-supply branch channels **52** and the common-collection branch channels **53** are indicated by imaginary lines.

[0117] As illustrated in FIG. **23**, the plurality of nozzles **11** are arranged two-dimensionally in a matrix and are arranged side by side in three directions of a first direction F, a second direction S and a third direction T. As illustrated in FIG. **23**, a group of the nozzles **11** arranged two-dimensionally in a matrix is defined as a nozzle array group **14**.

[0118] The head **1** has a plurality of nozzle arrays **12** in which a plurality of nozzles **11** are arrayed in a second direction S. The plurality of nozzle arrays **12** are arranged side by side in a first direction F that intersects the second direction S with a predetermined inclined degrees θ**1** (see FIG. **23**). The common-supply branch channel **52** and the common-collection branch channel **53** extend in the second direction S. Therefore, a longitudinal direction of the common-supply branch channel **52** and the common-collection branch channel **53** is along the second direction S.

[0119] In one nozzle array group **14**, the first direction F is a direction (nozzle array direction) in which most adjacent nozzles **11** are arranged (arrayed) and is a direction intersecting the second direction S at an angle θ**1** with respect to the second direction S. Thus, the common-supply branch channel **52** and the common-collection branch channel **53** are alternately arranged in the first direction F.

[0120] In one nozzle array group **14**, the third direction T is a direction intersecting the first direction F and the second direction S. In the present disclosure, the individual channels **25** configured by the individual supply channel **22**, the pressure chambers **21**, and the individual collection channels **23** is arranged along the third direction T.

[0121] The individual channel **25** (see FIG. **23**) configured by the individual supply channel **22**, the pressure chamber **21**, and the individual collection channel **23** has a shape of twice rotational symmetrical with an axis of the nozzle **11** (central axis in a direction of liquid discharge from the nozzle **11**).

[0122] Thus, the head **1** in an example illustrated in FIG. **24** can be designed such that the individual channel **25** is arranged reversal to nozzles **11**A and **11**E adjacent in a direction (third direction T) parallel to a direction of liquid flow in the individual channel **25** as in a relation between the individual channel **25** communicating with the nozzle **11**A and the individual channel **25** communicating with the nozzle **11**E, for example.

[0123] The supply port **54**A communicating with the individual channel **25** of the nozzle **11**A and the supply port **54**E communicating with the individual channel **25** of the nozzle **11**E are arranged in the identical common-supply branch channel **52**. Further, a direction of arrangement of the individual channel **25** communicating with the supply port **54**A can be arranged opposite (reversal) to a direction of arrangement of the individual channel **25** communicating with the supply port **54**E.

[0124] Thus, a package density of the individual channels **25** (nozzles **11**) can be increased without being restricted by an arrangement of the common-supply branch channel **52**, and the head thus can be downsized.

[0125] Further, in the example illustrated in FIG. **24**, the nozzle **11**A connected to the supply port **54**A and the nozzle **11**E connected to the supply port **54**E communicate with different common-collection branch channels **53** through collection ports **55**A and **55**E, respectively. Thus, two nozzles **11** communicating with two supply ports **54** arranged nearest to each other (closest to each other) and arranged in the identical common-supply branch channel **52** communicate with different common-collection branch channels **53** via two collection ports **55**, respectively.

[0126] The individual channels **25** are translationally symmetrical (not reversely arranged) in the second direction S along which the liquid flows in the common-supply branch channel **52** and the common-collection branch channel **53**.

[0127] As illustrated in FIG. **25**, an interval Pq between the nozzles **11** adjacent in the third direction T can be set in an arbitrary direction. However, the interval Pq can be set wider than an interval Pn between the nozzles **11** adjacent in the first direction F and an interval Pm between the nozzles **11** adjacent in the second direction S.

[0128] Thus, the head **1** in the third embodiment includes the nozzles **11**, the nozzle interval Pn between the nozzles **11** in the adjacent nozzle arrays **12** of which is arranged so that the actual landing position of the discharged droplet approaches the target landing position according to a direction of swerve and an amount of swerve of the discharged droplet in the first direction F. Thus, the nozzle array **12** includes the nozzles **11** in the nozzle arrays **12** adjacently arranged in the first direction F and the nozzles **11** arranged at least two different nozzle intervals Pn.

