US012391052B2

(12) United States Patent
Budraa

(10) Patent No.: US 12,391,052 B2
(45) Date of Patent: Aug. 19, 2025

(54) **PASSIVE MIXER IN JETTING CHANNELS OF A PRINTHEAD**

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(73) Assignee: **Ricoh Company, Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 71 days.

(21) Appl. No.: **18/110,822**

(22) Filed: **Feb. 16, 2023**

(65) **Prior Publication Data**

US 2024/0278584 A1 Aug. 22, 2024

(51) **Int. Cl.**
B41J 2/21 (2006.01)
B41J 2/14 (2006.01)
B41J 2/175 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/211*** (2013.01); ***B41J 2/1433*** (2013.01); ***B41J 2/17513*** (2013.01); *B41J 2002/14467* (2013.01); *B41J 2002/14483* (2013.01); *B41J 2202/11* (2013.01)

(58) **Field of Classification Search**
CPC B41J 2/211; B41J 2/1433; B41J 2/17513; B41J 2002/14467; B41J 2002/14483; B41J 2202/11
See application file for complete search history.

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Primary Examiner — Jason S Uhlenhake
(74) *Attorney, Agent, or Firm* — Duft & Bornsen, PC

(57) **ABSTRACT**

Printheads that jet print fluids. In an embodiment, a printhead comprises a plurality of jetting channels, where each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid. The printhead further comprises one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel.

22 Claims, 32 Drawing Sheets

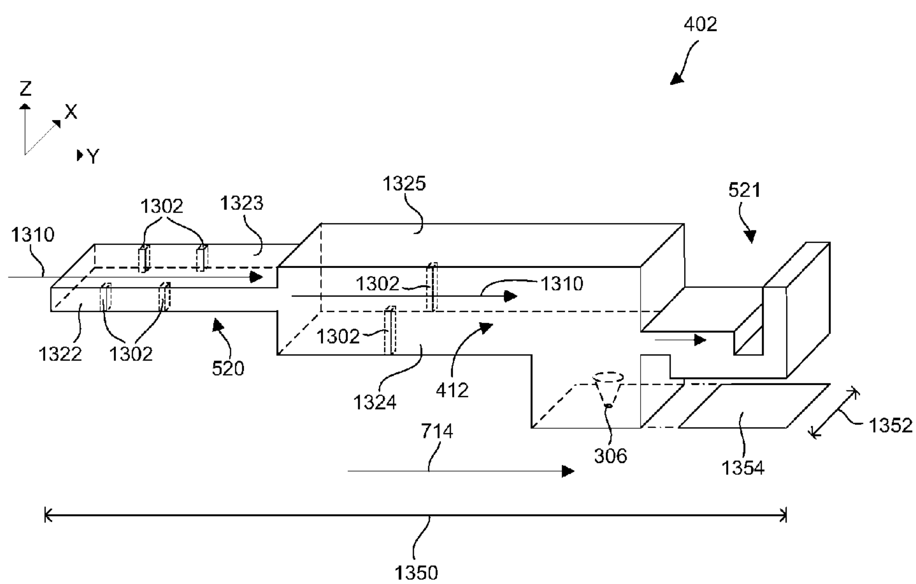

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FIG. 1

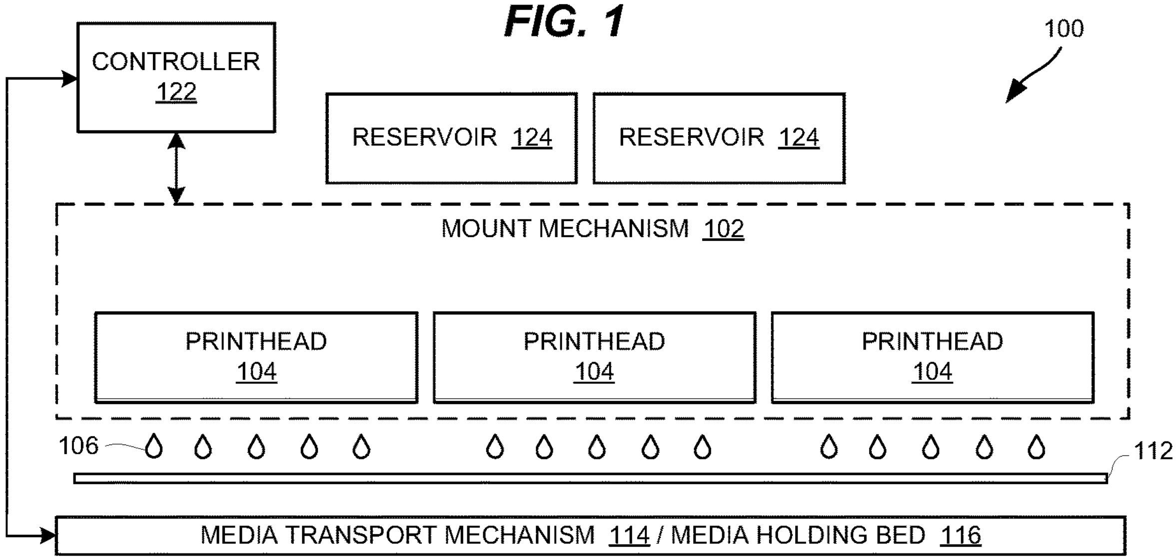

100
CONTROLLER 122
RESERVOIR 124
RESERVOIR 124
MOUNT MECHANISM 102
PRINTHEAD 104
PRINTHEAD 104
PRINTHEAD 104
106
112
MEDIA TRANSPORT MECHANISM 114 / MEDIA HOLDING BED 116

FIG. 2

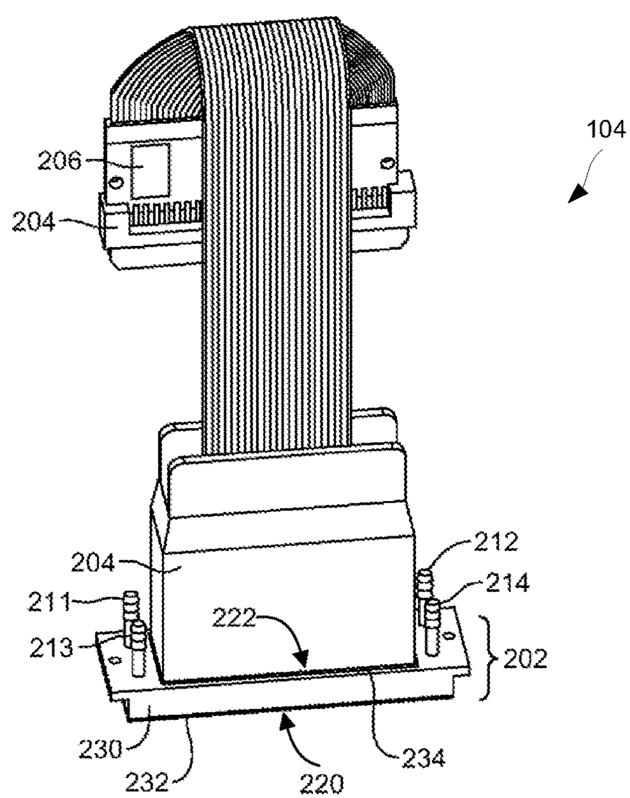

104
206
204
204
212
214
211
213
222
202
230
232
220
234

FIG. 3

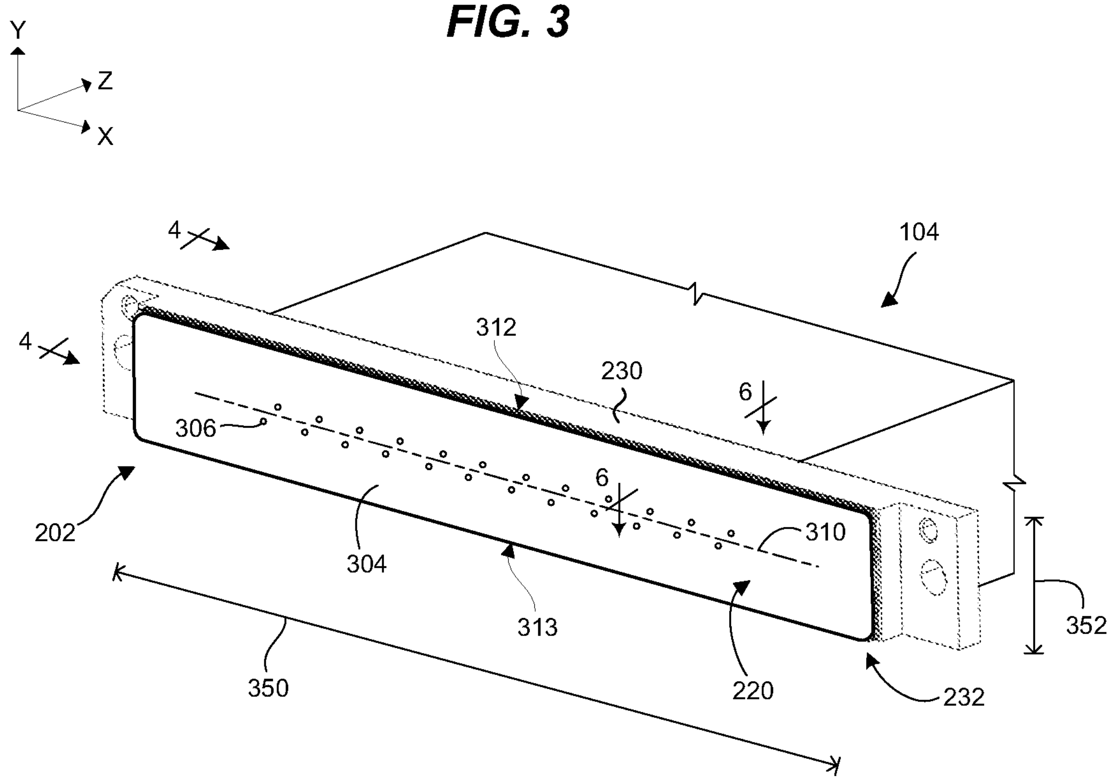

Y
Z
X
4
4
104
312
230
6
306
6
310
202
304
313
352
350
220
232

FIG. 4

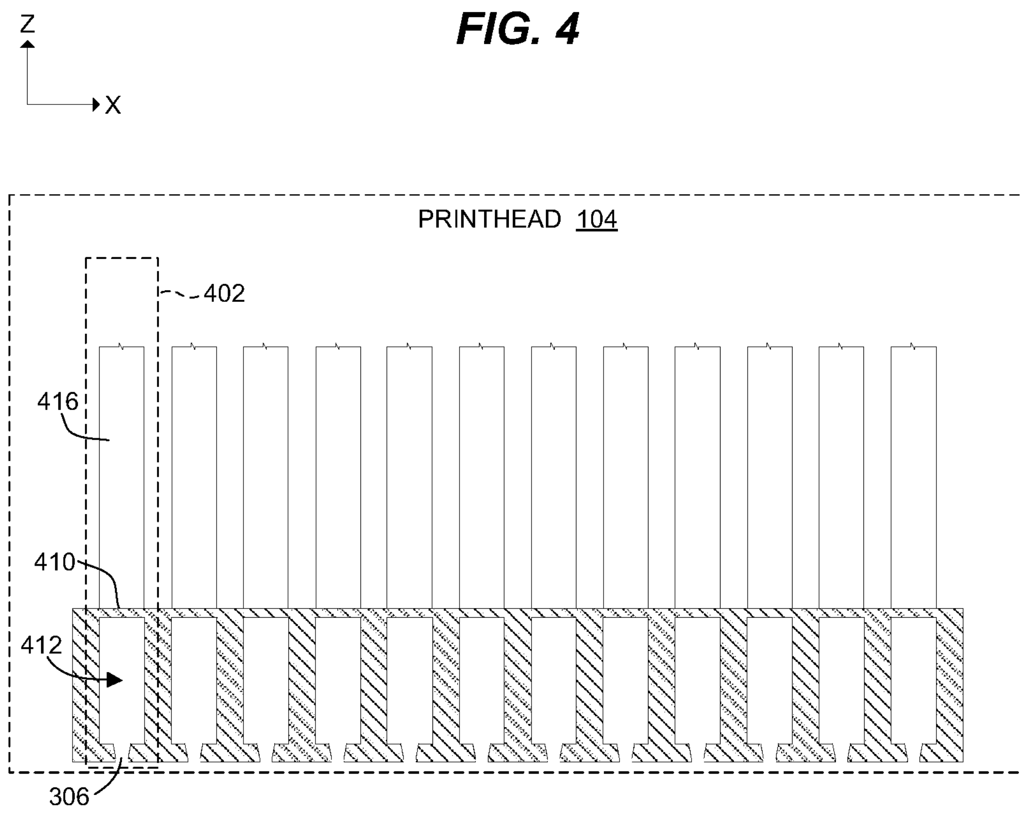

Z
X
PRINTHEAD 104
402
416
410
412
306

FIG. 5A

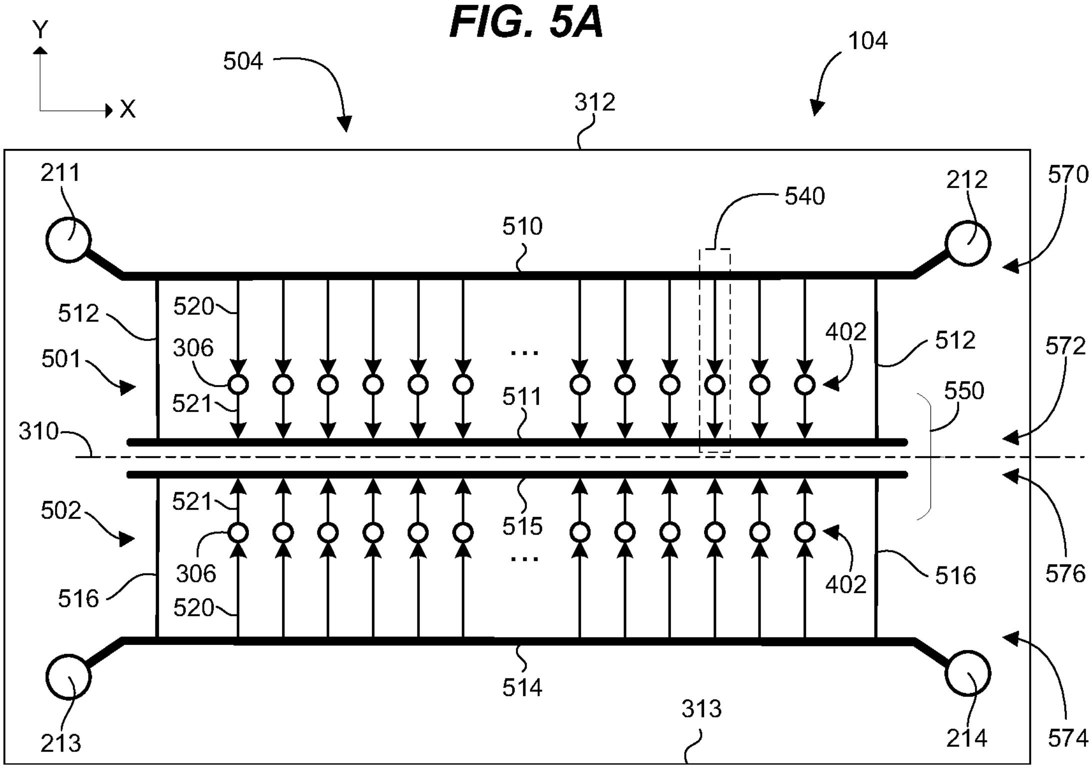
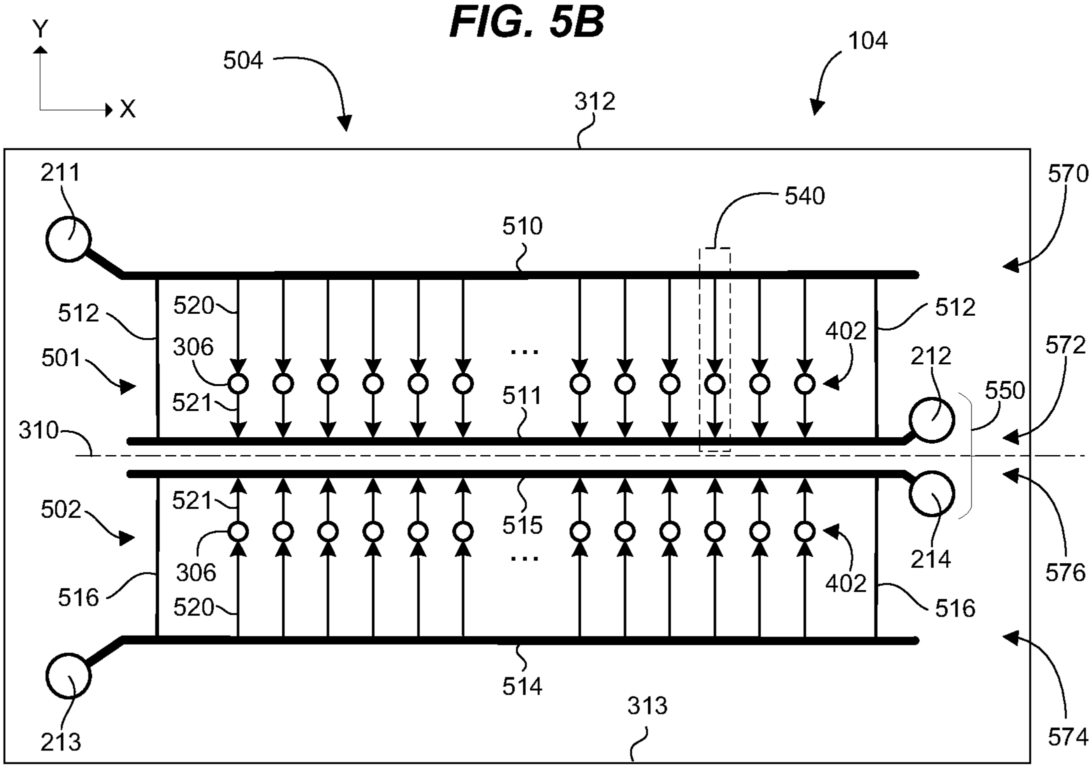

Y
X
504
104
312
211
212
570
540
510
512
520
402
512
572
501
306
511
550
521
310
502
521
515
576
306
402
516
516
520
514
213
313
214
574

FIG. 5B


Y
X
504
104
312
211
570
540
510
512
520
512
306
402
572
501
212
521
511
550
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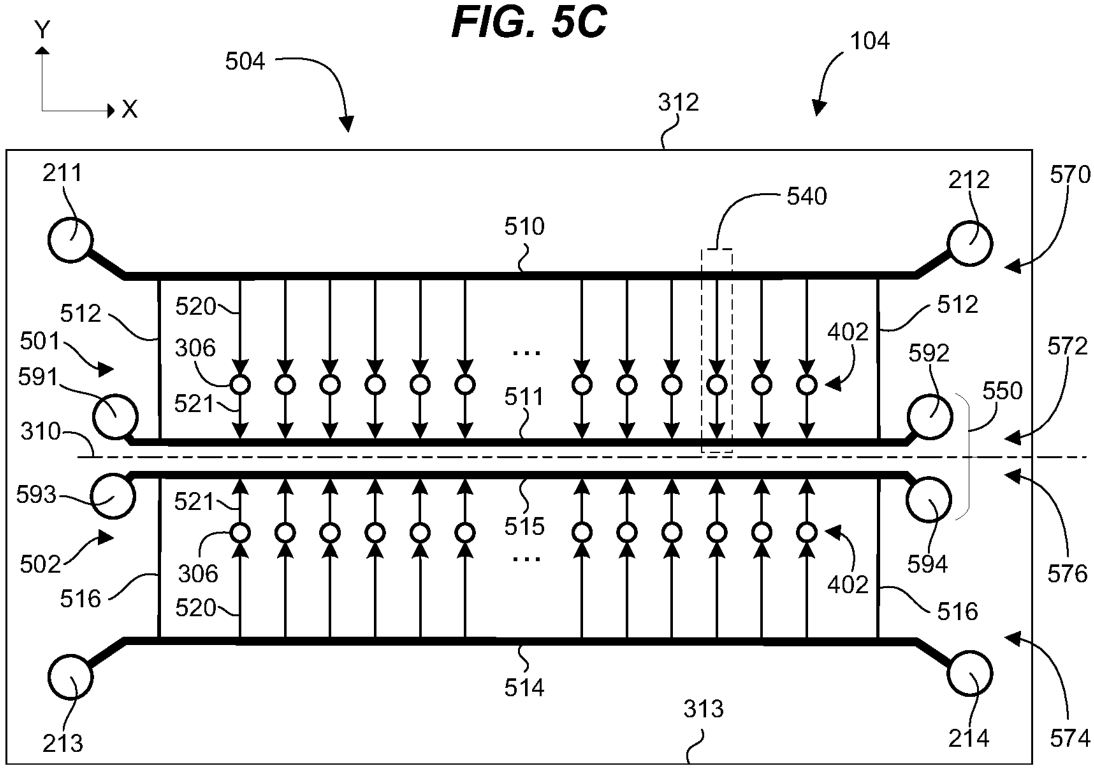
502
521
515
214
576
306
402
516
516
520
514
313
213
574

FIG. 5C



Y
X
504
104
312
211
212
570
540
510
512
520
512
402
501
306
592
591
521
511
572
550
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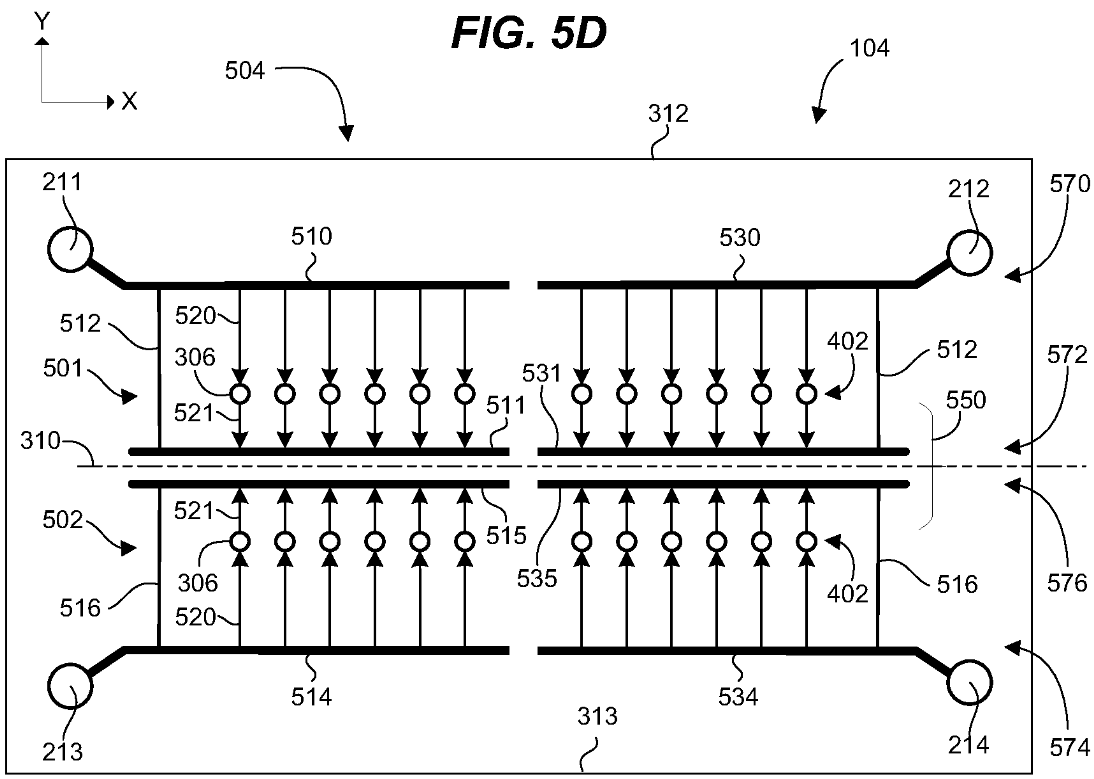
515
594
502
306
516
520
402
516
576
514
313
213
214
574