[0129] Thus, the head **1** can improve accuracy of the landing position of the discharged droplets.

[0130] FIGS. **26** and **27** illustrate an example of a head module according to an embodiment of the present disclosure. FIG. **26** is an exploded perspective view of a head module **100**. FIG. **27** is an exploded perspective view of the head module **100** viewed from a nozzle surface side of the head module **100**.

[0131] The head module **100** includes a plurality of heads **1** configured to discharge a liquid, a base **103** that holds the plurality of heads **1**, and a cover **113** serving as a nozzle cover of the plurality of heads **1**.

[0132] Further, the head module **100** includes a heat radiating member **104**, a manifold **105** forming a flow path to supply liquid to the plurality of heads **1**, a printed circuit board **106** (PCB) connected to the substrate **101** (flexible wiring substrate), and a module case **107**.

[0133] FIGS. **28** and **29** illustrate an example of a liquid discharge apparatus (printing apparatus **500**) according to the present disclosure. FIG. **28** is a side view of a liquid discharge apparatus (printing apparatus **500**) according to the present disclosure. FIG. **29** is a plan view of a head unit **550** of the liquid discharge apparatus (printing apparatus **500**) of FIG. **28** according to the present disclosure.

[0134] The liquid discharge apparatus (printing apparatus **500**) according to the present disclosure includes a feeder **501** to feed a continuous medium **510**, a guide conveyor **503** to guide and convey the continuous medium **510** fed from the feeder **501** to a printing unit **505**, the printing units **505** and **555** to discharge liquid onto the continuous medium **510** to form an image on the continuous medium **510**, a drier unit **507** to dry the continuous medium **510**, and an ejector **509** to eject the continuous medium **510**.

[0135] The continuous medium **510** is fed from a winding roller **511** of the feeder **501**, guided and conveyed with rollers of the feeder **501**, the guide conveyor **503**, the drier unit **507**, and wound around a take-up roller **591** of the ejector **509**.

[0136] In the printing unit **505**, the continuous medium **510** is conveyed opposite the head unit **550** on a conveyance guide **559**. The head unit **550** discharges a liquid from the nozzles **11** of the head **1** to form an image on the continuous medium **510**.

[0137] The head unit **550** includes four head devices **551**A to **551**D to discharge liquid of respective colors such as yellow, magenta, cyan, and black.

[0138] Here, the head devices **551**A to **551**D in the head unit **550** respectively includes two head modules **100**A and **100**B according to the present disclosure in the common base member **552**.

[0139] The head module **100**A includes head arrays **1A1**, **1B1**, **1A2**, and **1B2**. Each of the head arrays **1A1**, **1B1**, **1A2**, and **1B2** includes a plurality of heads **1** arranged in a direction perpendicular to a conveyance direction of the continuous medium **510**. The head module **100**B includes head arrays **1C1**, **1D1**, **1C2**, and **1D2**. Each of the head arrays **1C1**, **1D1**, **1C2**, and **1D2** includes a plurality of heads **1** arranged in a direction perpendicular to the conveyance direction of the continuous medium **510**. The head **1** in each of the head arrays **1A1** and **1A2** of the head module **100**A discharges liquid of the same color. Similarly, the head arrays **1B1** and **1B2** of the head module **100**A are grouped as one set that discharge liquid of the same color. The head arrays **1C1** and **1C2** of the head module **100**B are grouped as one set that discharge liquid of the same color. The head arrays **1D1** and **1D2** are grouped as one set to discharge liquid of the same color.

[0140] FIG. **30** illustrates an example of a liquid circulation device **600** employed in the liquid discharge apparatus (printing apparatus **500**) according to the present disclosure. FIG. **30** is a circuit diagram illustrating a structure of the liquid circulation device **600**. Although only one head **1** is illustrated in FIG. **30**, in the structure including a plurality of heads **1** as illustrated in FIGS. **28** to **29**, supply channels and collection channels are coupled via manifolds or the like to the supply sides and collection sides of the plurality of heads **1**. The head **1** of a circulation type in the third embodiment is used as the head **1**.

[0141] The liquid circulation device **600** includes a supply tank **601**, a collection tank **602**, a main tank **603**, a first liquid feed pump **604**, a second liquid feed pump **605**, a compressor **611**, a regulator **612**, a vacuum pump **621**, a regulator **622**, and a supply-side pressure sensor **631**, and a collection-side pressure sensor **632**.

[0142] The compressor **611** and the vacuum pump **621** together generate a difference of pressure between the pressure in the supply tank **601** and the pressure in the collection tank **602**.

[0143] The supply-side pressure sensor **631** is connected between the supply tank **601** and the head **1** and connected to the supply channels connected to the supply port **81** of the head **1**. The collection-side pressure sensor **632** is connected between the head **1** and the collection tank **602** and is connected to the collection channels connected to the collection port **82** of the head **1**.

[0144] One of the collection tanks **602** is connected to the supply tank **601** via the first liquid feed pump **604**, and the other of the collection tanks **602** is connected to the main tank **603** via the second liquid feed pump **605**.

[0145] Accordingly, the liquid flows from the supply tank **601** into the head **1** via the supply port **81** and exits the head **1** from the collection port **82** into the collection tank **602**. Further, the first liquid feed pump **604** feeds the liquid from the collection tank **602** to the supply tank **601**. Thus, the liquid circulation channel is constructed.

[0146] Here, a compressor **611** is connected to the supply tank **601** and is controlled so that a predetermined positive pressure is detected by the supply-side pressure sensor **631**. Conversely, a vacuum pump **621** is connected to the collection tank **602** and is controlled so that a predetermined negative pressure is detected by the collection-side pressure sensor **632**.

[0147] Such a configuration allows the menisci of ink to be maintained at a constant negative pressure while circulating liquid through the inside of the head **1**.

[0148] When droplets are discharged from the nozzles **11** of the head **1**, the amount of liquid in each of the supply tank **601** and the collection tank **602** decreases. Therefore, the liquid is replenished from the main tank **603** to the collection tank **602** using the second liquid feeding pump **605** as appropriate.

[0149] The timing of supply of liquid from the main tank **603** to the collection tank **602** can be controlled in accordance with a result of detection by a liquid level sensor in the collection tank **602**. For example, the liquid is supplied to the collection tank **602** from the main tank **603** when the liquid level in the collection tank **602** becomes lower than a predetermined height.

[0150] Next, another example of the printing apparatus **500** as a liquid discharge apparatus according to the present disclosure is described with reference to FIGS. **31** and **32**. FIG. **31** is a plan view of a portion of the printing apparatus **500**. FIG. **32** is a side view of a portion of the printing apparatus **500** of FIG. **31**.

[0151] The printing apparatus **500** is a serial type apparatus, and the carriage **403** is reciprocally moved in the main scanning direction MSD by the main scan moving unit **493**. The main scanning moving unit **493** includes a guide member **401**, a main scanning motor **405**, a timing belt **408**, and the like. The guide member **401** is bridged between a left side plate **491**A and a right-side plate **491**B to moveably hold the carriage **403**. The main scanning motor **405** reciprocally moves the carriage **403** in the main scanning direction MSD via the timing belt **408** bridged between a driving pulley **406** and a driven pulley **407**.

[0152] The carriage **403** mounts a liquid discharge device **440**. The head **1** according to the present disclosure and a head tank **441** forms the liquid discharge device **440** as a single unit. The head **1** of the liquid discharge device **440** discharges liquid of each color, for example, yellow (Y), cyan (C), magenta (M), and black (K). The head **1** includes a nozzle array **12** including a plurality of nozzles **11** arrayed in array in a sub-scanning direction SSD perpendicular to the main scanning direction indicated by array MSD in FIG. **31**. The head **1** is mounted to the carriage **403** so that ink droplets are discharged downward.

[0153] The head **1** is connected to the liquid circulation device **600** described above, and a liquid of a required color is circulated and supplied.

[0154] The printing apparatus **500** includes a conveyor **495** to convey a medium **410** (sheet). The conveyor **495** includes a conveyance belt **412** as a conveyor and a sub-scanning motor **416** to drive the conveyance belt **412**.

[0155] The conveyance belt **412** attracts the medium **410** and conveys the medium **410** at a position facing the head **1**. The conveyance belt **412** is an endless belt and is stretched between a conveyance roller **413** and a tension roller **414**. Attraction of the medium **410** to the conveyance belt **412** may be applied by electrostatic adsorption, air suction, or the like.