FIG. 5D



Y
X
504
104
312
211
212
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510
530
512
520
402
512
306
501
531
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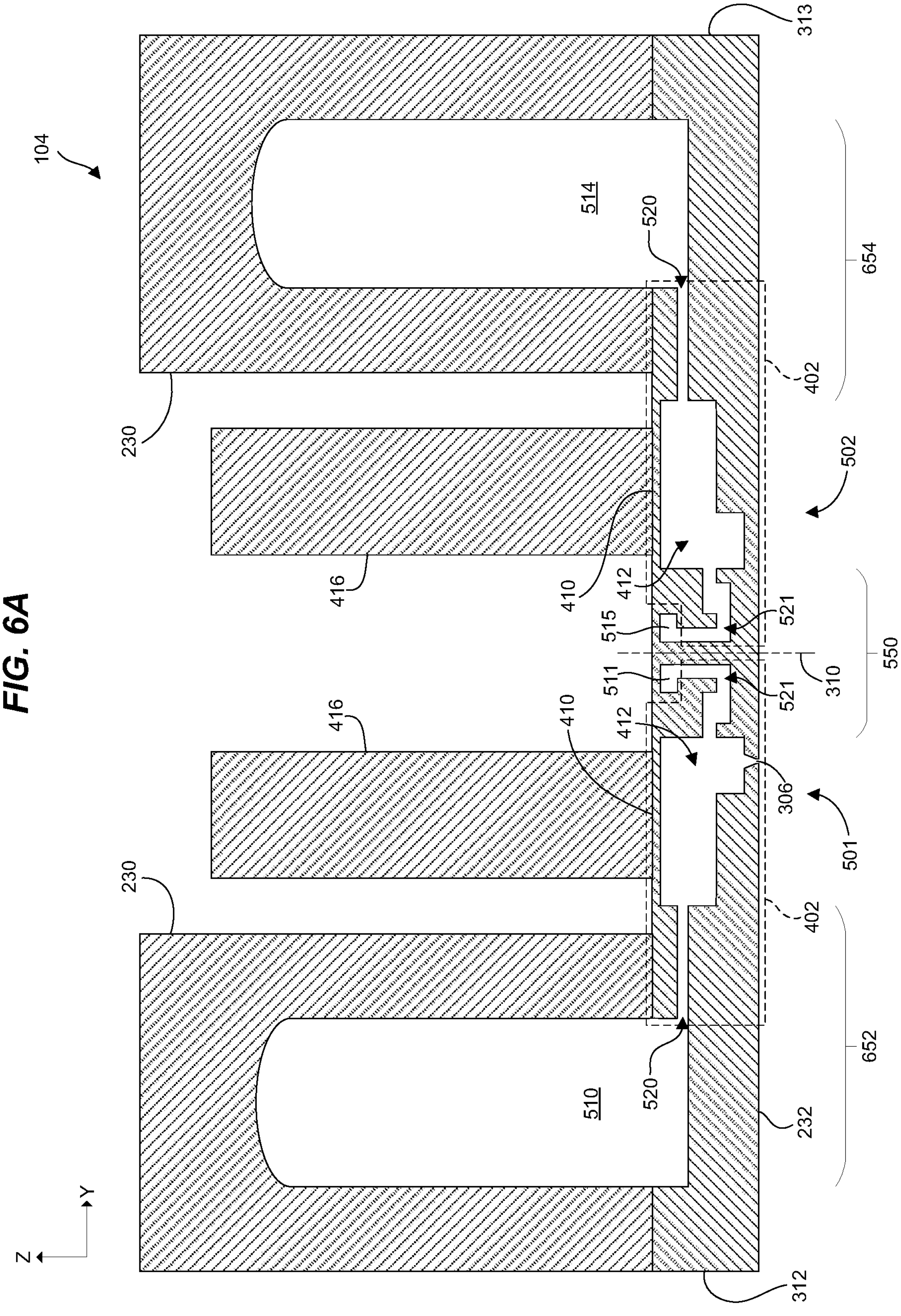
534
313
213
214
574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313
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520
654
402
230
502
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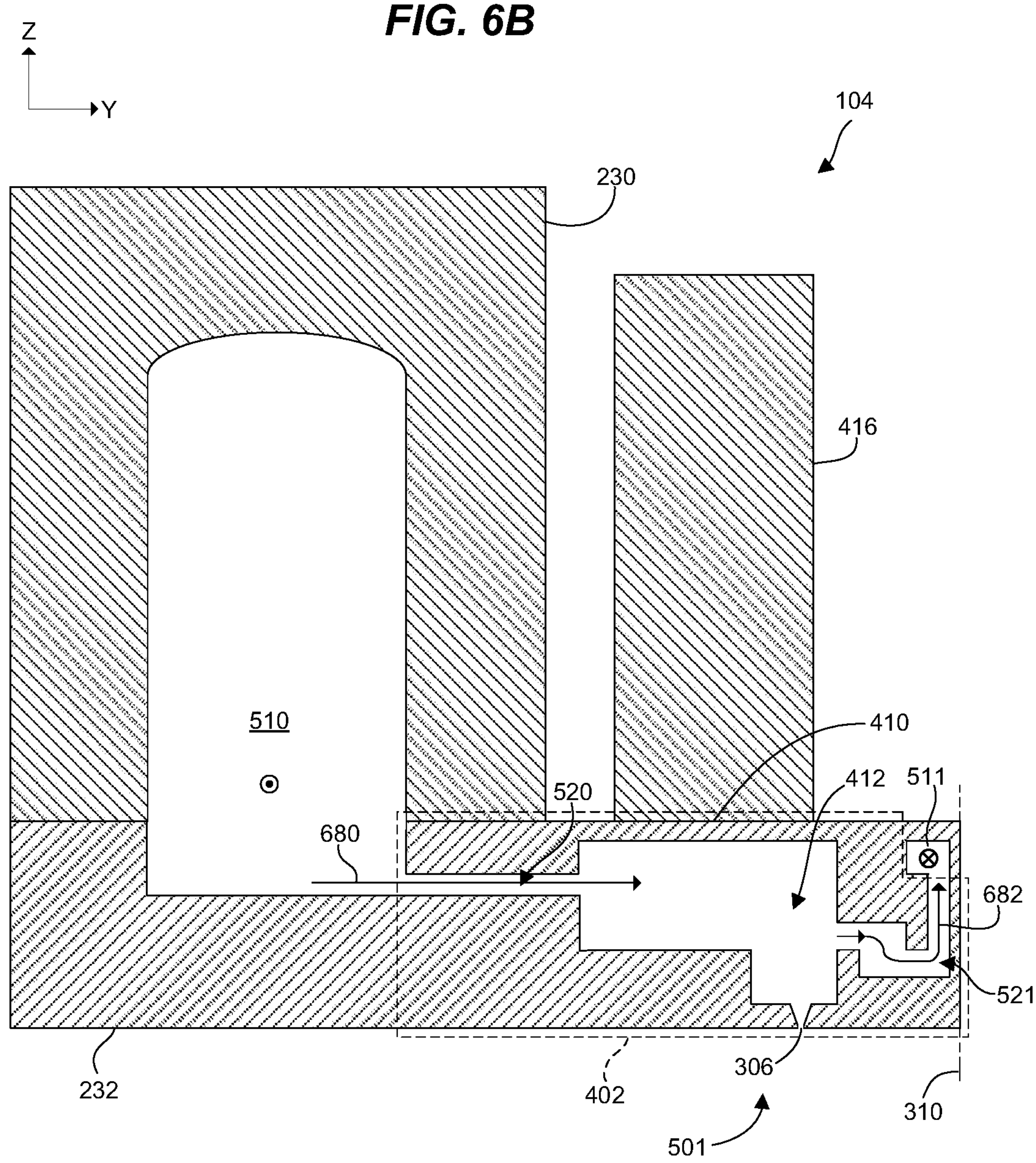
412
416
515
521
550
310
511
306
501
652
510
232
312
Z
Y

FIG. 6A

FIG. 6B



Z
Y
104
230
416
510
410
412
511
520
680
682
521
306
232
402
310
501

FIG. 7

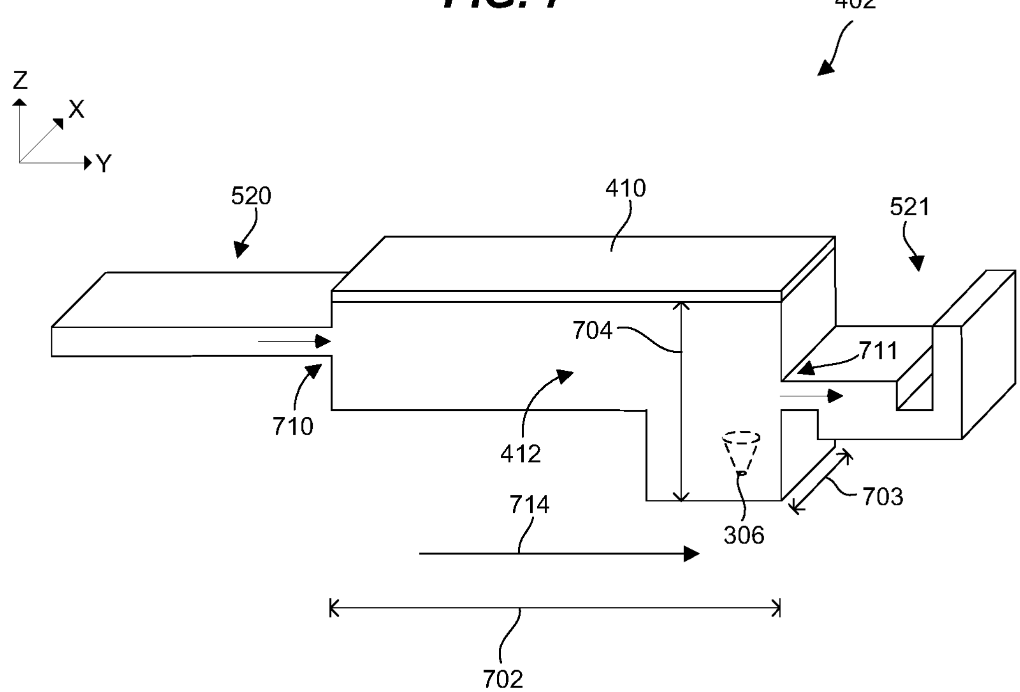
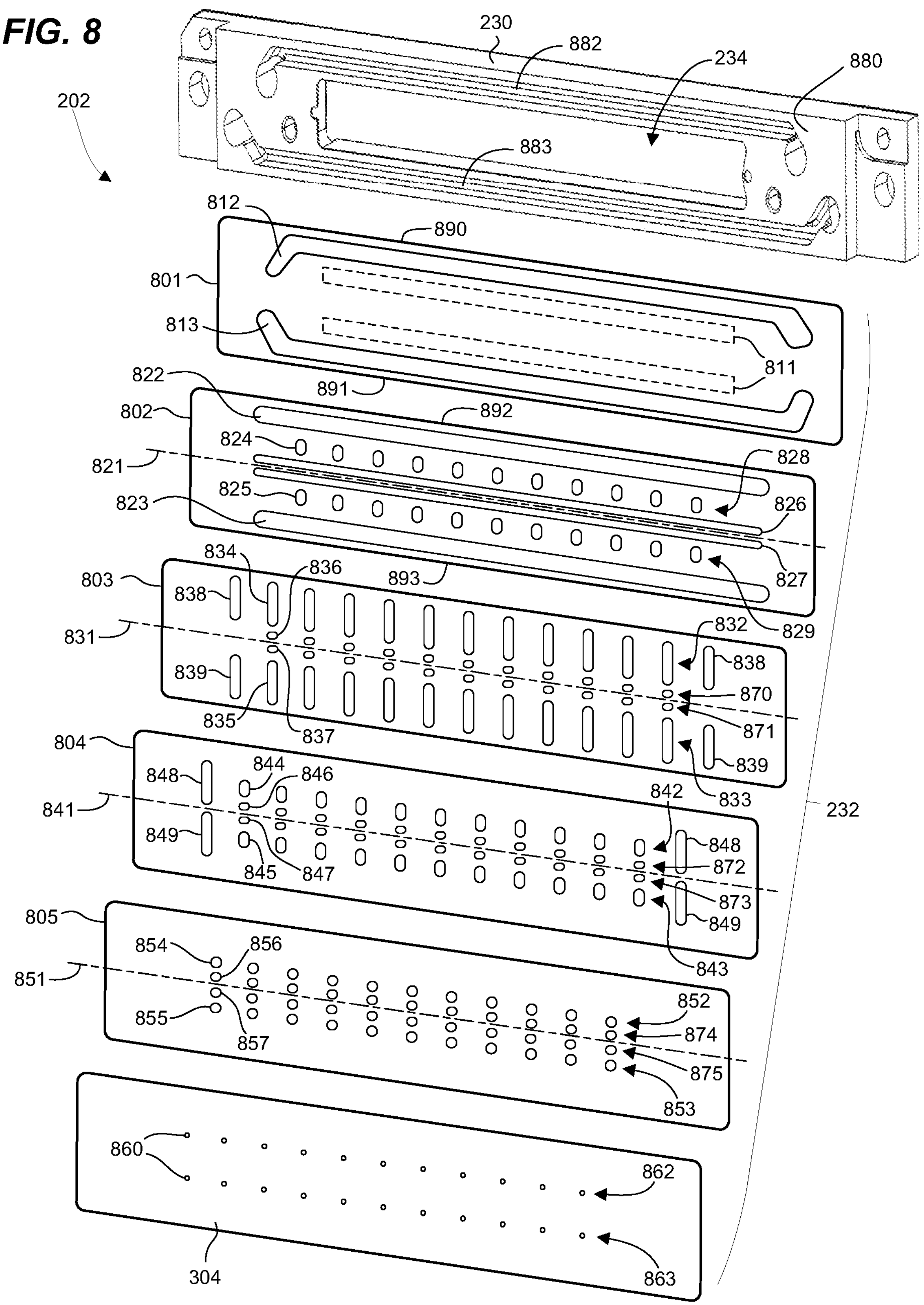
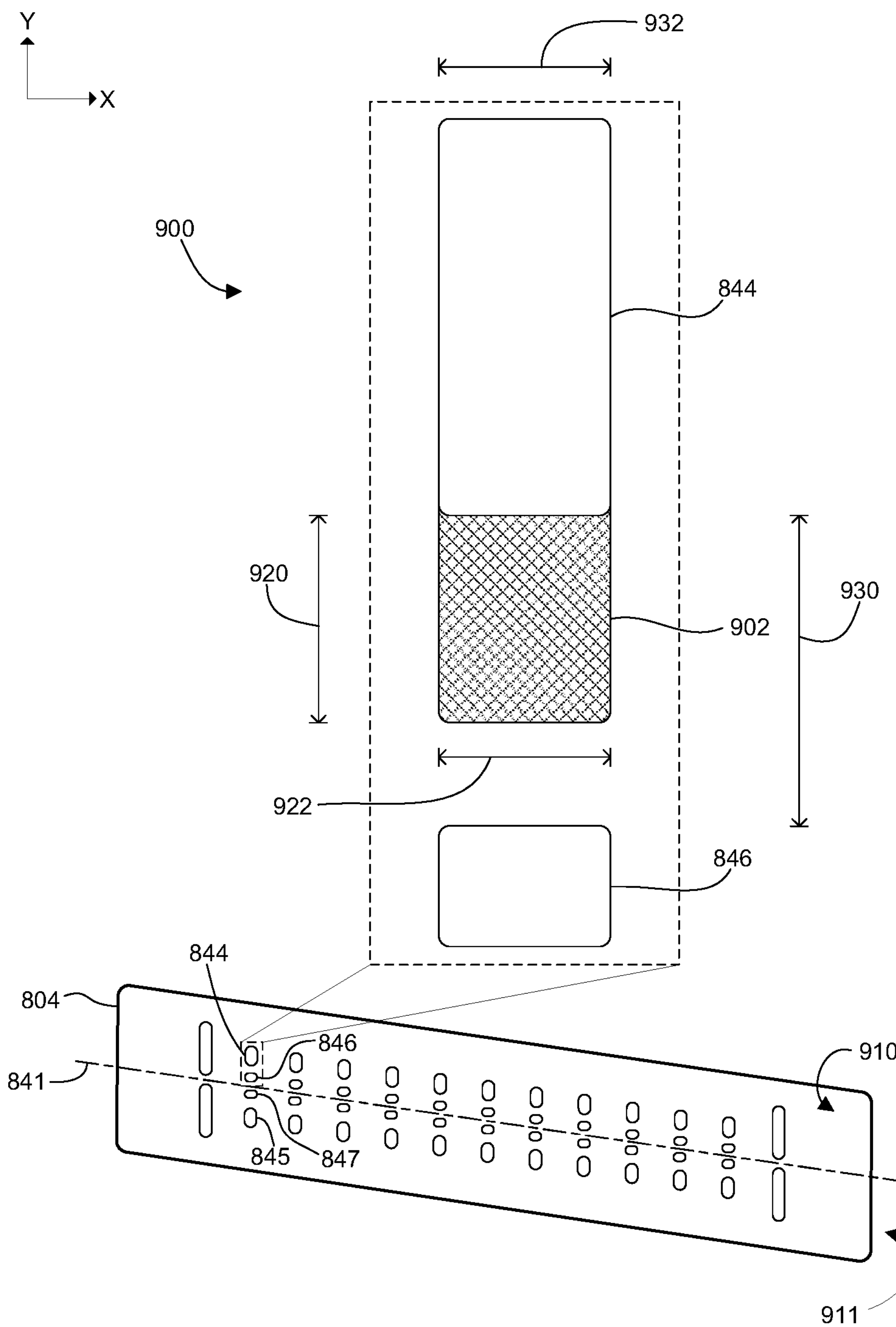


FIG. 8



202
230
882
234
880
883
812
890
801
813
811
822
891
802
892
824
828
821
825
826
823
834
836
827
803
893
838
829
831
832
838
839
870
871
835
837
804
839
833
848
844
846
842
232
841
848
872
849
845
847
873
849
805
843
854
856
851
852
874
855
857
875
853
860
862
304
863