[0156] The conveyance belt **412** rotates in the sub-scanning direction as indicated by arrow SSD as the conveyance roller **413** is rotationally driven by the sub-scanning motor **416** via the timing belt **417** and the timing pulley **418**.

[0157] At one side in the main scanning direction MSD of the carriage **403**, a maintenance unit **420** to maintain the head **1** in good condition is disposed on a lateral side of the conveyance belt **412**.

[0158] The maintenance unit **420** includes, for example, a cap **421** to cap the nozzle surface of the head **1** and a wiper **422** to wipe the nozzle surface of the head **1**.

[0159] The main scan moving unit **493**, the maintenance unit **420**, and the conveyor **495** are mounted to a housing that includes a left side plate **491**A, a right-side plate **491**B, and a rear side plate **491**C.

[0160] In the printing apparatus **500** thus configured, the medium **410** is conveyed on and attracted to the conveyance belt **412** and is conveyed in the sub-scanning direction SSD by the cyclic rotation of the conveyance belt **412**.

[0161] The head **1** is driven in response to image signals while the carriage **403** moves in the main scanning direction MSD, to discharge liquid to the medium **410** stopped, thus forming an image on the medium **410**.

[0162] Next, the liquid discharge device **440** according to another embodiment of the present disclosure is described with reference to FIG. **33**. FIG. **33** is a plan view of a portion of another example of the liquid discharge device **440**.

[0163] The liquid discharge device **440** includes a housing, the main scan moving unit **493**, the carriage **403**, and the head **1** among components of the printing apparatus **500**. The left side plate **491**A, the right-side plate **491**B, and the rear side plate **491**C constitute the housing.

[0164] Note that, in the liquid discharge device **440**, the maintenance unit **420** described above may be mounted on, for example, the right-side plate **491**B.

[0165] Next, still another example of the liquid discharge device **440** according to the present disclosure is described with reference to FIG. **34**. FIG. **34** is a front view of still another example of the liquid discharge device **440**.

[0166] The liquid discharge device **440** includes the head **1**, to which a channel part **444** is attached, and a tube **456** connected to the channel part **444**.

[0167] Further, the channel part **444** is disposed inside a cover **442**. Instead of the channel part **444**, the liquid discharge device **440** may include the head tank **441**. A connector **443** electrically connected with the head **1** is provided on an upper part of the channel part **444**.

[0168] In the present disclosure, discharged liquid is not limited to a particular liquid as long as the liquid has a viscosity or surface tension to be discharged from a head (liquid discharge head). However, preferably, the viscosity of the liquid is not greater than 30 mPa s under ordinary temperature and ordinary pressure or by heating or cooling. Examples of the liquid include a solution, a suspension, or an emulsion that contains, for example, a solvent, such as water or an organic solvent, a colorant, such as dye or pigment, a functional material, such as a polymerizable compound, a resin, or a surfactant, a biocompatible material, such as DNA, amino acid, protein, or calcium, or an edible material, such as a natural colorant. Such a solution, a suspension, or an emulsion can be used for, e.g., inkjet ink, surface treatment solution, a liquid for forming components of electronic element or light-emitting element or a resist pattern of electronic circuit, or a material solution for three-dimensional fabrication.

[0169] Examples of an energy source to generate energy to discharge liquid include a piezoelectric actuator (a laminated piezoelectric element or a thin-film piezoelectric element), a thermal actuator that employs a thermoelectric conversion element, such as a heating resistor, and an electrostatic actuator including a diaphragm and opposed electrodes.

[0170] The "liquid discharge device" is an assembly of parts relating to liquid discharge. The term "liquid discharge device" represents a structure including the head and a functional part(s) or mechanism combined to the head to form a single unit. For example, the "liquid discharge device" includes a combination of the head with at least one of a head tank, a carriage, a supply unit, a maintenance unit, a main scan moving unit, and a liquid circulation apparatus.

[0171] Here, examples of the "single unit" include a combination in which the head and a functional part(s) or unit(s) are secured to each other through, e.g., fastening, bonding, or engaging, and a combination in which one of the head and a functional part(s) or unit(s) is movably held by another. The head may be detachably attached to the functional part(s) or unit(s) s each other.