FIG. 9



Y
X
932
900
844
920
902
930
922
846
844
804
846
910
841
845
847
911

FIG. 10

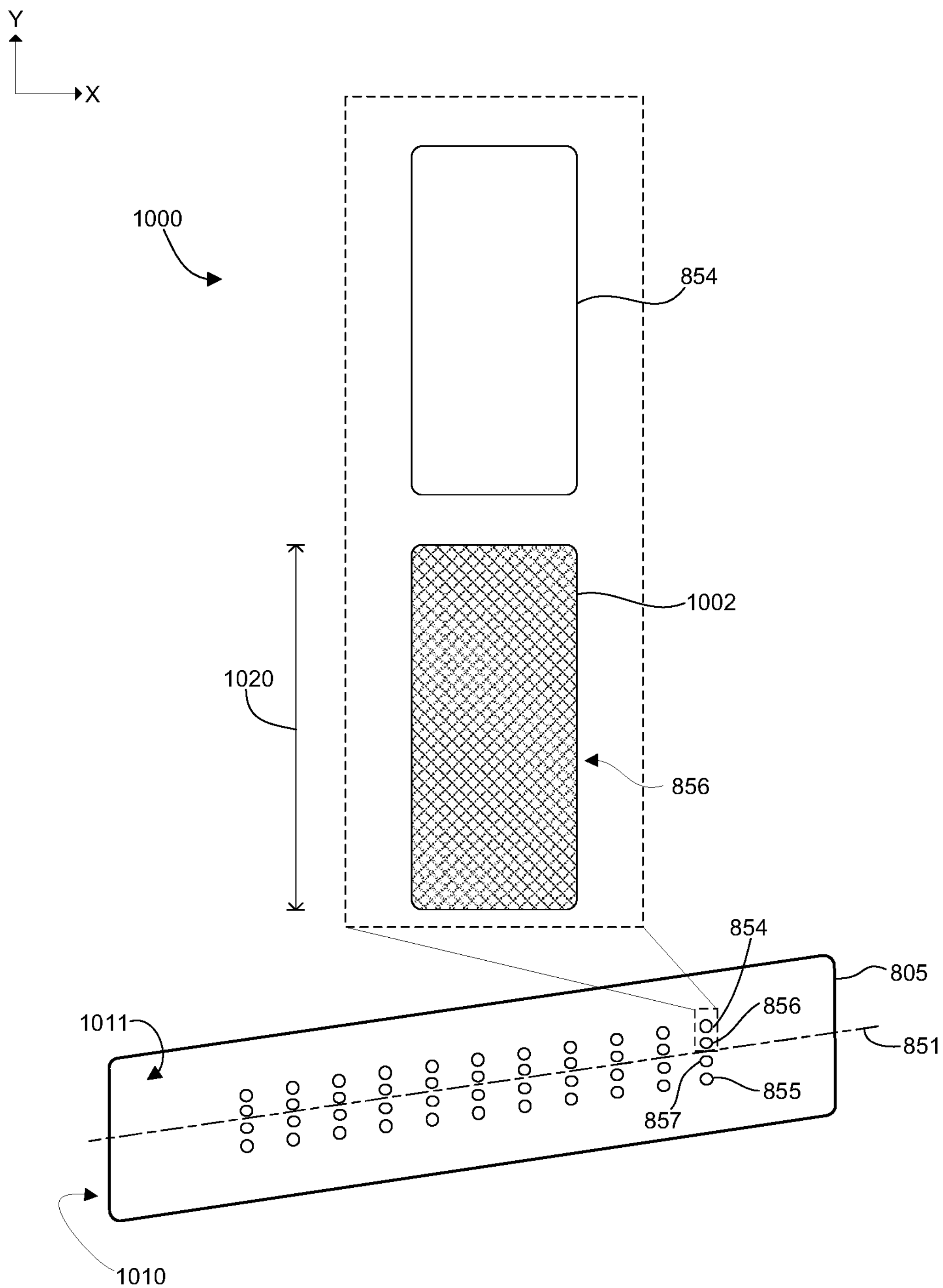


FIG. 11

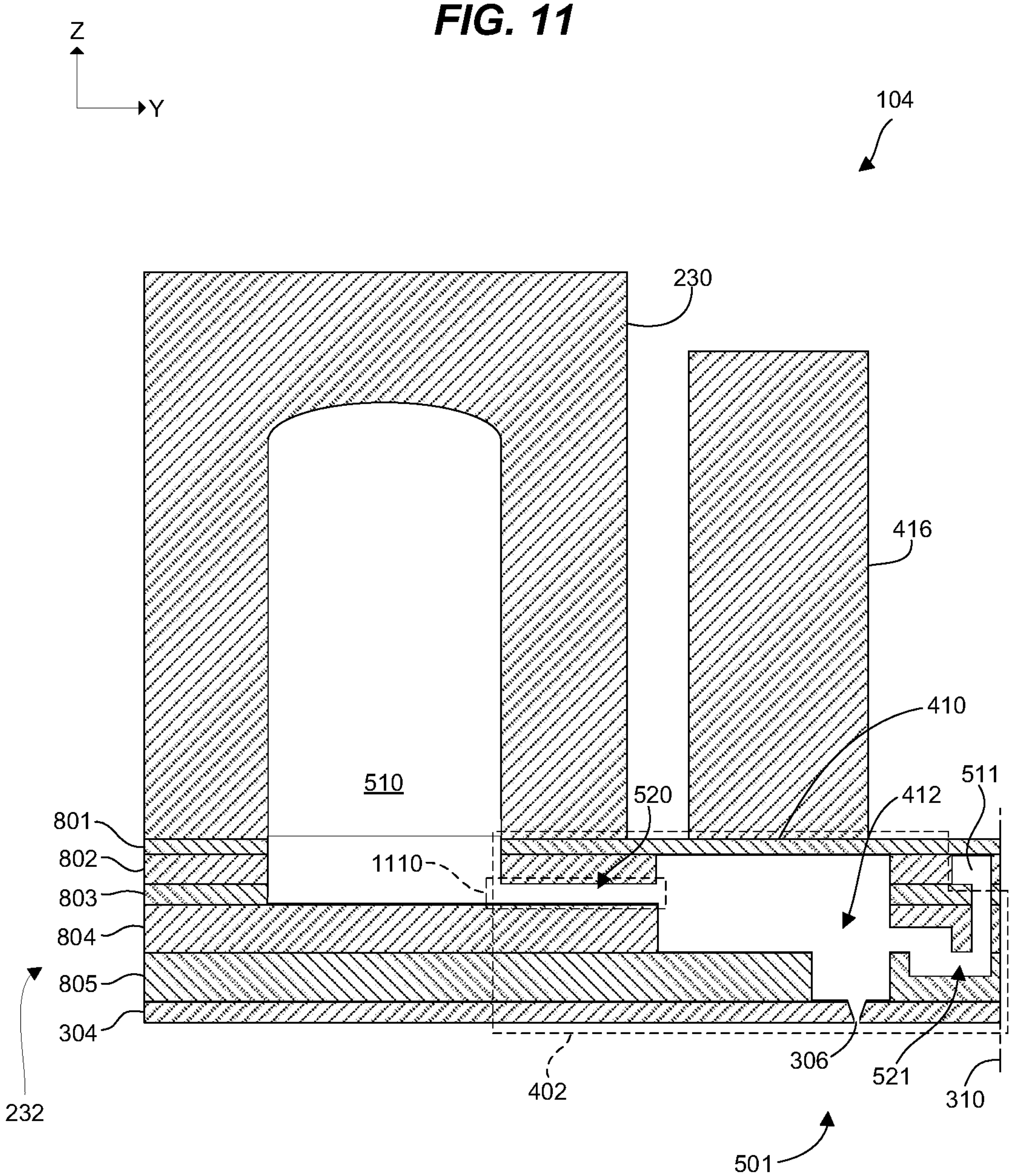

Z
Y
104
230
416
410
510
520
412
511
801
802
803
804
805
304
1110
232
402
306
521
310
501

FIG. 12

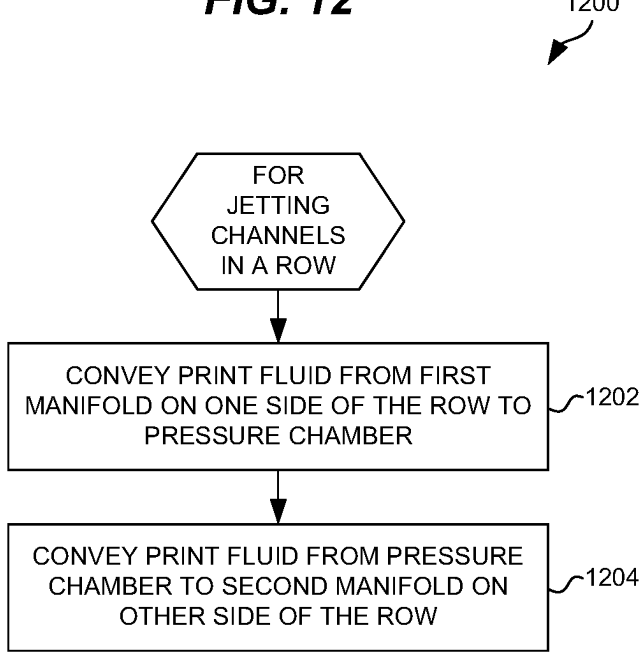

1200
FOR JETTING CHANNELS IN A ROW
CONVEY PRINT FLUID FROM FIRST MANIFOLD ON ONE SIDE OF THE ROW TO PRESSURE CHAMBER
1202
CONVEY PRINT FLUID FROM PRESSURE CHAMBER TO SECOND MANIFOLD ON OTHER SIDE OF THE ROW
1204

FIG. 13

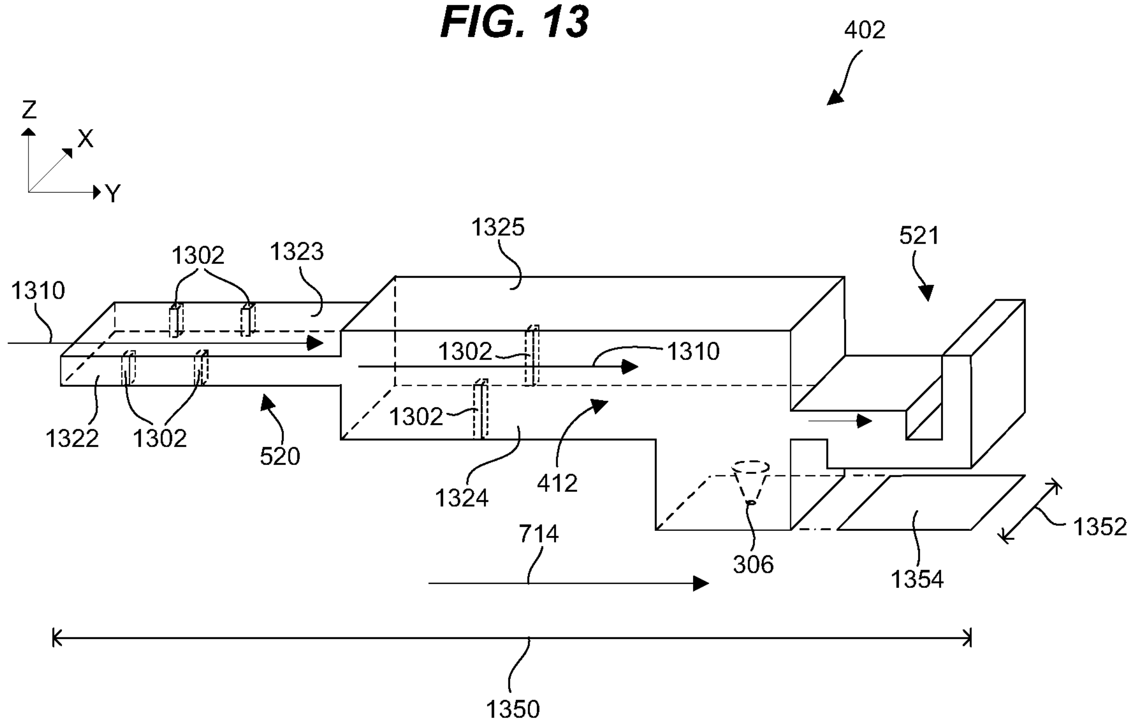

402
Z
X
Y
1325
521
1302
1323
1310
1302
1310
1302
1322
1302
520
1324
412
714
306
1354
1352
1350

FIG. 14A

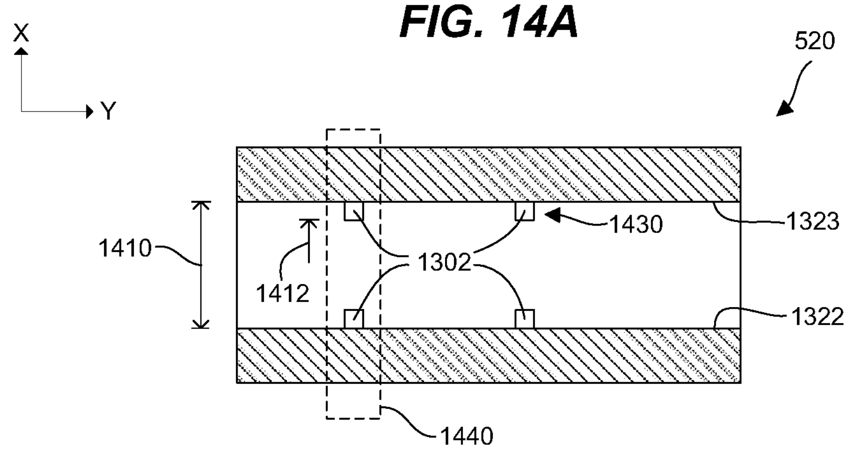


FIG. 14B

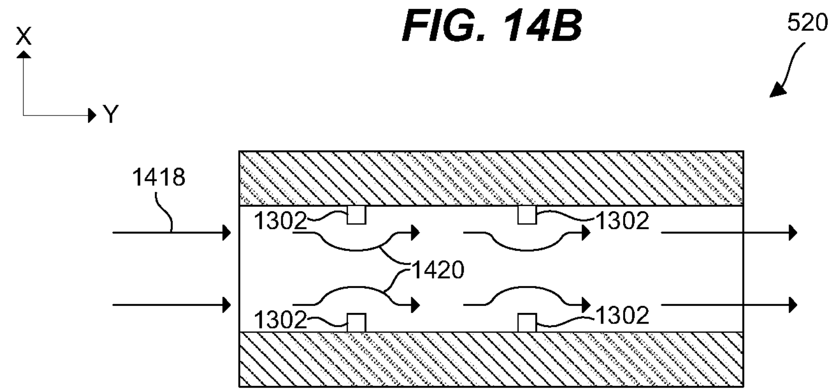


FIG. 14C

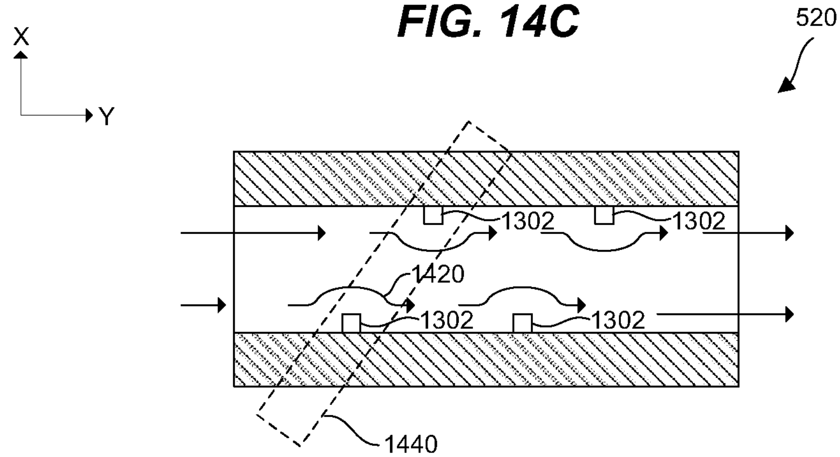


FIG. 14D

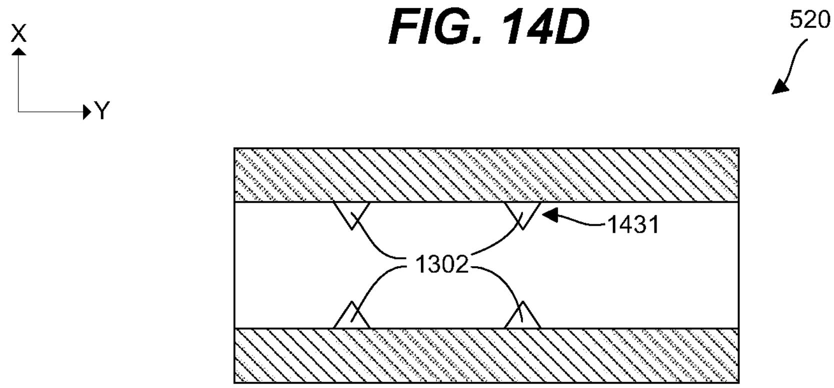


FIG. 14E

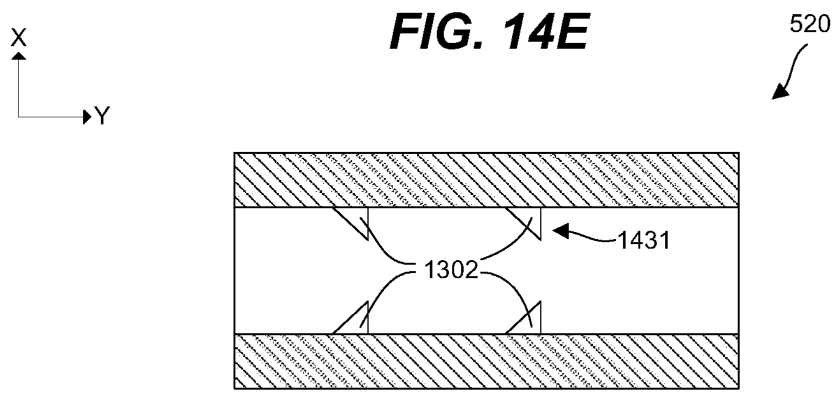


FIG. 14F

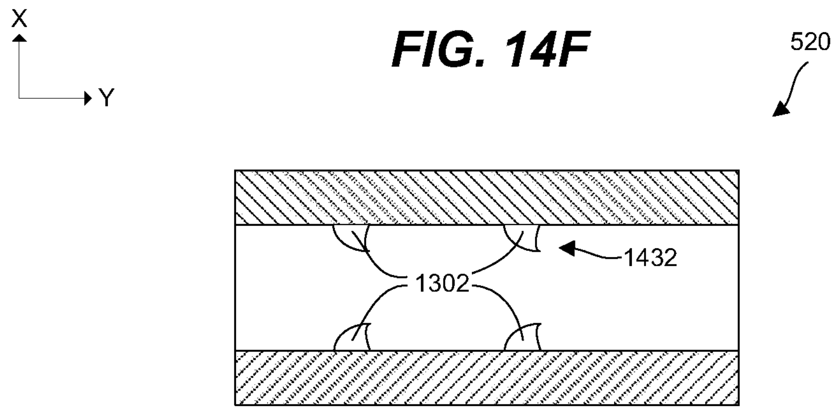


FIG. 14G

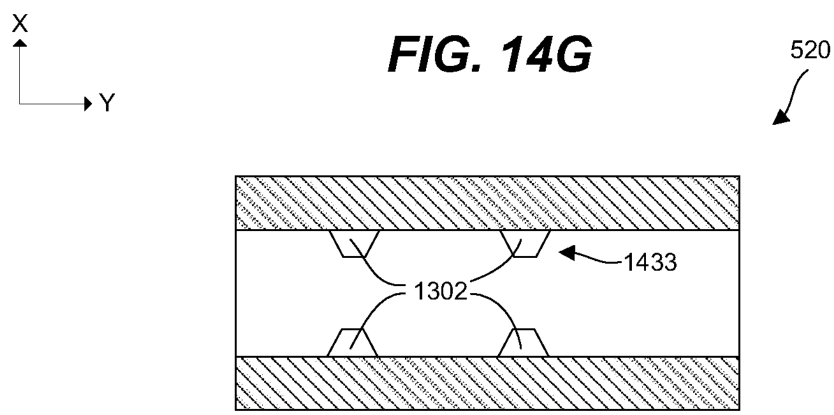


FIG. 14H

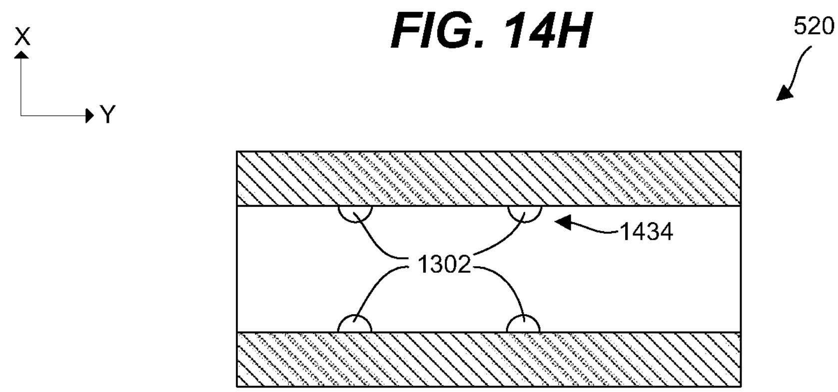


FIG. 15

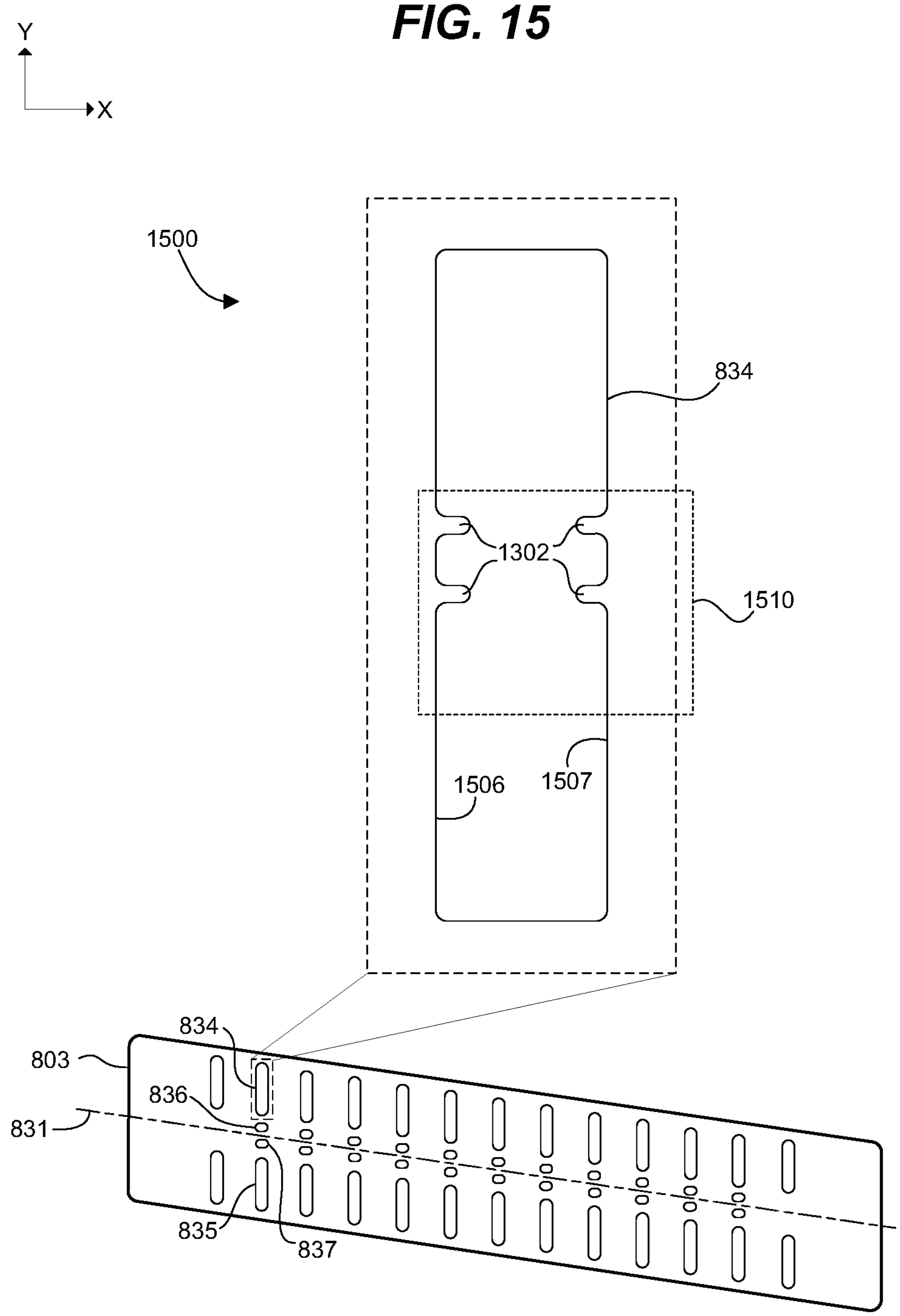


FIG. 16

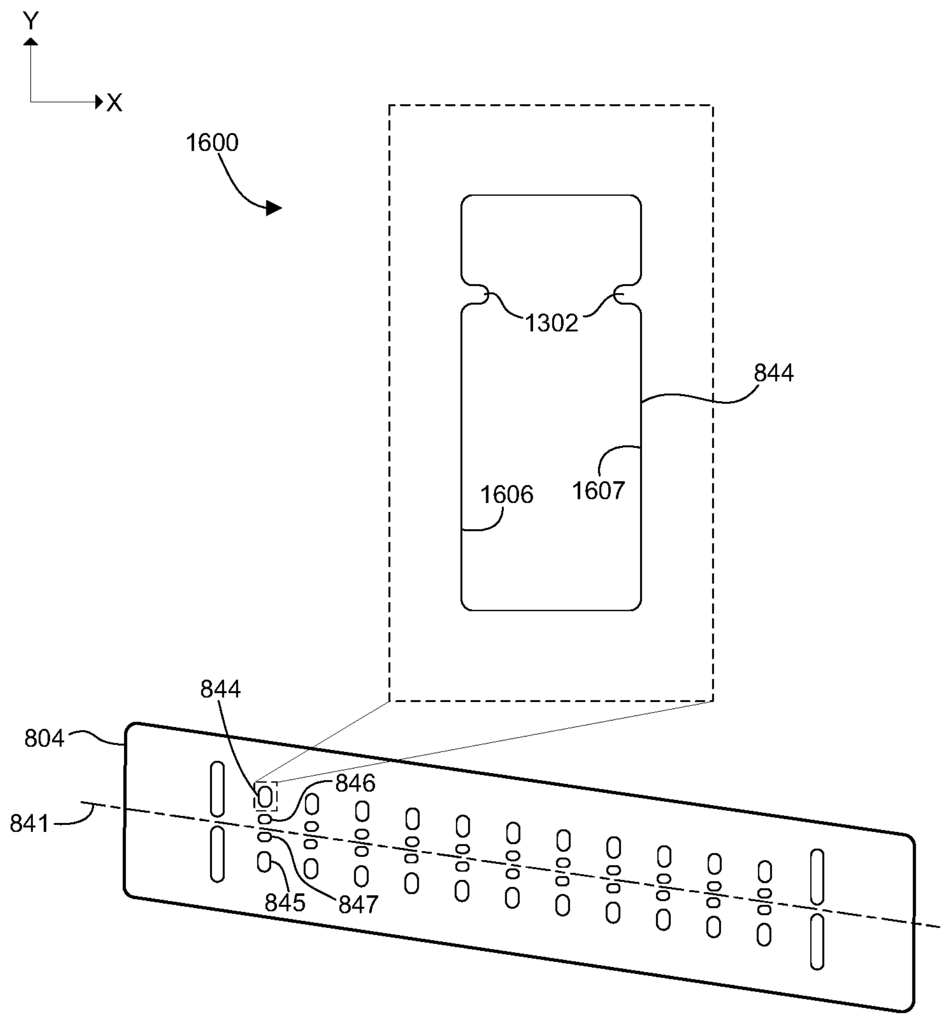


FIG. 17

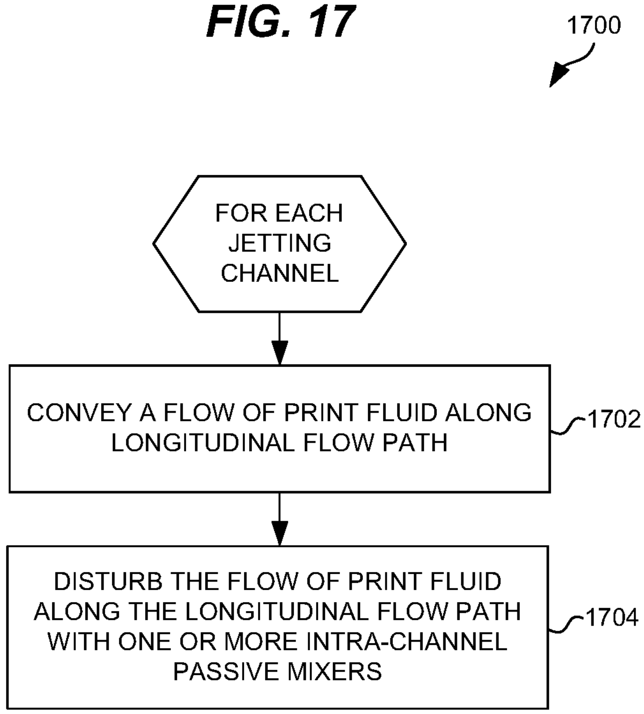

1700
FOR EACH JETTING CHANNEL
CONVEY A FLOW OF PRINT FLUID ALONG LONGITUDINAL FLOW PATH
1702
DISTURB THE FLOW OF PRINT FLUID ALONG THE LONGITUDINAL FLOW PATH WITH ONE OR MORE INTRA-CHANNEL PASSIVE MIXERS
1704

FIG. 18

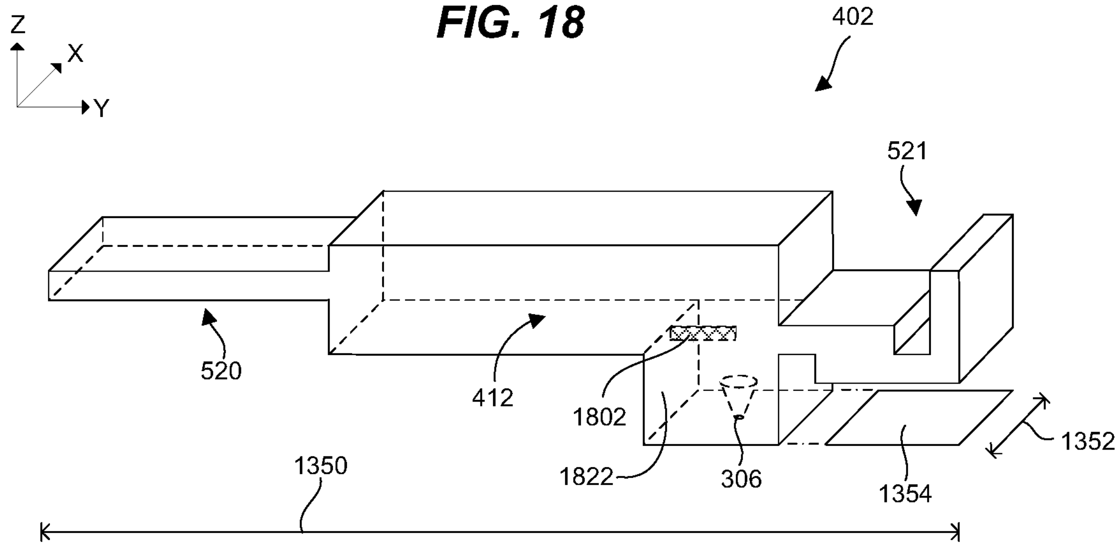


FIG. 19

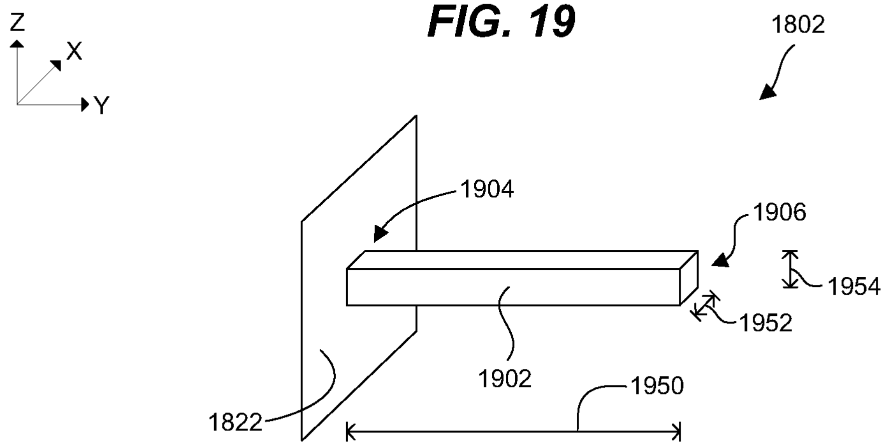


FIG. 20

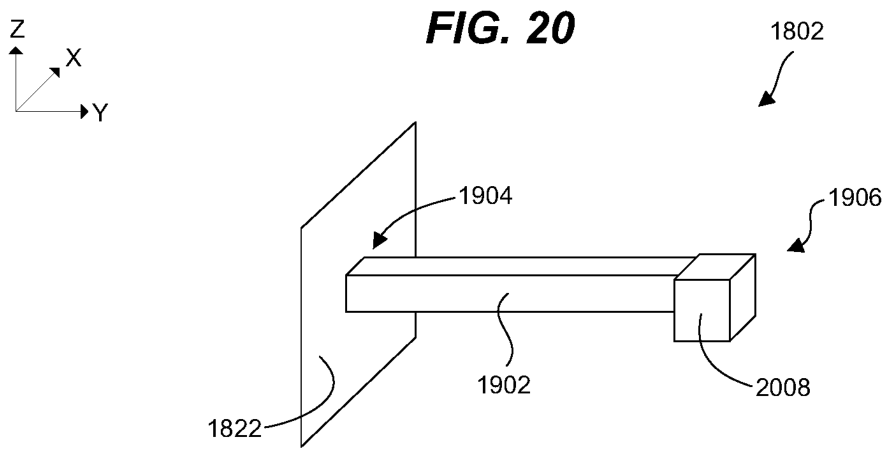


FIG. 21A

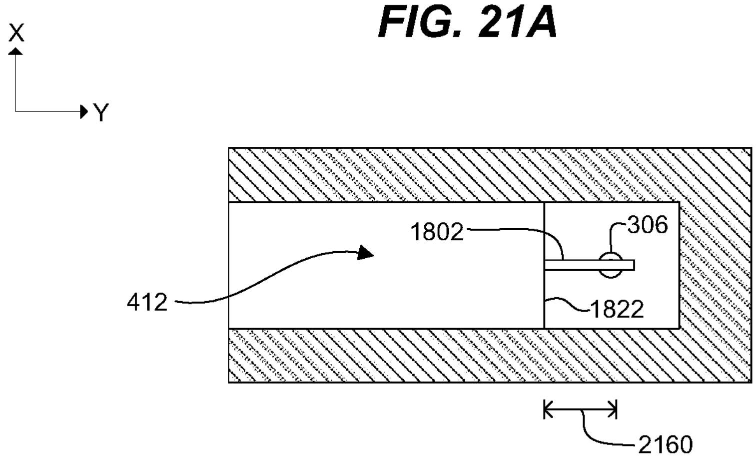


FIG. 21B

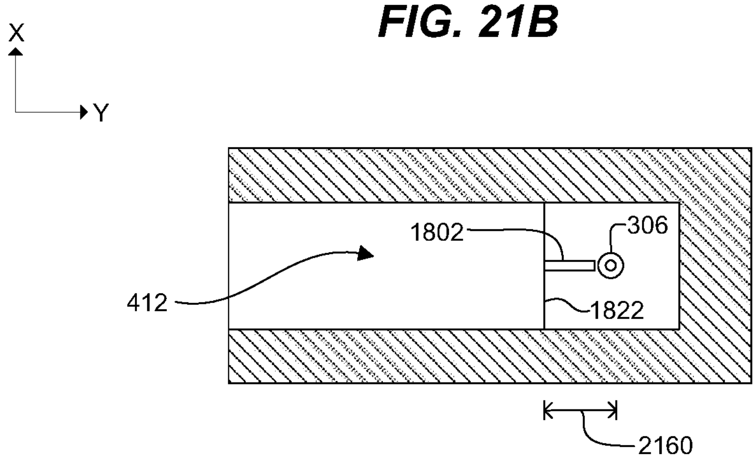


FIG. 21C

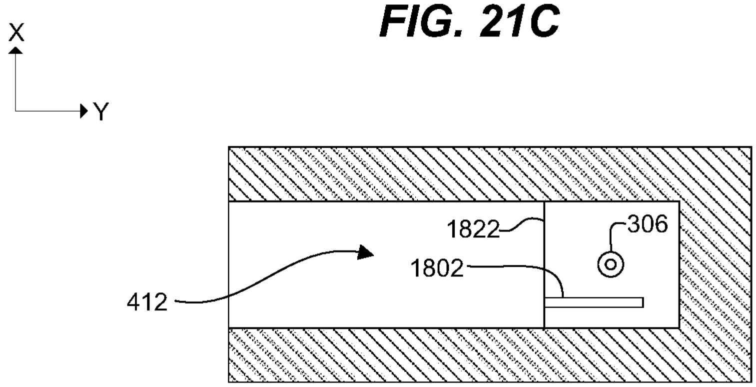


FIG. 21D

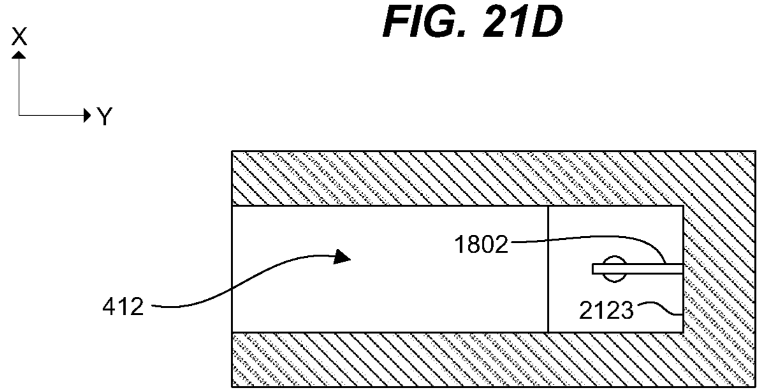


FIG. 21E

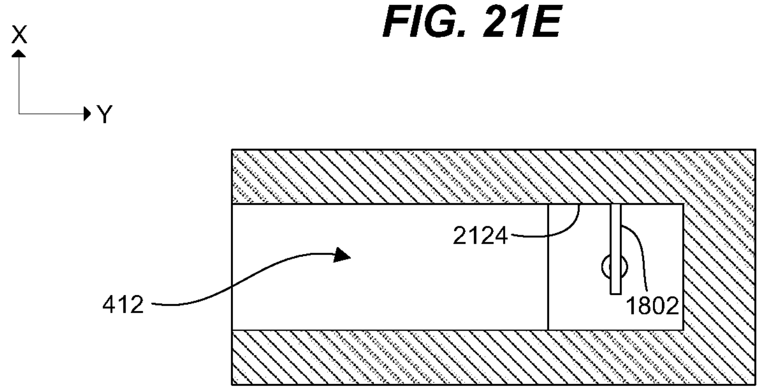


FIG. 21F

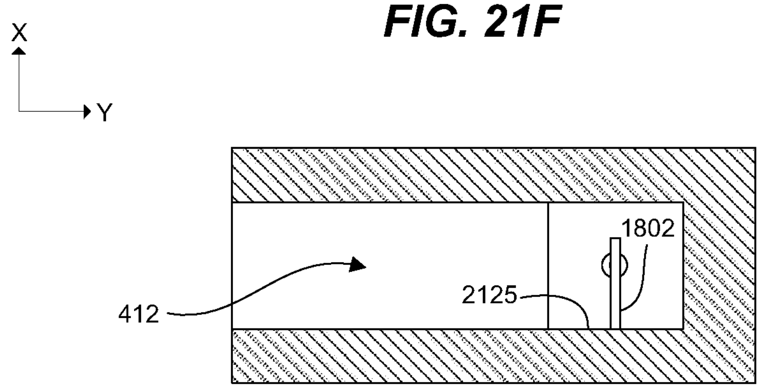


FIG. 21G

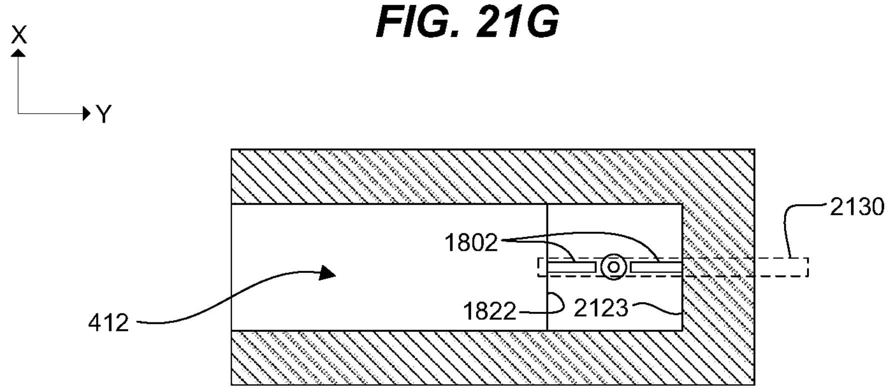


FIG. 21H

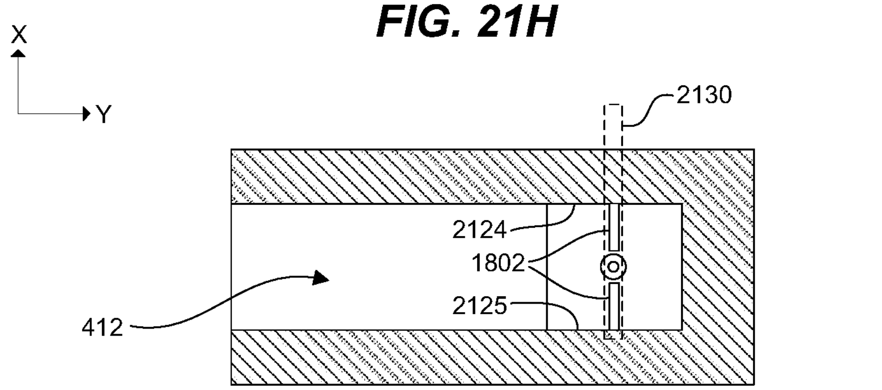


FIG. 21I

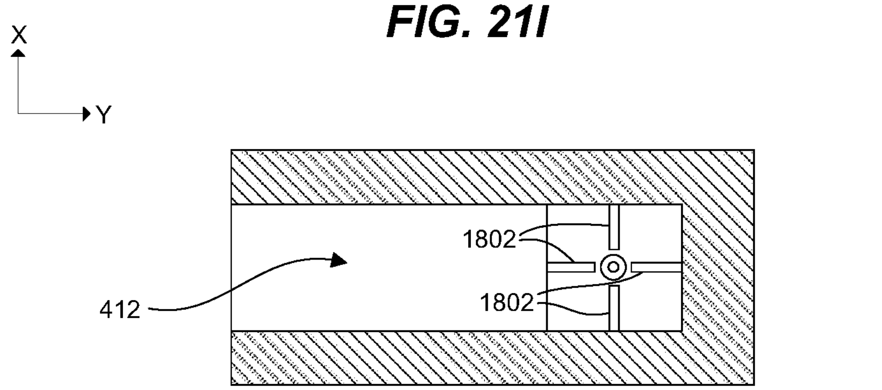


FIG. 22

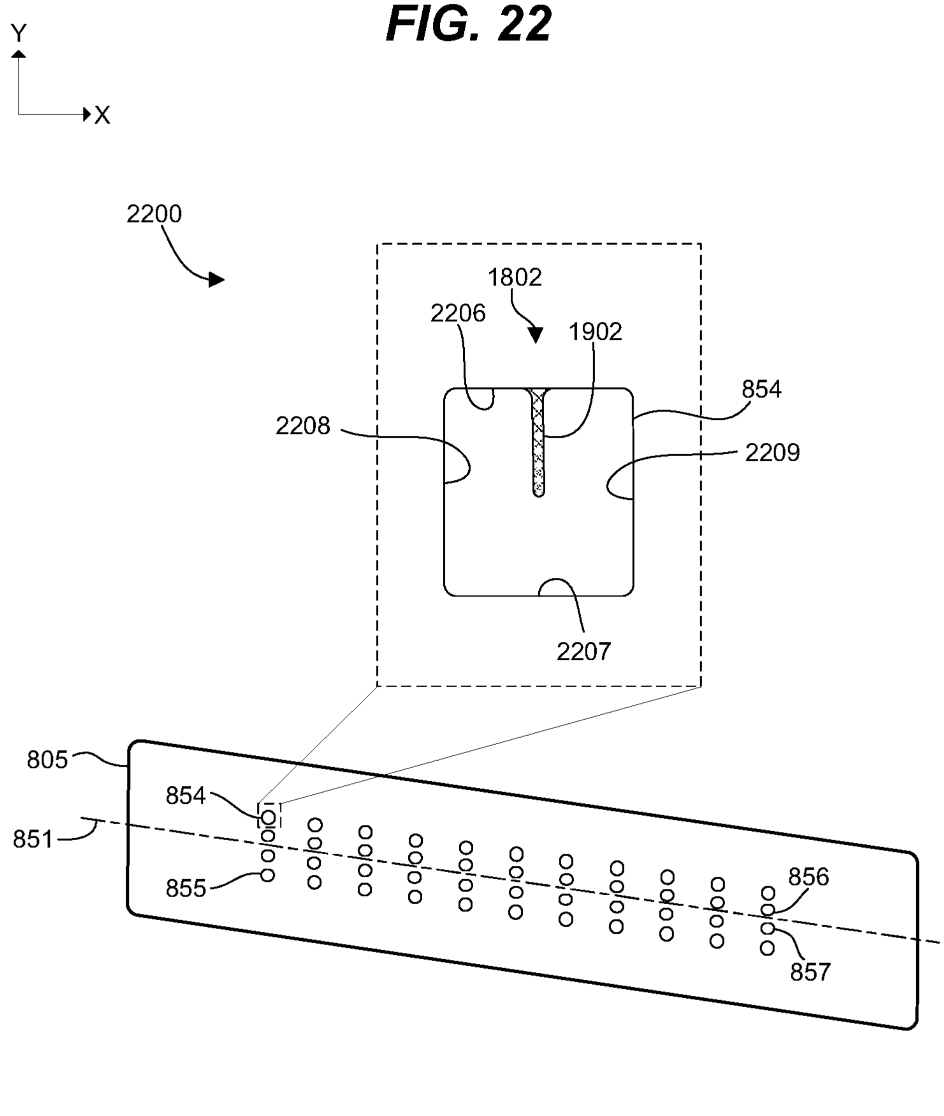

Y
X
2200
1802
2206
1902
854
2208
2209
2207
805
854
851
855
856
857

FIG. 23

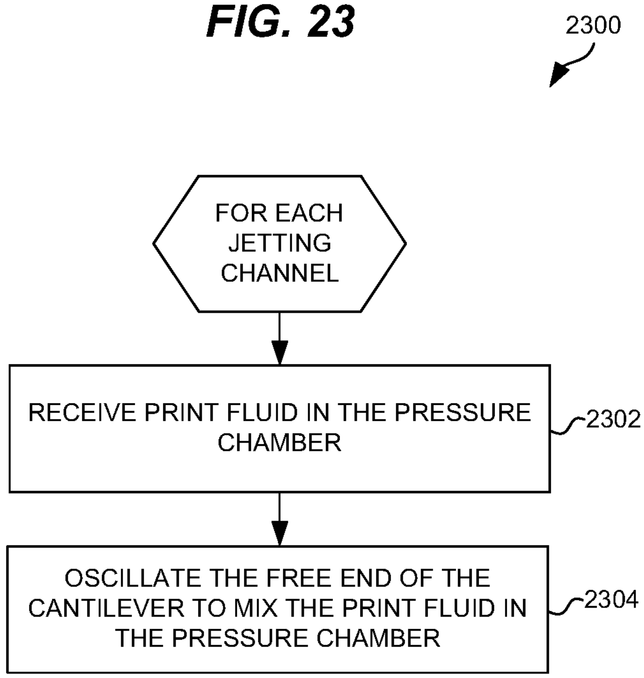

2300
FOR EACH JETTING CHANNEL
RECEIVE PRINT FLUID IN THE PRESSURE CHAMBER
2302
OSCILLATE THE FREE END OF THE CANTILEVER TO MIX THE PRINT FLUID IN THE PRESSURE CHAMBER
2304