[0172] For example, the head and the head tank may form the liquid discharge device as a single unit. Alternatively, the head and the head tank coupled (connected) with a tube or the like may form the liquid discharge device as a single unit. Here, a unit including a filter may further be added to a portion between the head tank and the head.

[0173] In another example, the head and the carriage may form the liquid discharge device as a single unit.

[0174] In still another example, the liquid discharge device includes the head movably held by a guide that forms part of a main scan moving unit, so that the head and the main scan moving unit form a single unit. The liquid discharge device may include the head, the carriage, and the main scan moving unit that form a single unit.

[0175] In still another example, a cap that forms part of a maintenance unit may be secured to the carriage mounting the head so that the head, the carriage, and the maintenance unit form a single unit to form the liquid discharge device.

[0176] Further, in another example, the liquid discharge device includes tubes connected to the head tank or the channel member mounted on the head so that the head and a supply unit form a single unit. Liquid is supplied from a liquid reservoir source to the head via the tube.

[0177] The main scan moving unit may be a guide only. The supply unit may be a tube(s) only or a loading unit only.

[0178] The "liquid discharge device" includes a head module including the above-described head, the head module, and head device in which the above-described functional components and mechanisms are combined to form a single unit.

[0179] The term "liquid discharge apparatus" used herein also represents an apparatus including the head, the liquid discharge device, the head module, and the head device to discharge liquid by driving the head. The liquid discharge apparatus may be, for example, an apparatus capable of discharging liquid to a material to which liquid can adhere or an apparatus to discharge liquid toward gas or into liquid.

[0180] The "liquid discharge apparatus" may include devices to feed, convey, and eject the material on which liquid can adhere. The liquid discharge apparatus may further include a pretreatment apparatus to coat a treatment liquid onto the material, and a post-treatment apparatus to coat a treatment liquid onto the material, onto which the liquid has been discharged.

[0181] The "liquid discharge apparatus" may be, for example, an image forming apparatus to form an image on a sheet by discharging ink, or a three-dimensional fabrication apparatus to discharge a fabrication liquid to a powder layer in which powder material is formed in layers to form a three-dimensional fabrication object.

[0182] The "liquid discharge apparatus" is not limited to an apparatus to discharge liquid to visualize meaningful images, such as letters or figures. For example, the liquid discharge apparatus may be an apparatus to form arbitrary images, such as arbitrary patterns, or fabricate three-dimensional images.

[0183] The above-described term "material on which liquid can be adhered" represents a material on which liquid is at least temporarily adhered, a material on which liquid is adhered and fixed, or a material into which liquid is adhered to permeate. Examples of the "material on which liquid can be adhered" include recording media such as a paper sheet, recording paper, and a recording sheet of paper, film, and cloth, electronic components such as an electronic substrate and a piezoelectric element, and media such as a powder layer, an organ model, and a testing cell. The "material on which liquid can be adhered" includes any material on which liquid adheres unless particularly limited.

[0184] Examples of the "material on which liquid can be adhered" include any materials on which liquid can be adhered even temporarily, such as paper, thread, fiber, fabric, leather, metal, plastic, glass, wood, and ceramic.

[0185] The "liquid discharge apparatus" may be an apparatus to relatively move the head and a material on which liquid can be adhered. However, the liquid discharge apparatus is not limited to such an apparatus. For example, the liquid discharge apparatus may be a serial head apparatus that moves the head or a line head apparatus that does not move the head.

[0186] Examples of the "liquid discharge apparatus" further include a treatment liquid coating apparatus to discharge a treatment liquid to a sheet to coat the treatment liquid on the surface of the sheet to reform the sheet surface and an injection granulation apparatus in which a composition liquid including raw materials dispersed in a solution is injected through nozzles to granulate fine particles of the raw materials.

[0187] The terms "image formation", "recording", "printing", "image printing", and "fabricating" used herein may be used synonymously with each other.

[0188] Numerous additional modifications and variations are possible in light of the above teachings. Such modifications and variations are not to be regarded as a departure from the scope of the present disclosure and appended claims, and all such modifications are intended to be included within the scope of the present disclosure and appended claims.