FIG. 24

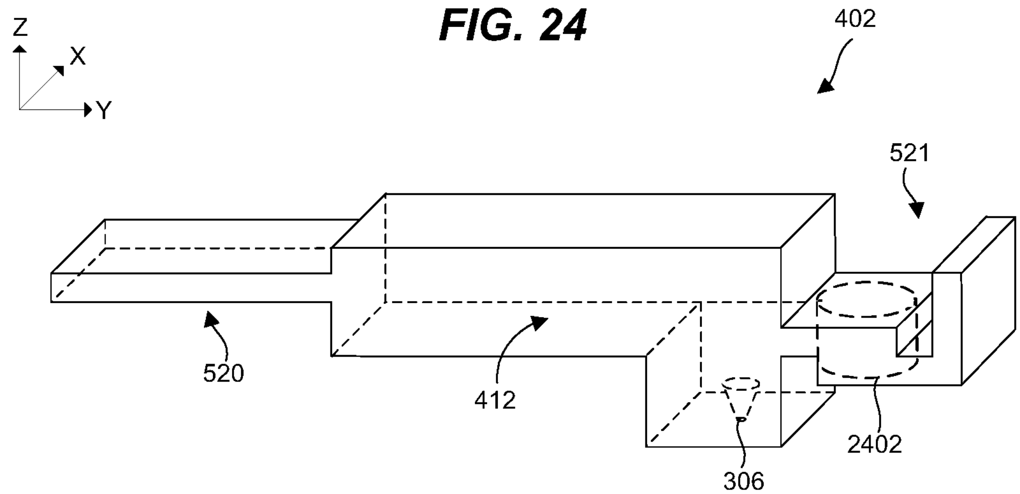


FIG. 25A

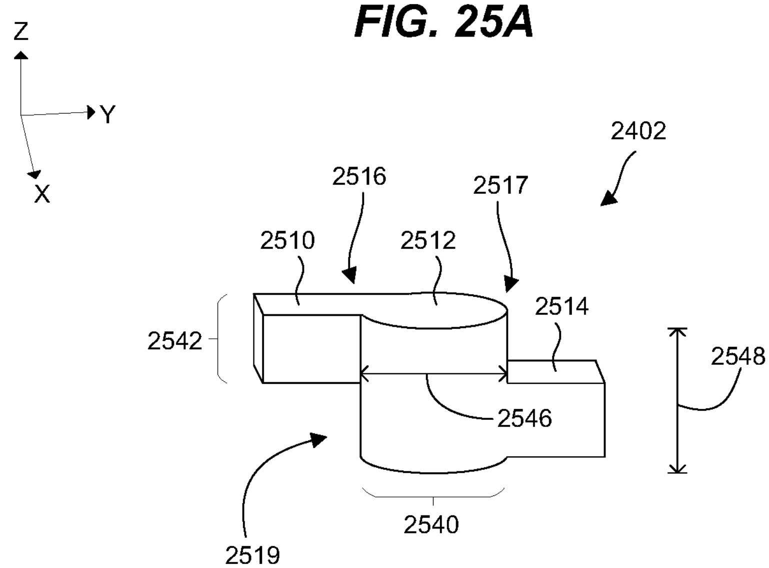


FIG. 25B

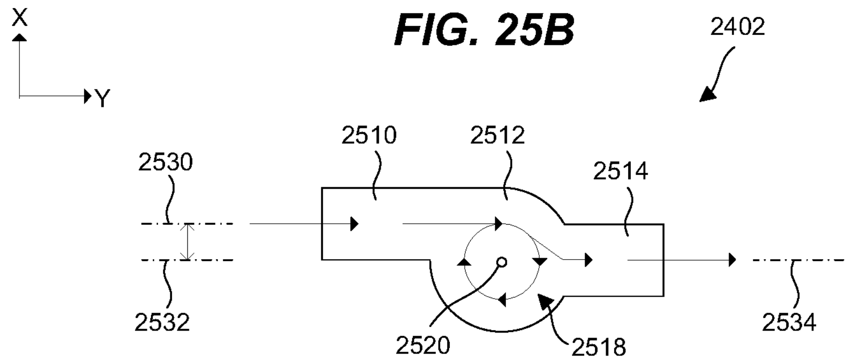


FIG. 25C

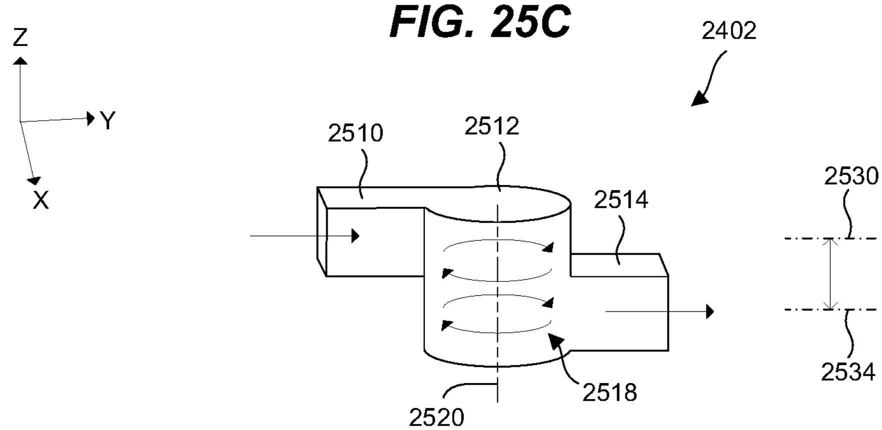


FIG. 25D

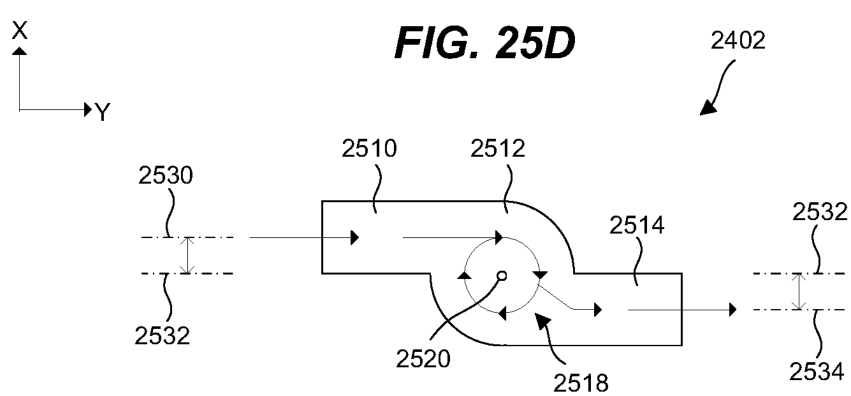


FIG. 26

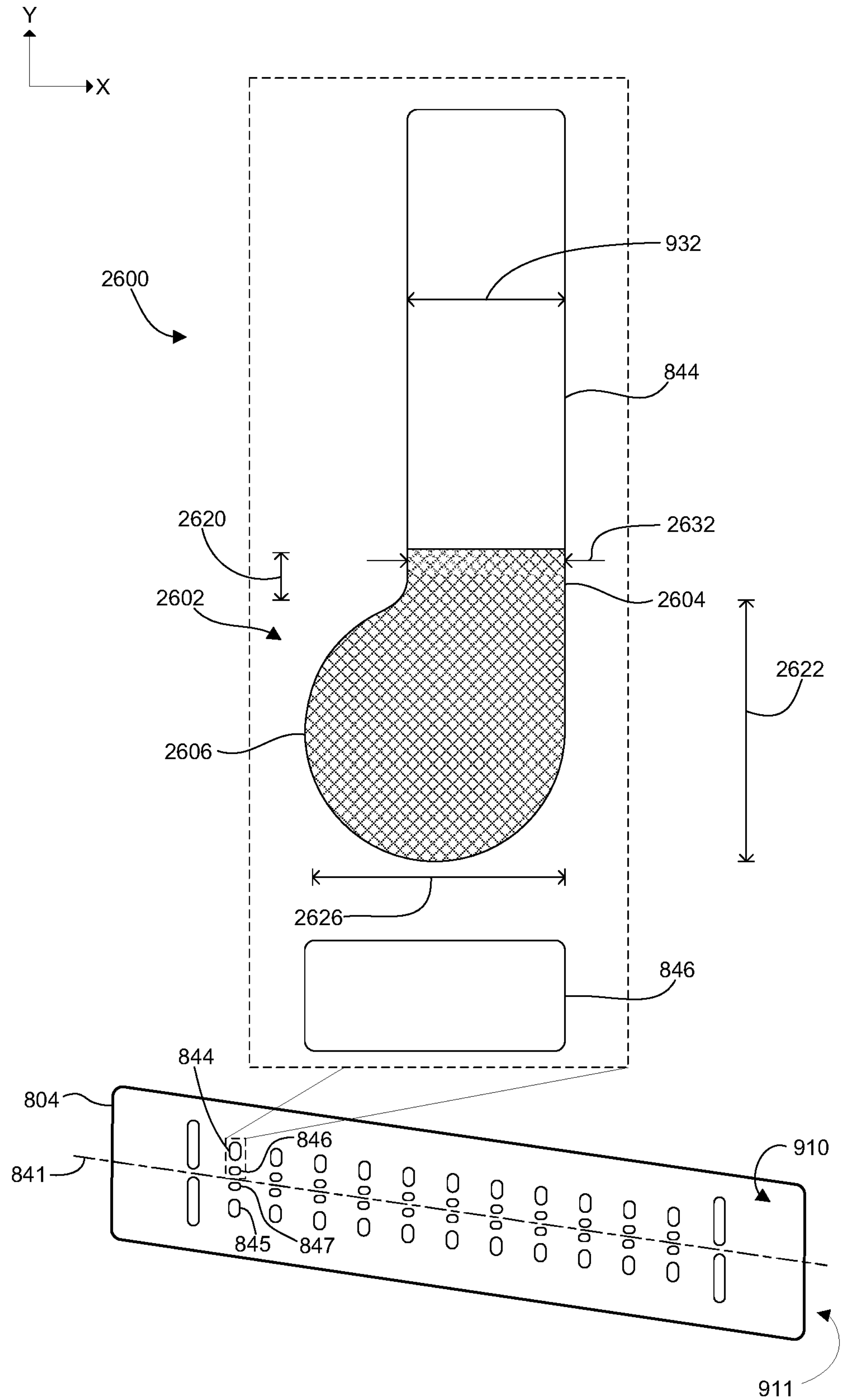

Y
X
2600
932
844
2620
2632
2602
2604
2622
2606
2626
846
844
804
846
841
910
845
847
911

FIG. 27

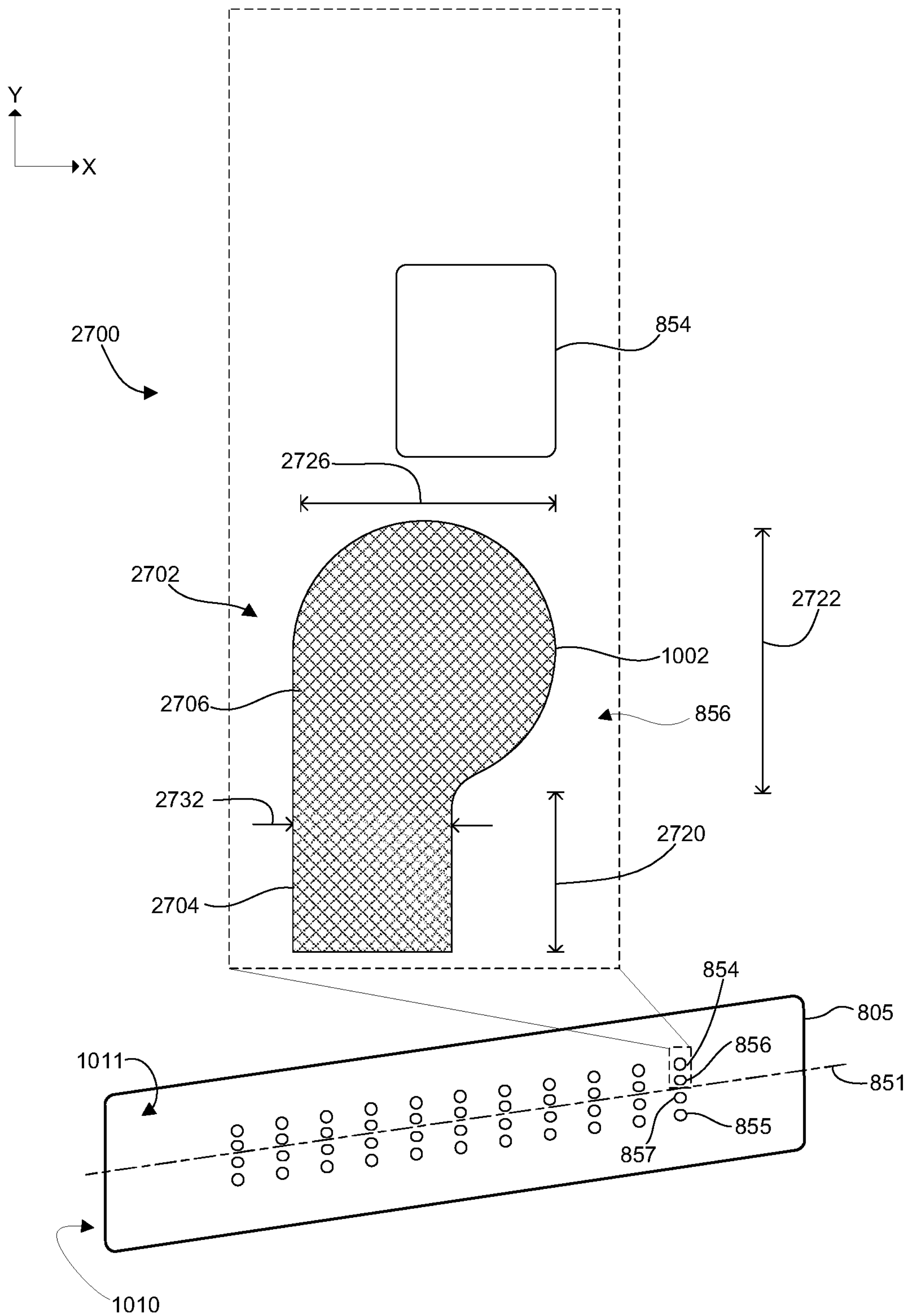

Y
X
2700
854
2726
2702
2722
1002
2706
856
2732
2720
2704
854
805
856
1011
851
855
857
1010

FIG. 28

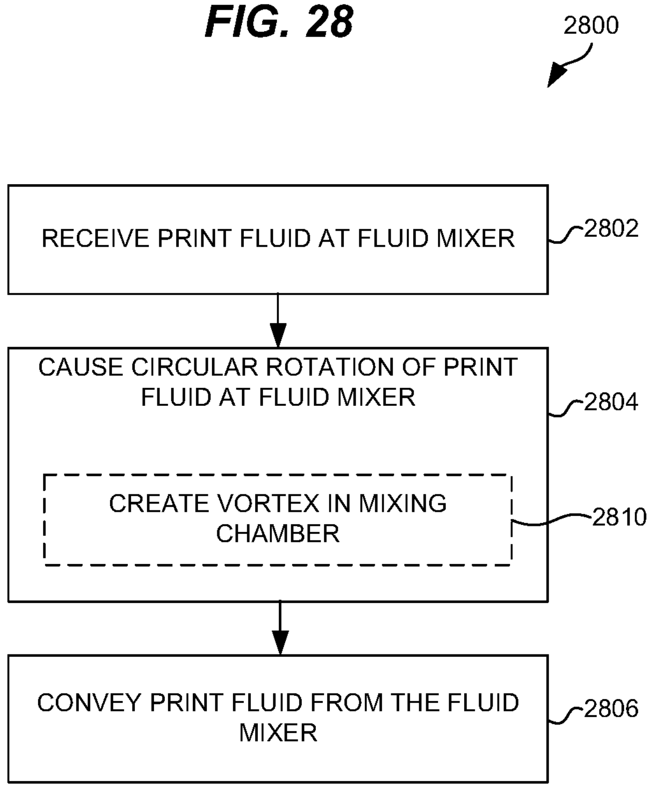

2800
RECEIVE PRINT FLUID AT FLUID MIXER
2802
CAUSE CIRCULAR ROTATION OF PRINT FLUID AT FLUID MIXER
2804
CREATE VORTEX IN MIXING CHAMBER
2810
CONVEY PRINT FLUID FROM THE FLUID MIXER
2806

FIG. 29

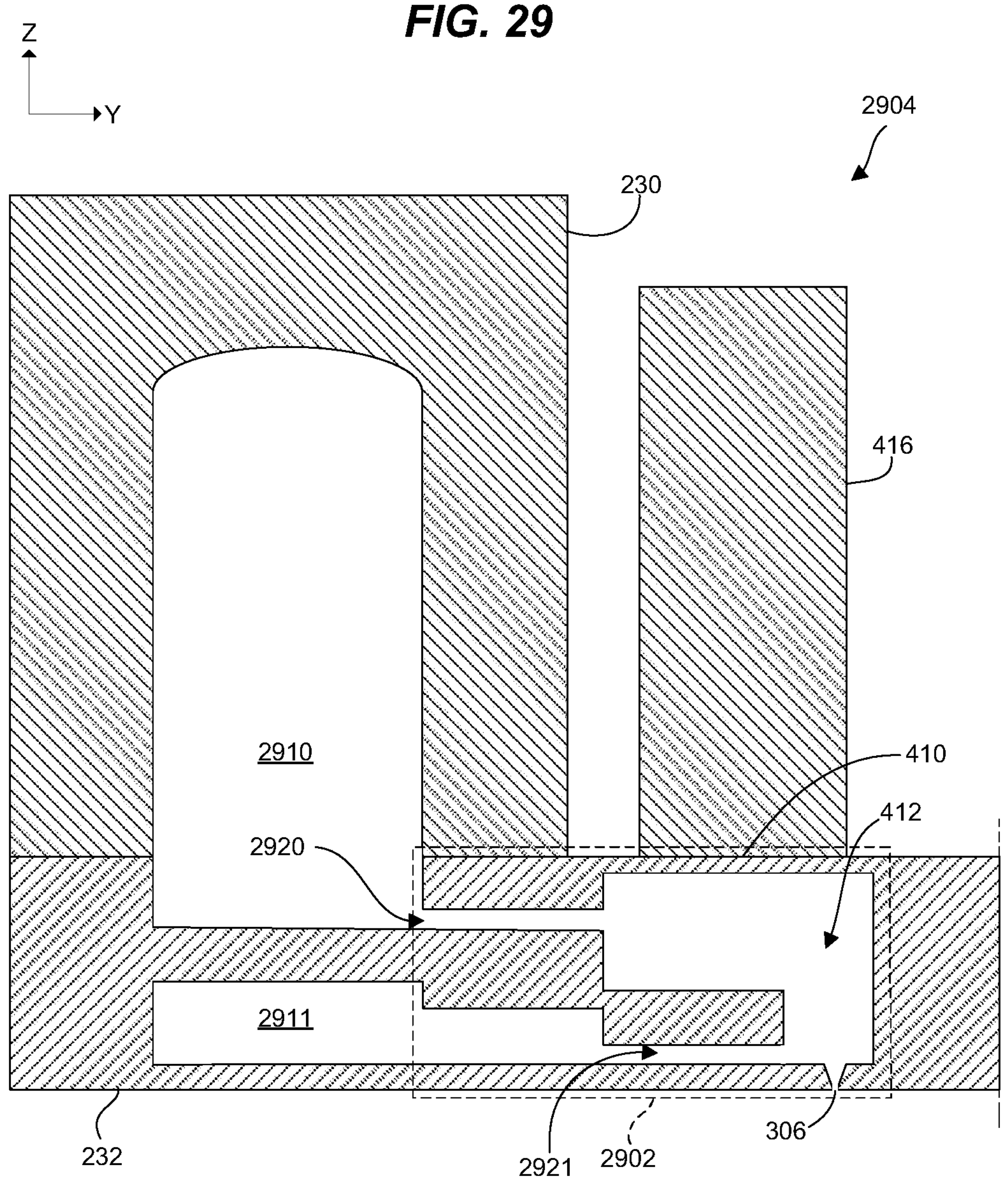
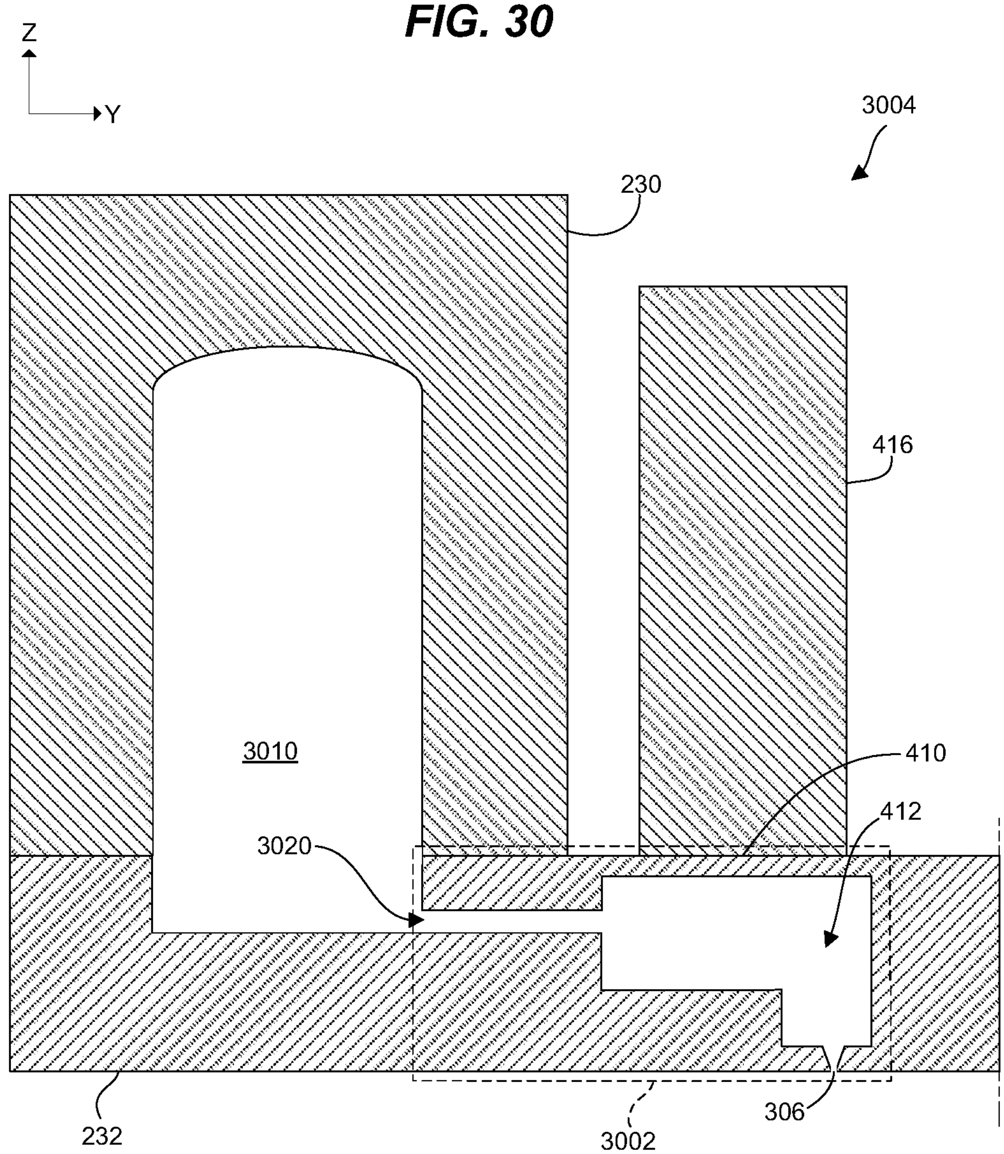


FIG. 30



PASSIVE MIXER IN JETTING CHANNELS OF A PRINTHEAD

TECHNICAL FIELD

The following disclosure relates to the field of image formation, and in particular, to printheads and/or the design of printheads.

BACKGROUND

Image formation is a procedure whereby a digital image (e.g., a 2D image, a 3D image or model, etc.) is recreated by propelling droplets of ink or another type of print fluid onto a medium, such as paper, plastic, a substrate for 3D printing, etc. Image formation is commonly employed in apparatuses, such as printers (e.g., inkjet printer, 3D printer, etc.), facsimile machines, copying machines, plotting machines, multifunction peripherals, etc. The core of a typical jetting apparatus or image forming apparatus is one or more liquid-droplet ejection heads (referred to generally herein as "printheads") having nozzles that discharge liquid droplets, a mechanism for moving the printhead and/or the medium in relation to one another, and a controller that controls how liquid is discharged from the individual nozzles of the printhead onto the medium in the form of pixels.

A typical printhead includes a plurality of nozzles aligned in one or more rows along a discharge surface of the printhead. Each nozzle is part of a "jetting channel", which includes the nozzle, a pressure chamber, and a diaphragm that vibrates in response to an actuator, such as a piezoelectric actuator. A printhead also includes a driver circuit that controls when each individual jetting channel fires based on image or print data. To jet from a jetting channel, the driver circuit provides one or more jetting pulses to the actuator, which cause the actuator to deform a wall of the pressure chamber (i.e., the diaphragm). The deformation of the pressure chamber creates pressure waves within the pressure chamber that eject one or more droplets of print fluid (e.g., ink) out of the nozzle.

Nozzle failures may occur in a printhead due to a variety of factors, such as drying of print fluid at a nozzle or meniscus, sedimentation of the print fluid, bubbles present in the print fluid, etc. These and other nozzle failures may result in poor print quality.

SUMMARY

Embodiments described herein provide for intra-channel passive mixers in jetting channels of a printhead, and associated method of using the printhead. In an embodiment, one or more intra-channel passive mixers are implemented within a jetting channel. The intra-channel passive mixers project into a flow path of print fluid within the jetting channel, and create turbulence in the print fluid which acts to mix the print fluid. One technical benefit is the print fluid is mixed within the jetting channel to restore homogeneity of the print fluid.

In an embodiment, a printhead comprises a plurality of jetting channels, where each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid. The printhead further comprises one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel.

In an embodiment, a printhead comprises a housing, and a plate stack attached to the housing that forms a plurality of jetting channels. Each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid. The plate stack further forms one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel.

In an embodiment, a method comprises operating a printhead comprising a plurality of jetting channels where each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid, and further comprising one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel. Operating the printhead comprises conveying a flow of the print fluid along the longitudinal flow path, and disturbing the flow of the print fluid along the longitudinal flow path with the one or more intra-channel passive mixers.

The above summary provides a basic understanding of some aspects of the specification. This summary is not an extensive overview of the specification. It is intended to neither identify key or critical elements of the specification nor delineate any scope particular embodiments of the specification, or any scope of the claims. Its sole purpose is to present some concepts of the specification in a simplified form as a prelude to the more detailed description that is presented later.

DESCRIPTION OF THE DRAWINGS

Some embodiments of the present disclosure are now described, by way of example only, and with reference to the accompanying drawings. The same reference number represents the same element or the same type of element on all drawings.

FIG. **1** is a schematic diagram of a jetting apparatus in an illustrative embodiment.

FIG. **2** is a perspective view of a printhead in an illustrative embodiment.

FIG. **3** is a perspective view of a printhead in an illustrative embodiment.

FIG. **4** is a cross-sectional view of a printhead in an illustrative embodiment.

FIG. **5**A-**5**D are schematic diagrams of a printhead in an illustrative embodiment.

FIGS. **6**A-**6**B are cross-sectional views of a portion of a printhead in an illustrative embodiment.

FIG. **7** is a perspective view of a jetting channel in an illustrative embodiment.

FIG. **8** illustrates an exploded, perspective view of a head member of a printhead in an illustrative embodiment.

FIG. **9** illustrates a chamber plate in an illustrative embodiment.

FIG. **10** illustrates a chamber plate in an illustrative embodiment.

FIG. **11** is a cross-sectional view of a portion of a printhead in an illustrative embodiment.

FIG. **12** is a flow chart illustrating a method of operating a printhead in an illustrative embodiment.

FIG. **13** is a perspective view of a jetting channel with one or more intra-channel passive mixers in an illustrative embodiment.

FIGS. **14**A-**14**H are plan views of intra-channel passive mixers of a jetting channel in illustrative embodiments.

FIG. **15** illustrates a restrictor plate in an illustrative embodiment.

FIG. **16** illustrates a chamber plate in an illustrative embodiment.

FIG. **17** is a flow chart illustrating a method of operating a printhead with one or more intra-channel passive mixers in an illustrative embodiment.

FIG. **18** is a perspective view of a jetting channel with one or more intra-chamber active mixers in an illustrative embodiment.

FIG. **19** is a perspective view of an intra-chamber active mixer in an illustrative embodiment.

FIG. **20** is a perspective view of an intra-chamber active mixer in another illustrative embodiment.

FIGS. **21**A-**21**I are plan views of a pressure chamber with one or more intra-chamber active mixers in illustrative embodiments.

FIG. **22** illustrates a chamber plate in an illustrative embodiment.

FIG. **23** is a flow chart illustrating a method of operating a printhead with an intra-chamber active mixer in an illustrative embodiment.

FIG. **24** is a perspective view of a jetting channel with an intra-channel fluid mixer in an illustrative embodiment.

FIGS. **25**A-**25**D illustrate an intra-channel fluid mixer in illustrative embodiments.

FIG. **26** illustrates a chamber plate in an illustrative embodiment.

FIG. **27** illustrates a chamber plate in an illustrative embodiment.

FIG. **28** is a flow chart illustrating a method of operating a printhead with an intra-channel fluid mixer in an illustrative embodiment.

FIG. **29** is a cross-section of a flow-through printhead in an illustrative embodiment.

FIG. **30** is a cross-section of a non-flow-through printhead in an illustrative embodiment.

DETAILED DESCRIPTION

The figures and the following description illustrate specific exemplary embodiments. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the embodiments and are included within the scope of the embodiments. Furthermore, any examples described herein are intended to aid in understanding the principles of the embodiments, and are to be construed as being without limitation to such specifically recited examples and conditions. As a result, the inventive concept(s) is not limited to the specific embodiments or examples described below, but by the claims and their equivalents.

FIG. **1** is a schematic diagram of a jetting apparatus **100** in an illustrative embodiment. A jetting apparatus **100** is a device or system that uses one or more printheads to eject a print fluid or marking material onto a medium. One example of jetting apparatus **100** is an inkjet printer (e.g., continuous feed or cutsheet printer) that performs single-pass printing. Other examples of jetting apparatus **100** include a scan pass inkjet printer (e.g., a wide format printer), a multifunction printer, a desktop printer, an industrial printer, a 3D printer, etc. Generally, jetting apparatus **100** includes a mount mechanism **102** that supports one or more printheads **104** in relation to a medium **112**. Mount mechanism **102** may be fixed within jetting apparatus **100** for single-pass printing. Alternatively, mount mechanism **102** may be disposed on a carriage assembly that reciprocates back and forth along a scan line or sub-scan direction for multi-pass printing. Printheads **104** are a device, apparatus, or component configured to eject droplets **106** of a print fluid, such as ink (e.g., water, solvent, oil, or UV-curable), through a plurality of nozzles (not visible in FIG. **1**). The droplets **106** ejected from the nozzles of printheads **104** are directed toward medium **112**. Medium **112** comprises any type of material upon which ink or another print or jetting fluid is applied by a printhead, such as paper, plastic, card stock, transparent sheets, a substrate for 3D printing, cloth, etc. Typically, nozzles of printheads **104** are arranged in one or more rows so that ejection of a print fluid from the nozzles causes formation of characters, symbols, images, layers of an object, etc., on medium **112** as printhead **104** and/or medium **112** are moved relative to one another. Jetting apparatus **100** may include a media transport mechanism **114** or a media holding bed **116**. Media transport mechanism **114** is configured to move medium **112** relative to printheads **104**. Media holding bed **116** (e.g., a platen) is configured to support medium **112** in a stationary position while the printheads **104** move in relation to medium **112**.

Jetting apparatus **100** also includes a jetting apparatus controller **122** that controls the overall operation of jetting apparatus **100**. Jetting apparatus controller **122** may connect to a data source to receive a print job, print data, image data, or the like, and control each printhead **104** to discharge the print fluid onto medium **112**. Jetting apparatus **100** also includes one or more reservoirs **124** for a print fluid or multiple types of print fluid. Although not shown in FIG. **1**, reservoirs **124** are fluidly coupled to printheads **104**, such as with hoses or the like.

FIG. **2** is a perspective view of a printhead **104** in an illustrative embodiment. In this embodiment, printhead **104** includes a head member **202** and electronics **204**. Head member **202** is an elongated component that forms the jetting channels of printhead **104**. A typical jetting channel includes a nozzle, a pressure chamber, and a diaphragm that is driven by an actuator, such as a piezoelectric actuator. Electronics **204** control how the nozzles of printhead **104** jet droplets in response to data signals and control signals received from another controller (e.g., jetting apparatus controller **122**). Electronics **204** include an embedded printhead controller **206** or driver circuits configured to drive individual jetting channels based on the data signals and control signals. The bottom surface of head member **202** in FIG. **2** includes the nozzles of the jetting channels, and represents the discharge surface **220** of printhead **104**. The top surface of head member **202** in FIG. **2** (referred to as I/O surface **222**) represents the Input/Output (I/O) portion for receiving one or more print fluids into printhead **104**, and/or conveying print fluids (e.g., fluids that are not jetted) out of printhead **104**. I/O surface **222** includes a plurality of I/O ports **211**-**214**. An I/O port **211**-**214** may comprise an inlet I/O port, which is an opening in head member **202** that acts as an inlet or entry point for a print fluid. An I/O port **211**-**214** may comprise an outlet I/O port, which is an opening in head member **202** that acts as an outlet or exit point for a print fluid. I/O ports **211**-**214** may include a hose coupling, hose barb, etc., for coupling with a hose of a reservoir, a cartridge, or the like. The number of I/O ports **211**-**214** is provided as an example, as printhead **104** may include other numbers of I/O ports.

In general, head member **202** includes a housing **230** and a plate stack **232**. Housing **230** is a rigid member made from stainless steel or another type of material. Housing **230** includes an access hole **234** that provides a passageway for electronics **204** to pass through housing **230** so that actuators may interface with (i.e., come into contact with) diaphragms of the jetting channels. Plate stack **232** attaches to an interface surface (not visible) of housing **230**. Plate stack **232** (also referred to as a laminate plate stack) is a series of plates that are fixed or bonded to one another to form a laminated stack. Plate stack **232** may include the following plates: one or more nozzle plates, one or more chamber plates, one or more restrictor plates, a support (or support) plate, and a diaphragm plate. A nozzle plate includes a plurality of nozzles that are arranged in one or more rows. A chamber plate includes a plurality of openings that form the pressure chambers of the jetting channels. A restrictor plate includes a plurality of openings that form restrictors to fluidly couple the pressure chambers of the jetting channels with a manifold. A diaphragm plate is a sheet of a semi-flexible material that vibrates in response to actuation by an actuator (e.g., piezoelectric actuator).

FIG. **2** illustrates one particular configuration of a printhead **104**, and it is understood that other printhead configurations are considered herein that have a plurality of jetting channels.

FIG. **3** is a perspective view of a printhead **104** in an illustrative embodiment. In an embodiment, head member **202** is an assembly that includes housing **230**, and plate stack **232** affixed or attached to housing **230**. Plate stack **232** is an elongated stack having a length **350** (i.e., along the x-axis) and a width **352** (i.e., along the y-axis). For this description, the x-axis is along the length **350** of the printhead **104**, and may be referred to as the x-direction, the lengthwise direction, the longitudinal direction, etc. The y-axis is along the width **352** of the printhead **104**, and may be referred to as the y-direction, the widthwise direction, the transverse direction, etc. The z-axis is along the height of the printhead **104**, and may be referred to as the z-direction, the height direction, etc. Plate stack **232** includes one or more nozzle plates **304** having orifices that form nozzles **306** of the jetting channels. Thus, the bottom surface of nozzle plate **304** defines the discharge surface **220** of printhead **104**. Nozzles **306** are shown in two nozzle rows in FIG. **3** disposed longitudinally along the length **350** of plate stack **232** and generally parallel to longitudinal sides **312**-**313** of printhead **104**/plate stack **232**. A longitudinal centerline **310** of printhead **104**/plate stack **232** is shown along the x-axis between adjacent rows of jetting channels (illustrated by their corresponding nozzles), and represents an axis of symmetry between the rows. Although two rows of nozzles **306** are illustrated in FIG. **3**, the jetting channels and their corresponding nozzles **306** may be arranged in a single row or more than two rows in other embodiments.

FIG. **4** is a cross-sectional view of a printhead **104** in an illustrative embodiment. FIG. **4** shows a cross-section of a portion of a row of jetting channels **402** along cut-plane **4**-**4** in FIG. **3**. A jetting channel **402** is a structural element within printhead **104** configured to jet or eject a print fluid. Each jetting channel **402** includes a diaphragm **410**, a pressure chamber **412** (also referred to as a Helmholtz chamber), and a nozzle **306**. An actuator **416** contacts diaphragm **410** to control jetting from a jetting channel **402**. Jetting channels **402** may be formed in rows along the length **350** of printhead **104** (i.e., plate stack **232**), and each jetting channel **402** may have a similar configuration as shown in FIG. **4**.

FIG. **5**A-**5**D are schematic diagrams of a printhead **104** in an illustrative embodiment. In FIG. **5**A, printhead **104** may be a flow-through print head **504** where print fluid may be circulated through jetting channels **402** past their corresponding nozzles **306**. Thus, the jetting channels **402** themselves may be referred to as flow-through jetting channels **540**. Rows **501**-**502** of jetting channels **402** in printhead **104** are schematically illustrated in FIG. **5**A as rows of nozzles **306**. In general, a plurality of jetting channels **402** for printhead **104** are arranged in rows **501**-**502** disposed longitudinally (i.e., along the x-axis) along the length **350** of the printhead **104**, and are generally in parallel with one another. Printhead **104** includes manifolds **510**-**511** and **514**-**515**. A manifold is a common conduit or channel internal to printhead **104** (i.e., internal to housing **230** and/or plate stack **232**) that provides a common fluid pathway for a plurality of jetting channels **402**. In row **501**, for example, each jetting channel **402** may be fluidly coupled to manifolds **510**-**511**. In an embodiment, manifold **510** may be referred to as a supply manifold when configured or operated to supply print fluid to a set of jetting channels **402** in row **501**. Manifold **510**, for example, may be fluidly coupled between I/O ports **211**-**212** to receive a print fluid from an external source, and may act as a common supply conduit having the capacity to supply print fluid to a plurality of jetting channels **402**. Manifold **511** may be referred to as a return manifold when configured or operated to receive print fluid from jetting channels **402** in row **501**. The print fluid that is not jetted from a nozzle **306** of a jetting channel **402** may be referred to herein as "non-jetted print fluid". Thus, a manifold that receives a print fluid from jetting channels **402** may be referred to herein as receiving non-jetted print fluid. Manifold **511** may act as a common return conduit having the capacity to receive non-jetted print fluid from a plurality of jetting channels **402** in row **501**. Manifold **511** is fluidly coupled with manifold **510** through the jetting channels **402** in row **501**, and may also be fluidly coupled with manifold **510** through one or more inter-manifold fluid passages **512**.

In row **502**, for example, each jetting channel **402** may be fluidly coupled to manifolds **514**-**515**. In an embodiment, manifold **514** may be referred to as a supply manifold when configured or operated to supply print fluid to a set of jetting channels **402** in row **502**. Manifold **514**, for example, may be fluidly coupled between I/O ports **213**-**214** to receive a print fluid from an external source, and may act as a common supply conduit having the capacity to supply print fluid to a plurality of jetting channels **402**. Manifold **515** may be referred to as a return manifold when configured or operated to receive print fluid from jetting channels **402** in row **502**. Manifold **515** may act as a common return conduit having the capacity to receive non-jetted print fluid from a plurality of jetting channels **402** in row **502**. Manifold **515** is fluidly coupled with manifold **514** through the jetting channels **402** in row **502**, and may also be fluidly coupled with manifold **514** through one or more inter-manifold fluid passages **516**.

Although manifolds **510** and **514** may be referred to herein as supply manifolds and manifolds **511** and **515** may be referred to herein as return manifolds, a flow of print fluid may be reversed in printhead **104**. Thus, manifolds **510** and **514** may comprise return manifolds and manifolds **511** and **515** may comprise supply manifolds when the flow is reversed (i.e., opposite flow to what is illustrated in FIG. **5**A).

In FIG. **5**A, each jetting channel **402**, as a flow-through type of jetting channel **540**, has an independent fluid path into a pressure chamber **412** and an independent fluid path out of the pressure chamber **412**, which are not shared or common with another jetting channel **402**. For example, each jetting channel **402** of row **501** includes a channel fluid passage **520** (also referred to as a channel fluid conduit) between manifold **510** and a pressure chamber **412** of the jetting channel **402** (see also, FIG. **4**), and also includes a channel fluid passage **521** between the pressure chamber **412** of the jetting channel **402** and manifold **511**. Channel fluid passages **520-521** represent distinct pathways for print fluid to flow, for example, from manifold **510** into a pressure chamber **412**, and for (non-jetted) print fluid to flow out of the pressure chamber **412** to manifold **511** (or in the reverse direction).

Similarly, each jetting channel **402** of row **502** includes a channel fluid passage **520** between manifold **514** and a pressure chamber **412** of the jetting channel **402** (see also, FIG. **4**), and also includes a channel fluid passage **521** between the pressure chamber **412** of the jetting channel **402** and manifold **515**. Channel fluid passages **520-521** represent distinct pathways for print fluid to flow, for example, from manifold **514** into a pressure chamber **412**, and for (non-jetted) print fluid to flow out of the pressure chamber **412** to manifold **515** (or in the reverse direction).

In an embodiment, the major portions or sections of manifolds **510-511** and **514-515** are disposed longitudinally (i.e., along the x-axis) within printhead **104** to fluidly couple with jetting channels **402** arranged in a row **501-502**. In some flow-through printheads, a return manifold is disposed longitudinally on the same side of a row of jetting channels as the supply manifold. In an embodiment herein, manifolds **510-511** are disposed on opposite sides of the row **501** of jetting channels **402**. Likewise, manifolds **514-515** are disposed on opposite sides of the row **502** of jetting channels **402**. To illustrate this structure, longitudinal sides **312-313** of printhead **104** are shown. Manifold **510** is disposed on one side **570** (i.e., a first side) of the row **501** of jetting channels **402** between longitudinal side **312** and row **501**, and manifold **511** is disposed on the other side **572** (i.e., a second side) of the row **501** of jetting channels **402** between adjacent rows **501-502** (i.e., between row **501** and the longitudinal centerline **310**). A "side" of a row of jetting channels **402** comprises a longitudinal side along the length of the row. Manifold **511** is disposed in an intermediate region **550** between the rows **501-502** of jetting channels **402** as are the channel fluid passages **521** of the individual jetting channels **402** in row **501**. Likewise, manifold **514** is disposed on one side **574** (i.e., a first side) of the row **502** of jetting channels **402** between longitudinal side **313** and the row **502**, and manifold **515** is disposed on the other side **576** (i.e., a second side) of the row **502** of jetting channels **402** between adjacent rows **501-502** (i.e., between row **502** and the longitudinal centerline **310**). Manifold **515** is disposed in intermediate region **550** between the rows **501-502** as are the channel fluid passages **521** of the individual jetting channels **402** in row **502**. Thus, manifold **511** is disposed between row **501** and manifold **515**, and manifold **515** is disposed between row **502** and manifold **511**.

In FIG. **5**B, manifold **510**, for example, may be fluidly coupled to I/O port **211** such as to receive a print fluid from an external source, and manifold **511** may be fluidly coupled to I/O port **212** such as to provide an exit path for print fluid out of the printhead **104** to an external container. Likewise, manifold **514**, for example, may be fluidly coupled to I/O port **213** such as to receive a print fluid from an external source, and manifold **515** may be fluidly coupled to I/O port **214** such as to provide an exit path for print fluid out of the printhead **104** to an external container. For the sake of brevity, it is understood that the concepts described above for FIG. **5**A apply to the configuration in FIG. **5**B.

In FIG. **5**C, a printhead **104** may include additional I/O ports **591-594**. Manifold **510**, for example, may be fluidly coupled to I/O ports **211-212**, manifold **511** may be fluidly coupled to I/O ports **591-592**, manifold **514** may be fluidly coupled to I/O ports **213-214**, and manifold **515** may be fluidly coupled to I/O ports **593-594**. For the sake of brevity, it is understood that the concepts described above for FIG. **5**A apply to the configuration in FIG. **5**C.