What is claimed is:

1. A liquid discharge head comprising:

a plurality of nozzle arrays arranged in a first direction,

wherein the plurality of nozzle arrays each includes nozzles from which a liquid is discharged, the nozzles arranged in a second direction intersecting the first direction, and

one of two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction include at least two nozzles arranged at different nozzle intervals from corresponding nozzles of another of the two nozzle arrays in the first direction.

2. The liquid discharge head according to claim **1**,

wherein two nozzles arrays of the plurality of nozzle arrays are arranged at an end part of the liquid discharge head in the first direction,

the two nozzle arrays include:

first nozzles arranged at a first nozzle interval wider than a nozzle interval of nozzles arranged at a central part of the liquid discharge head in the first direction; and

second nozzles arranged at a second nozzle interval narrower than a nozzle interval of nozzles arranged at the central part of the liquid discharge head in the first direction.

3. The liquid discharge head according to claim **1**,

wherein two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction include nozzles arranged at a constant nozzle interval in the first direction.

4. The liquid discharge head according to claim **1**, further comprising a plurality of nozzle array groups each including the plurality of nozzle arrays,

wherein nozzle intervals of the nozzles are different between the plurality of nozzle array groups.

5. A head module comprising a plurality of liquid discharge heads including the liquid discharge head according to claim **1**,

wherein the plurality of liquid discharge heads is arrayed in one direction.

6. A head device comprising a plurality of head modules including the head module according to claim **5**,

wherein the plurality of head modules is arrayed in the one direction.

7. A liquid discharge device comprising the head device according to claim **6**.

8. The liquid discharge device according to claim **7**,

wherein the liquid discharge head is integrated with at least one of:

a head tank configured to store the liquid to be supplied to the liquid discharge head,

a carriage on which the liquid discharge head is mounted,

a supply unit configured to supply the liquid to the liquid discharge head,

a recovery device configured to maintain the liquid discharge head, and

a main scan moving unit configured to move the liquid discharge head in a main scanning direction.

9. A liquid discharge apparatus comprising:

a liquid discharge head configured to discharge a liquid; and

a conveyor configured to convey a medium, onto which the liquid discharged from the liquid discharge head is applied, in a conveyance direction,

wherein the liquid discharge head includes:

a plurality of nozzle arrays arranged in a first direction perpendicular to the conveyance direction,

the plurality of nozzle arrays each includes nozzles from which the liquid is discharged, the nozzles arranged in a second direction intersecting the first direction, and

one of two nozzle arrays of the plurality of nozzle arrays adjacent to each other in the first direction includes at least two nozzles arranged at different nozzle intervals from corresponding nozzles of another of the two nozzle arrays in the first direction.

10. The liquid discharge apparatus according to claim **9**,

wherein two nozzle arrays of the plurality of nozzle arrays are arranged at an end part of the liquid discharge head in the first direction, and

the two nozzle arrays include:

first nozzles arranged at an upstream in the conveyance direction, the first nozzles arranged at a first nozzle interval wider than a nozzle interval of nozzles arranged at a central part of the liquid discharge head in the first direction, and

second nozzles arranged at a downstream of the first nozzles in the conveyance direction, the second nozzles arranged at a second nozzle interval narrower than a nozzle interval of nozzles arranged at the central part of the liquid discharge head in the first direction.

11. The liquid discharge apparatus according to claim **9**,

wherein a number of the plurality of nozzle arrays including the first nozzles is larger than a number of the plurality of nozzle arrays including the second nozzles.

12. The liquid discharge apparatus according to claim **9**, wherein nozzles disposed at a same stage in the second direction in each of the plurality of nozzle arrays arranged in the first direction include:

first nozzles arranged at an upstream in the conveyance direction, the first nozzles arranged at a first nozzle interval wider than a nozzle interval of nozzles arranged at a central part of the liquid discharge head in the first direction; and

second nozzles arranged at a downstream of the first nozzles in the conveyance direction, the second nozzles arranged at a second nozzle interval narrower than a nozzle interval of nozzles arranged at the central part of the liquid discharge head in the first direction.

13. The liquid discharge apparatus according to claim **12**, wherein a number of the plurality of nozzle arrays including the first nozzles is larger than a number of the plurality of nozzle arrays including the second nozzles.

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