In the configurations illustrated in FIG. **5**A-**5**C, a printhead **104** may be operated to jet a single type of print fluid (e.g., a single color) or two different types of print fluids (e.g., two colors). However, a printhead **104** may be configured to jet more types of print fluids. FIG. **5**D is a schematic diagram of a printhead **104** in an illustrative embodiment. In this embodiment, printhead **104** includes manifolds **510-511**, **514-515**, **530-531**, and **534-535**. In row **501**, a subset of jetting channels **402** is fluidly coupled to manifolds **510-511**, and a subset of jetting channels **402** is fluidly coupled to manifolds **530-531**. In row **502**, a subset of jetting channels **402** is fluidly coupled to manifolds **514-515**, and a subset of jetting channels **402** is fluidly coupled to manifolds **534-535**. For the sake of brevity, it is understood that the concepts described above for FIG. **5**A apply to the configuration in FIG. **5**D. In the configuration illustrated in FIG. **5**D, printhead **104** may be operated to jet a single type of print fluid (e.g., a single color), two different types of print fluids (e.g., two colors), or four different types of print fluids (e.g., four colors).

One or more methods may be used to circulate print fluid through jetting channels **402** of printhead **104**. For example, the pressure in the manifold **510** and/or manifold **511** may be regulated to create a pressure differential between the manifolds **510-511**. The pressure differential causes the print fluid to flow through the jetting channels **402** in row **501**. Similarly, the pressure in the manifold **514** and/or manifold **515** may be regulated to create a pressure differential between the manifolds **514-515**. The pressure differential causes the print fluid to flow through the jetting channels **402** in row **502**.

FIGS. **6**A-**6**B are cross-sectional views of a portion of printhead **104** in an illustrative embodiment. FIGS. **6**A-**6**B show a cross-section of printhead **104** along cut-plane **6-6** in FIG. **3**. In FIG. **6**A, two jetting channels **402** are shown in adjacent rows **501-502**. As in FIG. **4**, a jetting channel **402** includes diaphragm **410**, pressure chamber **412**, and nozzle **306** (it is noted that the nozzle **306** of the jetting channel **402** in row **502** is not visible in this cross-section). Manifold **510** of printhead **104** is fluidly coupled to a jetting channel **402** of row **501**. More particularly, pressure chamber **412** of the jetting channel **402** is fluidly coupled to manifold **510** through a channel fluid passage **520**. In an embodiment, the channel fluid passage **520** may include/comprise a restrictor that controls or regulates a flow of print fluid between manifold **510** and pressure chamber **412** along channel fluid passage **520**. Pressure chamber **412** of the jetting channel **402** is also fluidly coupled to manifold **511** through a channel fluid passage **521**.

Manifold **514** of printhead **104** is fluidly coupled to a jetting channel **402** of row **502**. More particularly, pressure chamber **412** of the jetting channel **402** is fluidly coupled to manifold **514** through a channel fluid passage **520**. In an embodiment, the channel fluid passage **520** may include/comprise a restrictor that controls a flow of print fluid between manifold **514** and pressure chamber **412** along channel fluid passage **520**. Pressure chamber **412** of the jetting channel **402** is also fluidly coupled to manifold **515** through a channel fluid passage **521**.

As illustrated in FIG. **6**A, row **501** of jetting channels **402** and row **502** of jetting channels **402** are adjacent to one another within printhead **104**, and are separated by a longitudinal centerline **310**. Manifolds **511** and **515** are disposed in an intermediate region **550** of printhead **104**/plate stack **232** between the rows **501-502** of jetting channels **402**. More particularly, manifolds **511** and **515** are disposed between pressure chambers **412** of jetting channels **402** in adjacent rows **501-502**. For jetting channel **402** in row **501**, manifold **510** is disposed on one side of pressure chamber **412** (along the y-axis) in an outer region **652** of printhead **104**/plate stack **232** between the row **501** of jetting channels **402** and a longitudinal side **312**. Manifold **510** is fluidly coupled to the pressure chamber **412** via channel fluid passage **520** that is also disposed in outer region **652**. Manifold **511** is disposed on the other side of the pressure chamber **412** (in relation to manifold **510**) along the y-axis in the intermediate region **550**. Manifold **511** is disposed between the pressure chamber **412** and the longitudinal centerline **310**, and may be fluidly isolated from manifold **515** and/or jetting channels **402** in row **502**.

For jetting channel **402** in row **502**, manifold **514** is disposed on one side of pressure chamber **412** (along the y-axis) in an outer region **654** of printhead **104**/plate stack **232** between the row **502** of jetting channels **402** and a longitudinal side **313**. Manifold **514** is fluidly coupled to the pressure chamber **412** via channel fluid passage **520** that is also disposed in outer region **654**. Manifold **515** is disposed on the other side of the pressure chamber **412** (in relation to manifold **514**) along the y-axis in the intermediate region **550**. Manifold **515** is disposed between the pressure chamber **412** and the longitudinal centerline **310**, and may be fluidly isolated from manifold **511** and/or jetting channels **402** in row **501**.

FIG. **6**B shows a cross-section of a jetting channel **402** in row **501**. The arrows in FIG. **6**B illustrate a flow of a print fluid from manifold **510** to jetting channel **402**, and from jetting channel **402** to manifold **511**. The print fluid **680** flows from manifold **510** and into pressure chamber **412** through channel fluid passage **520**. One wall of pressure chamber **412** is formed with diaphragm **410** that physically interfaces with actuator **416**. Diaphragm **410** may comprise a sheet of semi-flexible material that vibrates in response to actuation by actuator **416**. To jet from jetting channel **402**, one or more jetting pulses are sent to actuator **416**, which actuates or "fires" in response to the jetting pulses. Firing of actuator **416** creates pressure waves in pressure chamber **412** that cause jetting of one or more droplets from nozzle **306**. The non-jetted print fluid **682**, which is not jetted from nozzle **306**, flows from pressure chamber **412** into manifold **511** through channel fluid passage **521**.

FIG. **7** is a perspective view of a jetting channel **402** in an illustrative embodiment. As above, jetting channel **402** includes pressure chamber **412**, diaphragm **410**, and a nozzle **306**. Pressure chamber **412** has a length **702** (i.e., along the y-axis), a width **703** (i.e., along the x-axis), and a height **704** (i.e., along the z-axis). Jetting channel **402** also includes channel fluid passages **520-521**. In general, the major flow of print fluid flows longitudinally or lengthwise through jetting channel **402** along the y-axis. In an embodiment of a flow in a flow direction **714**, print fluid flows into one side **710** (i.e., a first side) of pressure chamber **412** through channel fluid passage **520**. The print fluid (i.e., non-jetted print fluid) flows out of the opposite side **711** (i.e., second side) of pressure chamber **412** through channel fluid passage **521**. Thus, the print fluid flows into and out of pressure chamber **412** via channel fluid passage **520** and channel fluid passage **521** in a same lengthwise direction (i.e., along the y-axis) of the jetting channel **402**. Further, the first side **710** of pressure chamber **412** is disposed closer to a longitudinal side **312-313** of printhead **104** than the second side **711**, and the second side **711** is disposed closer to an intermediate region **550** of printhead **104** than the first side **710** (see FIG. **6**A). In this structure, channel fluid passage **520** and channel fluid passage **521** are disposed on opposite sides **710-711** of the pressure chamber **412** in the lengthwise direction. For example, channel fluid passage **520** and channel fluid passage **521** are disposed on opposite sides **710-711** of the pressure chamber **412** in relation to nozzle **306**. It is noted again that the flow direction **714** may be reversed in other embodiments.

A jetting channel **402** as shown in FIGS. **4**, **6**A-**6**B, and **7** are examples to illustrate a basic structure of a jetting channel, such as the diaphragm, pressure chamber, nozzle, and channel fluid passages. Other types of jetting channels are also considered herein. For example, some jetting channels may have a pressure chamber having a different shape than is illustrated in FIGS. **4**, **6**A-**6**B, and **7**, some jetting channels may have a channel fluid passage **521** having a different shape than is illustrated in FIGS. **6**A-**6**B and **7**, etc.

FIG. **8** illustrates an exploded, perspective view of a head member **202** of a printhead **104** in an illustrative embodiment. In this embodiment, head member **202** is an assembly that includes housing **230** and plate stack **232**. Plate stack **232** is affixed or attached to an interface surface **880** of housing **230**, and forms rows of jetting channels **402**. Housing **230** is an elongated member made from a rigid material, such as stainless steel. Housing **230** has a length, a width, and a height, and the dimensions of housing **230** are such that the length is greater than the width. The direction of a row of jetting channels **402** corresponds with the length of housing **230**. Housing **230** includes access hole **234** at or near its center that extends from I/O surface (not visible) through to an opposing interface surface **880**. Access hole **234** provides passage way for an actuator assembly (not shown), such as a plurality of piezoelectric actuators, to pass through and contact diaphragms **410** of the jetting channels **402**. Interface surface **880** is the surface of housing **230** that faces plate stack **232**, and interfaces with a plate of plate stack **232**. Housing **230** also includes manifold ducts **882-883** that extend longitudinally along a length of interface surface **880**. A manifold duct **882-883** comprises an elongated cut or groove along interface surface **880** that is configured to convey a print fluid, and forms at least a portion of a manifold for printhead **104**.

Plate stack **232** includes a series of plates **801-805** and **304** that are fixed or bonded to one another to form a laminated plate structure. Plate stack **232** illustrated in FIG. **8** is intended to be an example of a basic structure of a printhead. There may be additional plates of plate stack **232** that are not shown in FIG. **8**, and the configuration of the various plates may vary as desired. Also, FIG. **8** is not drawn to scale.

In an embodiment, plate stack **232** includes the following plates: a diaphragm plate **801**, a support plate **802**, a restrictor plate **803**, chamber plates **804-805**, and a nozzle plate **304**. Diaphragm plate **801** is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and is substantially flat or planar. Diaphragm plate **801** includes diaphragms **811** comprising a sheet of a semi-flexible material that forms the diaphragms **410** of the jetting channels **402**. Diaphragm plate **801** further includes manifold openings **812-813**. A manifold opening is an aperture or hole that forms at least part of a manifold for jetting channels **402** in a row. Manifold opening **812** extends longitudinally along diaphragm plate **801** between a longitudinal side **890** of diaphragm plate **801** and diaphragms **811** for a row of jetting channels **402**, and is fluidly coupled with a manifold duct **882** of housing **230**. Manifold opening **813** extends longitudinally along diaphragm plate **801** between the other longitudinal side **891** of diaphragm plate **801** and diaphragms **811** for another row of jetting channels **402**, and is fluidly coupled with a manifold duct **883** of housing **230**.

Support plate **802** (also referred to as a spacer plate) is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and is substantially flat or planar. Support plate **802** includes manifold openings **822-823**, chamber openings **824-825**, and manifold openings **826-827**. Chamber openings **824** comprise apertures or holes generally aligned longitudinally in a linear row **828**, and configured to form at least part of the pressure chambers **412** in a first row **501** of jetting channels **402**. Manifold opening **822** is an elongated opening that extends longitudinally along support plate **802** between a longitudinal side **892** of support plate **802** and chamber openings **824** in linear row **828**, and generally in parallel with the linear row **828** of chamber openings **824**. Manifold opening **826** is an elongated opening that extends longitudinally along support plate **802** between the linear row **828** of chamber openings **824** and a longitudinal centerline **821** of support plate **802**, and generally in parallel with the linear row **828** of chamber openings **824**. Chamber openings **825** comprise apertures or holes generally aligned longitudinally in a linear row **829**, and configured to form at least part of the pressure chambers **412** for a second (adjacent) row **502** of jetting channels **402**. Manifold opening **823** is an elongated opening that extends longitudinally along support plate **802** between the other longitudinal side **893** of support plate **802** and chamber openings **825** in linear row **829**, and generally in parallel with the linear row **829** of chamber openings **825**. Manifold opening **827** is an elongated opening that extends longitudinally along support plate **802** between the linear row **829** of chamber openings **825** and the longitudinal centerline **821** of support plate **802**, and generally in parallel with the linear row **829** of chamber openings **825**.

Restrictor plate **803** is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and is substantially flat or planar. Restrictor plate **803** includes restrictor openings **834-835** and channel connector openings **836-837**. Restrictor openings **834** are elongated apertures or holes each oriented transversely, and generally aligned longitudinally in a linear row **832**. Restrictor openings **834** are configured to fluidly couple pressure chambers **412** of a first row **501** of jetting channels **402** with a manifold (i.e., formed by manifold opening **822**, manifold opening **812**, etc.). Restrictor openings **834** at least in part define restrictors (or a channel fluid passage **520**) for individual jetting channels **402** in the first row **501**. Thus, restrictor openings **834** are each configured to fluidly couple an individual one of the pressure chambers **412** of the jetting channels **402** in the first row **501** with a manifold (e.g., manifold **510**). Channel connector openings **836** comprise apertures or holes generally aligned in a linear row **870** in parallel with the linear row **832** of restrictor openings **834**. Channel connector openings **836** are disposed between restrictor openings **834** and a longitudinal centerline **831** of restrictor plate **803**. Channel connector openings **836** are configured to fluidly couple pressure chambers **412** of jetting channels **402** in a first row **501** with a manifold (i.e., formed by manifold opening **826**). Restrictor openings **835** are elongated apertures or holes each oriented transversely, and generally aligned longitudinally in a linear row **833**. Restrictor openings **835** are configured to fluidly couple pressure chambers **412** of jetting channels **402** in a second row **502** with a manifold (i.e., formed by manifold opening **823**, manifold opening **813**, etc.). Restrictor openings **835** at least in part define restrictors for individual jetting channels **402** in the second row **502**. Thus, restrictor openings **835** are each configured to fluidly couple an individual one of the pressure chambers **412** of the jetting channels **402** in the second row **502** with a manifold (e.g., manifold **514**). Channel connector openings **837** comprise apertures or holes generally aligned in a linear row **871** in parallel with the linear row **833** of restrictor openings **835**. Channel connector openings **837** are disposed between restrictor openings **835** and the longitudinal centerline **831** of restrictor plate **803**. Channel connector openings **837** are configured to fluidly couple pressure chambers **412** of jetting channels **402** in a second row **502** with a manifold (i.e., formed by manifold opening **827**). Restrictor plate **803** further includes inter-manifold openings **838-839**. Inter-manifold openings **838** are elongated apertures or holes each oriented transversely, and at least in part form an inter-manifold fluid passage **512** configured to fluidly couple two manifolds. Inter-manifold openings **839** are elongated apertures or holes each oriented transversely, and at least in part form an inter-manifold fluid passage **516** configured to fluidly couple two manifolds.

Chamber plate **804** is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and substantially flat or planar. Chamber plate **804** includes chamber openings **844-845** and channel connector openings **846-847**. Chamber openings **844** are apertures or holes generally aligned longitudinally in a linear row **842**, and form at least part of the pressure chambers **412** of jetting channels **402** in a first row **501**. Channel connector openings **846** comprise apertures or holes generally aligned in a linear row **872** in parallel with the linear row **842** of chamber openings **844**. Channel connector openings **846** are disposed between chamber openings **844** and a longitudinal centerline **841** of chamber plate **804**. Channel connector openings **846** are each configured to fluidly couple an individual pressure chambers **412** of jetting channels **402** in a first row **501** with a manifold (i.e., formed by manifold opening **826**), and therefore at least in part form a channel fluid passage **521**. Chamber openings **845** are apertures or holes generally aligned longitudinally in a linear row **843**, and form at least part of the pressure chambers **412** of jetting channels **402** in a second row **502**. Channel connector openings **847** comprise apertures or holes generally aligned in a linear row **873** in parallel with the linear row **843** of chamber openings **845**. Channel connector openings **847** are disposed between chamber openings **845** and the longitudinal centerline **841** of chamber plate **804**. Channel connector openings **847** are each configured to fluidly couple an individual pressure chamber **412** of jetting channels **402** in a second row **502** with a manifold (i.e., formed by manifold opening **827**), and therefore at least in part form a channel fluid passage **521**. Chamber plate **804** further includes inter-manifold openings **848-849**. Inter-manifold openings **848** are elongated apertures or holes each oriented transversely, and at least in part form an inter-manifold fluid passage **512** configured to fluidly couple two manifolds. Inter-manifold openings **849** are elongated apertures or holes each oriented transversely, and at least in part form an inter-manifold fluid passage **516** configured to fluidly couple two manifolds.

Chamber plate **805** is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and substantially flat or planar. Chamber plate **805** includes chamber openings **854-855** and channel connector features **856-857**. Chamber openings **854** are apertures or holes generally aligned longitudinally in a linear row **852**, and form at least part of the pressure chambers **412** of jetting channels **402** in a first row **501**. Channel connector features **856** may comprise apertures, holes, etches, etc., generally aligned in a linear row **874** in parallel with the linear row **852** of chamber openings **854**. Channel connector features **856** are disposed between chamber openings **854** and a longitudinal centerline **851** of chamber plate **805**. Channel connector features **856** are each configured to fluidly couple an individual pressure chamber **412** of jetting channels **402** in a first row **501** with a manifold (i.e., formed by manifold opening **826**), and therefore at least in part form a channel fluid passage **521**. Chamber openings **855** are apertures or holes generally aligned longitudinally in a linear row **853**, and form at least part of the pressure chambers **412** of jetting channels **402** in a second row **502**. Channel connector features **857** comprise apertures, holes, etches, etc., generally aligned in a linear row **875** in parallel with the linear row **853** of chamber openings **855**. Channel connector features **857** are disposed between chamber openings **855** and the longitudinal centerline **851** of chamber plate **805**. Channel connector features **857** are each configured to fluidly couple an individual pressure chamber **412** of jetting channels **402** in a second row **502** with a manifold (i.e., formed by manifold opening **827**), and therefore at least in part form a channel fluid passage **521**. Channel connector features **856-857** are referred to generally as "features" as they may comprise a hole, a partial etch, etc.

Nozzle plate **304** is a thin sheet of material (e.g., metal (i.e., stainless steel), plastic, etc.) that is generally rectangular in shape and is substantially flat or planar. Nozzle plate **304** includes apertures or nozzle holes **860** that form nozzles **306** of the jetting channels **402**. For example, nozzle holes **860** may be generally aligned longitudinally in a linear row **862** to form the nozzles **306** of jetting channels **402** in a first row **501**, and may be generally aligned longitudinally in a linear row **863** to form the nozzles **306** of jetting channels **402** in a second row **502**. One technical benefit of plate stack **232** is flow-through jetting channels may be formed with a reduced number of plates.

In an embodiment, one or both of chamber plates **804-805** may be etched or otherwise patterned to form channel fluid passages **521**. FIG. **9** illustrates chamber plate **804** in an illustrative embodiment. As described above, chamber plate **804** is a substantially flat or planar sheet of material, and thus has opposing planar surfaces **910-911**. Planar surface **910** faces toward the discharge surface **220** of the printhead **104**, while planar surface **911** faces toward housing **230**. Zoom window **900** illustrates a magnified view of a chamber opening **844** and a channel connector opening **846** of chamber plate **804**. Chamber opening **844** is an elongated opening etched or cut into chamber plate **804**, and channel connector opening **846** is an opening etched or cut into chamber plate **804** between chamber opening **844** and the longitudinal centerline **841** of chamber plate **804**. In an embodiment, chamber plate **804** further includes a partially-etched segment **902** that extends part way from chamber opening **844** toward channel connector opening **846**. To form partially-etched segment **902**, chamber plate **804** is partially etched from planar surface **910** to an etching depth less than the thickness of chamber plate **804**. For example, partially-etched segment **902** may comprise a "half-etch" where the etching depth is about half the thickness of chamber plate **804**. Thus, partially-etched segment **902** does not form a hole through chamber plate **804**. Partially-etched segment **902** begins at chamber opening **844** and extends along a length **920** (i.e., along the y-axis) toward channel connector opening **846**. In an embodiment, the length **920** of partially-etched segment **902** is less than a distance **930** between chamber opening **844** and channel connector opening **846**. A width **922** (i.e., along the x-axis) of partially-etched segment **902** may correspond with a width **932** of chamber opening **844**. A partially-etched segment **902** may be etched between each chamber opening **844-845** and channel connector opening **846-847** of chamber plate **804** in a similar manner. One technical benefit is channel fluid passages **521** may be patterned using existing lithography processes.

FIG. **10** illustrates chamber plate **805** in an illustrative embodiment. As described above, chamber plate **805** is a substantially flat or planar sheet of material, and thus has opposing planar surfaces **1010-1011**. Planar surface **1010** faces toward the discharge surface **220** of the printhead **104**, while planar surface **1011** faces toward housing **230**. Zoom window **1000** illustrates a magnified view of a chamber opening **854** and a channel connector feature **856** of chamber plate **805**. Chamber opening **854** is an opening etched or cut into chamber plate **805**. In an embodiment, channel connector feature **856** comprises a partially-etched segment **1002** in chamber plate **805**. To form partially-etched segment **1002**, chamber plate **805** is partially etched from planar surface **1011** to an etching depth less than the thickness of chamber plate **805**. For example, partially-etched segment **1002** may comprise a "half-etch" where the etching depth is about half the thickness of chamber plate **805**. Thus, partially-etched segment **1002** does not form a hole through chamber plate **805**. Partially-etched segment **1002** extends along a length **1020** (i.e., along the y-axis) between the longitudinal centerline **851** of chamber plate **805** and chamber opening **854**. Each of the channel connector features **856** of chamber plate **805** may comprise a partially-etched segment **1002** as described above. In other embodiments, channel connector features **856** may comprise holes, holes and partially-etched segments, etc. One technical benefit is channel fluid passages **521** may be patterned using existing lithography processes.

The configuration of plate stack **232** in FIGS. **8-10** is provided as an example, and other configurations are considered herein.

FIG. **11** is a cross-sectional view of a portion of a printhead **104** in an illustrative embodiment with a plate stack **232** as in FIGS. **8-10**. FIG. **11** shows a cross-section of printhead **104** along cut-plane **6-6** in FIG. **3** to show a jetting channel **402** in row **501**. Printhead **104** includes housing **230** and plate stack **232** affixed or attached to housing **230** to form jetting channels **402**. As above, plate stack **232** includes diaphragm plate **801**, support plate **802**, restrictor plate **803**, chamber plates **804-805**, and nozzle plate **304**. A nozzle hole **860** of nozzle plate **304** defines the nozzle **306** of the jetting channel **402** (see also, FIG. **8**). A chamber opening **854** of chamber plate **805**, a chamber opening **844** of chamber plate **804**, a restrictor opening **834** of restrictor plate **803**, and a chamber opening **824** of support plate **802** form or define the pressure chamber **412** of the jetting channel **402**. The restrictor opening **834**, in conjunction with chamber plate **804** and support plate **802**, form or define a restrictor **1110** that comprises the channel fluid passage **520** configured to control or regulate a flow of print fluid between manifold **510** and pressure chamber **412**. Manifold openings **812** and **822** of diaphragm plate **801** and support plate **802**, in conjunction with manifold duct **882** of housing **230**, form or define manifold **510**. Although not shown in FIG. **11**, manifold openings **813** and **823** of diaphragm plate

801 and support plate 802, in conjunction with manifold duct 883 of housing 230, form or define manifold 514 as shown in FIGS. 6A and 8. Manifold opening 826 of support plate 802 defines manifold 511. Channel connector opening 836 of restrictor plate 803, channel connector opening 846 of chamber plate 804, and channel connector feature 856 of chamber plate 805 form or define the channel fluid passage 521 between the pressure chamber 412 and manifold 511. Although not shown in FIG. 11, manifold opening 827 of support plate 802 defines manifold 515 as shown in FIGS. 6A and 8. Channel connector opening 837 of restrictor plate 803, channel connector opening 847 of chamber plate 804, and channel connector feature 857 of chamber plate 805 form or define the channel fluid passage 521 between the pressure chamber 412 and manifold 515 as shown in FIGS. 6A and 8. In an embodiment, manifold 511 and manifold 515 are formed by the support plate 802. In an embodiment, manifold 510 and manifold 514 are formed by at least the support plate 802.

One technical benefit of the structure of printhead 104 disclosed above is print fluid may be circulated through jetting channels 402 by routing non-jetting print fluid toward the center of the printhead 104, which avoids drying or sedimentation of the print fluid within the jetting channels 402. Another benefit is the channel fluid passages 521 disposed toward the center of the printhead 104 are shorter conduits than other designs, which results in smaller fluidic resistance and faster exit of non-jetted print fluid from the jetting channels 402 (i.e., faster circulation time). This design also allows for fewer plates of plate stack 232, which reduces manufacturing costs and allows for higher-frequency jetting.

FIG. 12 is a flow chart illustrating a method 1200 of operating a printhead 104 in an illustrative embodiment. The steps of method 1200 will be described with reference to printhead 104 in FIG. 5A, but those skilled in the art will appreciate that method 1200 may be performed by other printheads. Also, the steps of the flow charts described herein are not all inclusive and may include other steps not shown, and the steps may be performed in an alternative order.

For method 1200, it is assumed that printhead 104 includes a row 501 of jetting channels 402 fluidly coupled to manifolds 510-511 disposed on opposite sides of row 501. For each jetting channel 402 in row 501 (or a subset of jetting channels 402 in row 501), a print fluid is conveyed from manifold 510 (i.e., a first manifold) to the pressure chamber 412 (step 1202), such as through the individual channel fluid passage 520 for that jetting channel 402. Non-jetted print fluid is conveyed from the pressure chamber 412 to manifold 511 (i.e., a second manifold) (step 1204), such as through the individual channel fluid passage 521 for that jetting channel 402.

In step 1204, the non-jetted print fluid may flow out of the pressure chamber 412 toward manifold 511 in the same direction (i.e., along the y-axis) that the print fluid flowed into the pressure chamber 412 from manifold 510. In FIG. 7, for example, the print fluid flows into the pressure chamber 412 in the direction indicated by the arrows (i.e., from left to right), and the non-jetted print fluid flows out of the pressure chamber 412 in the same direction. Thus, the print fluid may flow into and out of the pressure chamber 412 via channel fluid passage 520 and channel fluid passage 521 in the same lengthwise direction (i.e., along the y-axis) of a jetting channel 402. Also, for step 1204, print fluid may flow into one side 710 (i.e., a first side) of pressure chamber 412 through channel fluid passage 520, and flow out of the opposite side 711 (i.e., second side) of pressure chamber 412 through channel fluid passage 521, as indicated in FIG. 7. One technical benefit of conveying print fluid into and out of a pressure chamber 412 from opposite sides of a row 501 is the non-jetted print fluid does not need to re-routed in the opposite direction (i.e., along the y-axis), which results in smaller fluidic resistance and faster exit of non-jetted print fluid from the jetting channels 402 (i.e., faster circulation time).

In printheads, such as printhead 104 disclosed above, nozzle failures may occur due to a variety of factors, such as drying of print fluid at a nozzle or meniscus, sedimentation of the print fluid, bubbles present in the print fluid, etc. These and other nozzle failures may result in poor print quality. Thus, it may be beneficial to mix or stir the print fluid in individual jetting channels 402.

Intra-Channel Passive Mixer

In an embodiment, one or more intra-channel passive mixers may be implemented in jetting channels 402. FIG. 13 is a perspective view of a jetting channel 402 with one or more intra-channel passive mixers 1302 in an illustrative embodiment. The diaphragm 410 has been removed in FIG. 13. In general, a print fluid flows longitudinally or lengthwise along jetting channel 402 (i.e., along the y-axis). Each jetting channel 402 has a length 1350 along the y-axis, and print fluid flows along the length 1350 of the jetting channel 402 in what is generally referred to as a longitudinal flow. In an embodiment along a flow direction 714, for example, the print fluid flows through channel fluid passage 520 (e.g., from manifold 510) into pressure chamber 412. The print fluid also flows along pressure chamber 412 where the print fluid is jetted from nozzle 306 or is circulated through channel fluid passage 521. Therefore, channel fluid passage 520 and pressure chamber 412 may each comprise a longitudinal flow path 1310 for print fluid along the length 1350 of the jetting channel 402.

Each jetting channel 402 includes vertical side walls along the z-axis. A vertical side wall of a jetting channel 402 is generally perpendicular or transverse to a plane 1354 of the discharge surface 220 of the printhead 104. Print fluid jets from a nozzle 306 of a jetting channel 402 generally along the z-axis, and a vertical side wall of a jetting channel 402 is parallel to the jetting direction of the jetting channel 402. For example, channel fluid passage 520 of the jetting channel 402 includes opposing vertical side walls 1322-1323, and pressure chamber 412 includes opposing vertical side walls 1324-1325. In an embodiment, one or more intra-channel passive mixers 1302 may be disposed in the jetting channel 402. An intra-channel passive mixer 1302 comprises a protuberance, projection, rib, or other structural element within a jetting channel that projects or protrudes (e.g., horizontally along the x-axis) from a vertical side wall of the jetting channel into a longitudinal flow path 1310 of print fluid along the length 1350 of the jetting channel. Thus, an intra-channel passive mixer 1302 projects across the width of 1352 of a jetting channel 402.

In an embodiment, one or more intra-channel passive mixers 1302 may be disposed at channel fluid passage 520 (e.g., at restrictor 1110). Thus, one or more intra-channel passive mixers 1302 may project from a vertical side wall(s) 1322-1323 of channel fluid passage 520. One technical benefit of implementing intra-channel passive mixers 1302 in channel fluid passage 520 is the print fluid is mixed before entering the pressure chamber 412. In an embodiment, one or more intra-channel passive mixers 1302 may be disposed at pressure chamber 412. Thus, one or more intra-channel passive mixers 1302 may project from a vertical side wall(s)

1324-1325 of pressure chamber **412**. One technical benefit of implementing intra-channel passive mixers **1302** in pressure chamber **412** is the print fluid is mixed within the pressure chamber **412**. In an embodiment, intra-channel passive mixers **1302** may be disposed at channel fluid passage **520** and at pressure chamber **412** as illustrated in FIG. **13**. Although a jetting channel **402** may include multiple vertical side walls, intra-channel passive mixers **1302** may project from vertical side walls that are generally parallel to the length **1350** of the jetting channel **402** (i.e., along the y-axis), and generally perpendicular or transverse to a width **1352** of the jetting channel **402** (i.e., along the x-axis) as shown in FIG. **13**. Other jetting channels **402** may have a similar configuration with intra-channel passive mixers **1302** as shown in FIG. **13**.

FIGS. **14**A-**14**H are plan views of intra-channel passive mixers **1302** of a jetting channel **402** in illustrative embodiments. FIG. **14**A is a plan view of channel fluid passage **520** having a plurality of intra-channel passive mixers **1302**. Channel fluid passage **520** has a width **1410** along the x-axis, and each intra-channel passive mixer **1302** extends or projects a distance **1412** inward from a side wall **1322-1323** of channel fluid passage **520**. The distance **1412** in which an intra-channel passive mixer **1302** projects inward in the x-direction from a side wall **1322-1323** may be in the range of about 30-70 micrometers, about 10-60% of the width **1410** of channel fluid passage **520**, etc. The length of an intra-channel passive mixer **1302** may be about 10-50 micrometers in the y-direction. Each intra-channel passive mixer **1302** may project about the same distance **1412**, or the distance **1412** may vary from one intra-channel passive mixer **1302** to another. FIG. **14**B is a plan view of channel fluid passage **520** showing a longitudinal flow **1418** of print fluid (illustrated by arrows). In a typical printhead, the flow of print fluid along a jetting channel is a laminar flow (or streamline flow). A laminar flow is a type of fluid flow in which the fluid travels smoothly or in regular paths. As the print fluid flows along channel fluid passage **520** (i.e., from left to right in FIG. **14**B) and encounters an intra-channel passive mixer **1302**, the intra-channel passive mixer **1302** creates a turbulent flow **1420** in the print fluid (i.e., a locally-turbulent flow proximate to the intra-channel passive mixer **1302**). The intra-channel passive mixers **1302** represent obstacles in channel fluid passage **520** that create a turbulent flow **1420** in which the print fluid undergoes irregular fluctuations and mixing. One technical benefit is the print fluid is mixed within channel fluid passage **520** via intra-channel passive mixers **1302** to restore homogeneity of the print fluid.

In an embodiment, a pair **1440** of intra-channel passive mixers **1302** may be disposed on opposing side walls **1322-1323** of channel fluid passage **520** as shown in FIG. **14**A that are generally aligned across the width **1410** of channel fluid passage **520**. In an embodiment, a pair **1440** of intra-channel passive mixers **1302** may be disposed on opposing side walls **1322-1323** and offset or staggered in relation to one another across the width **1410** of channel fluid passage **520**, as shown in FIG. **14**C. The intra-channel passive mixers **1302** in FIGS. **14**A-**14**C are shown with generally a square or rectangular shape **1430**. However, intra-channel passive mixers **1302** may have other shapes in other embodiments. For example, intra-channel passive mixers **1302** may have a generally triangular shape **1431** as shown in FIGS. **14**D-**14**E. Intra-channel passive mixers **1302** may have a generally shark-fin shape **1432** as shown in FIG. **14**F. Intra-channel passive mixers **1302** may have a generally trapezoidal shape **1433** as shown in FIG. **14**G. Intra-channel passive mixers **1302** may have a generally rounded shape **1434** as shown in FIG. **14**H. Any combination of different shapes may be implemented. Also, although four intra-channel passive mixers **1302** are illustrated in FIGS. **14**A-**14**H, the number of intra-channel passive mixers **1302** may vary as desired. For example, the number of intra-channel passive mixers **1302** and their location may depend on the turbulence length scale. For low viscosity print fluid, fewer intra-channel passive mixers **1302** may be needed. For higher viscosity print fluid, more intra-channel passive mixers **1302** may be needed. Also, although intra-channel passive mixers **1302** were shown in channel fluid passage **520** in FIGS. **14**A-**14**H, similar concepts apply when intra-channel passive mixers **1302** are disposed in a pressure chamber **412** of a jetting channel **402**, which is not shown for the sake of brevity. Each shape or combination of shapes for the intra-channel passive mixers **1302** provides a technical benefit of creating turbulence in a flow of print fluid to cause mixing of the print fluid. Also, different shapes may be matched to different ink types. For example, heavily pigment-loaded inks in combination with ink viscosity and surface tension may be more suitably matched with the shark-fin shape **1432** than a square or rectangular shape **1430**, avoiding pigment piling in a dead spot.

To implement intra-channel passive mixers **1302** in channel fluid passage **520**, a restrictor plate **803** as disclosed above (see FIG. **8**) may be etched or patterned with one or more intra-channel passive mixers **1302**. FIG. **15** illustrates restrictor plate **803** in an illustrative embodiment. Zoom window **1500** illustrates a magnified view of a restrictor opening **834** on restrictor plate **803**. Restrictor opening **834** is an elongated opening etched or cut into restrictor plate **803**, and has opposing vertical side walls **1506-1507**. In an embodiment, restrictor opening **834** is etched or patterned with one or more intra-channel passive mixers **1302** projecting inward from restrictor plate **803** into the restrictor opening **834**. For example, restrictor opening **834** is etched so that intra-channel passive mixers **1302** project from side walls **1506-1507** toward a middle region of restrictor opening **834**. Restrictor region **1510** of restrictor opening **834** represents where a restrictor **1110** of a jetting channel **402** is located. Thus, intra-channel passive mixers **1302** may be etched or patterned at restrictor region **1510** so that intra-channel passive mixers **1302** are disposed at the restrictor **1110** (e.g., channel fluid passage **520**) of the jetting channel **402**. Each restrictor opening **834-835** on restrictor plate **803** may be patterned in a similar manner. One technical benefit is intra-channel passive mixers **1302** may be patterned using existing lithography processes.

To implement intra-channel passive mixers **1302** in a pressure chamber **412**, a chamber plate **804** as disclosed above (see FIG. **8**) may be etched or patterned with one or more intra-channel passive mixers **1302**. FIG. **16** illustrates chamber plate **804** in an illustrative embodiment. Zoom window **1600** illustrates a magnified view of a chamber opening **844** of chamber plate **804**. Chamber opening **844** is an elongated opening etched or cut into chamber plate **804**, and has opposing side walls **1606-1607**. In an embodiment, chamber opening **844** is etched or patterned with one or more intra-channel passive mixers **1302** projecting inward from chamber plate **804** into the chamber opening **844**. For example, chamber opening **844** is etched so that intra-channel passive mixers **1302** project from side walls **1606-1607** toward a middle region of chamber opening **844**. Each chamber opening **844-845** on chamber plate **804** may be patterned in a similar manner. Also, chamber plate **805** of plate stack **232** may be etched in a similar manner, or as an alternative to etching chamber plate **804**. One technical benefit is intra-channel passive mixers **1302** may be patterned using existing lithography processes.

FIG. **17** is a flow chart illustrating a method **1700** of operating a printhead **104** with one or more intra-channel passive mixers **1302** in an illustrative embodiment. The steps of method **1700** will be described with reference to a printhead **104** having jetting channels **402** as in FIG. **13**, but those skilled in the art will appreciate that method **1700** may be performed by other printheads. For each jetting channel **402**, a flow of print fluid is conveyed along a longitudinal flow path **1310** of the jetting channel **402** (step **1702**). One or more intra-channel passive mixers **1302** disturb the flow of print fluid along the longitudinal flow path **1310** (step **1704**). For example, as the print fluid flows through channel fluid passage **520** into pressure chamber **412** (see FIG. **13**), one or more intra-channel passive mixers **1302** may disturb the flow of print fluid through channel fluid passage **520**. As the print fluid flows through pressure chamber **412**, one or more intra-channel passive mixers **1302** may disturb the flow of print fluid through pressure chamber **412**. One technical benefit is the print fluid is mixed within the jetting channel **402** to restore homogeneity of the print fluid.

Intra-Chamber Active Mixer

In an embodiment, one or more intra-chamber active mixers may be implemented in jetting channels **402**. FIG. **18** is a perspective view of a jetting channel **402** with one or more intra-chamber active mixers **1802** in an illustrative embodiment. The diaphragm **410** has been removed in FIG. **18**. As above, each pressure chamber **412** includes vertical side walls along the z-axis. In an embodiment, one or more intra-chamber active mixers **1802** may be disposed at the pressure chamber **412**. An intra-chamber active mixer **1802** comprises a structural element within a pressure chamber **412** of a jetting channel **402** configured to oscillate, vibrate, or otherwise move in response to fluidic vibration within the pressure chamber **412**. Other jetting channels **402** may have a similar configuration with an intra-chamber active mixer **1802** as shown in FIG. **18**. One technical benefit of implementing an intra-chamber active mixer **1802** is the print fluid is mixed within a pressure chamber **412** to restore homogeneity of the print fluid.

FIG. **19** is a perspective view of an intra-chamber active mixer **1802** in an illustrative embodiment. Intra-chamber active mixer **1802** includes a cantilever **1902**, which comprises a structural member that projects or protrudes from a vertical side wall of a pressure chamber **412**. One end **1904** (i.e., a connected end) of cantilever **1902** is rigidly connected or attached to a vertical side wall **1822**, and the other end **1906** (i.e., a free end) of cantilever **1902** is unattached to the pressure chamber **412** and is free to move. Cantilever **1902** has a length **1950**, a width **1952**, and a thickness **1954** or height. Although dimensions of a cantilever **1902** may vary as desired, the length **1950** of cantilever **1902** may be in the range of about 200-260 micrometers, the width **1952** of cantilever **1902** may be in the range of about 25-35 micrometers, and the thickness **1954** of cantilever **1902** may be in the range of about 15-60 micrometers.

FIG. **20** is a perspective view of an intra-chamber active mixer **1802** in another illustrative embodiment. As in FIG. **19**, intra-chamber active mixer **1802** includes a cantilever **1902**, which comprises a structural member that projects or protrudes from a vertical side wall of a pressure chamber **412**. One end **1904** (i.e., a connected end) of cantilever **1902** is rigidly connected or attached to a vertical side wall **1822**, and the other end **1906** (i.e., a free end) of cantilever **1902** is unattached to the pressure chamber **412** and is free to move. In this embodiment, intra-chamber active mixer **1802** further includes an end mass **2008** at the free end **1906** of cantilever **1902**.

The free end **1906** of cantilever **1902** is free to oscillate, vibrate, or otherwise move in response to fluidic vibration within the pressure chamber **412**. For example, when an actuator **416** fires in response to jetting pulses, pressure waves are created in pressure chamber **412** that cause jetting of droplets from its corresponding nozzle **306**. The pressure waves in the print fluid drive the free end **1906** of cantilever **1902** to oscillate or vibrate. In other words, intra-chamber active mixer **1802** is driven (e.g., solely) from energy of the pressure waves, which has a technical benefit in that a separate actuator or drive mechanism is not needed to cause oscillation of free end **1906** of the cantilever **1902**. Oscillation of cantilever **1902** creates local vortices and/or turbulence within the pressure chamber **412** that mix the print fluid within the pressure chamber **412**. Thus, cantilever **1902** forms a micro-stirrer within a pressure chamber **412**. One technical benefit of implementing an intra-chamber active mixer **1802** constructed with a cantilever **1902** or cantilever **1902** with an end mass **2008** is the print fluid is mixed within a pressure chamber **412** to restore homogeneity of the print fluid. This helps to prevent drying or sedimentation of the print fluid within the pressure chamber **412**, which can result in a partially-blocked or fully-blocked nozzle **306**. Another technical benefit is the jetting channel **402** may self-recover from missing jets caused by air bubbles.

The pressure waves in a pressure chamber **412** will resonate or absorb at a characteristic frequency. This characteristic frequency is determined by the geometry of the pressure chamber **412** (and other structures of a jetting channel **402**) and their associated fluidic properties, and is referred to as the resonance frequency or Helmholtz frequency of a jetting channel **402**. An intra-chamber active mixer **1802** also has a resonance frequency. For example, the resonance frequency of intra-chamber active mixer **1802** depends on the modulus of elasticity (i.e., the ratio of stress to strain in elastic range of deformation) for the material used to form cantilever **1902** (e.g., stainless steel), the moment of inertia for cantilever **1902** (e.g., a rectangular area), the length **1950** and width **1952** of cantilever **1902**, the mass of end mass **2008** (if implemented), etc. In an embodiment, the characteristics of intra-chamber active mixer **1802** may be selected so that the resonance frequency of intra-chamber active mixer **1802** differs from the Helmholtz frequency of the jetting channel **402** by a threshold amount. Thus, the length **1950** and width **1952** of cantilever **1902**, the mass of end mass **2008** (if implemented), the shape of cantilever **1902**, etc., may be selected so that the resonance frequency of intra-chamber active mixer **1802** differs from the Helmholtz frequency of the jetting channel **402** by the threshold amount. For example, a typical Helmholtz frequency of a jetting channel **402** may be in the range of about 80-120 kHz, and the resonance frequency of intra-chamber active mixer **1802** may be selected or provisioned to much lower than the Helmholtz frequency, such as in a range of about 0.1-5 KHz. In an embodiment, the resonance frequency of intra-chamber active mixer **1802** is selected so that vibration of cantilever **1902** is far apart from the Helmholtz frequency of the jetting channel **402**. One technical benefit is, due to the wide gap between the Helmholtz frequency of the jetting channel **402** and the resonance frequency of intra-chamber active mixer **1802**, oscillation of the intra-chamber active mixer **1802** does not interfere with jetting of a jetting channel **402**.

FIGS. **21**A-**21**I are plan views of a pressure chamber **412** with one or more intra-chamber active mixers **1802** in illustrative embodiments. In FIG. **21**A, an intra-chamber active mixer **1802** connects to a vertical side wall **1822** of the pressure chamber **412**. In an embodiment, vertical side wall **1822** is generally perpendicular or transverse to the length **1350** of the jetting channel **402** (i.e., along the y-axis), and generally parallel to a width **1352** of the jetting channel **402** (i.e., along the x-axis) as shown in FIG. **18**. Intra-chamber active mixer **1802** may be generally centered over or aligned with the nozzle **306** of the jetting channel **402** as shown in FIG. **21**A, which provides a technical benefit of mixing print fluid evenly within the pressure chamber **412**. The length **1950** of cantilever **1902** (see FIG. **19**) may be at least as long as the distance **2160** between the vertical side wall **1822** and the nozzle **306** so that intra-chamber active mixer **1802** vertically overlaps (i.e., along the z-axis) with the nozzle **306** as shown in FIG. **21**A. In an embodiment, the length **1950** of cantilever **1902** (see FIG. **19**) may be shorter than the distance **2160** between the vertical side wall **1822** and the nozzle **306** so that intra-chamber active mixer **1802** does not vertically overlap (i.e., along the z-axis) with the nozzle **306** as shown in FIG. **21**B. In FIG. **21**C, an intra-chamber active mixer **1802** may be generally offset from the nozzle **306** of the jetting channel **402**, which provides a technical benefit of manufacturing flexibility and turbulence location for mixing variations sometimes needed to avoid interference with the nozzle functions.

In some embodiments, an intra-chamber active mixer **1802** may be disposed on different vertical side walls of the pressure chamber **412**. For example, in FIG. **21**D, intra-chamber active mixer **1802** may connect to another vertical side wall **2123** of the pressure chamber **412** that is generally perpendicular or transverse to the length **1350** of the jetting channel **402** (i.e., along the y-axis), and generally parallel to a width **1352** of the jetting channel **402** (i.e., along the x-axis). In FIG. **21**E, intra-chamber active mixer **1802** may connect to another vertical side wall **2124** of pressure chamber **412** that is generally parallel to the length **1350** of the jetting channel **402** (i.e., along the y-axis), and generally perpendicular or transverse to a width **1352** of the jetting channel **402** (i.e., along the x-axis). In FIG. **21**F, intra-chamber active mixer **1802** may connect to another vertical side wall **2125** of pressure chamber **412** that is generally parallel to the length **1350** of the jetting channel **402** (i.e., along the y-axis), and generally perpendicular or transverse to a width **1352** of the jetting channel **402** (i.e., along the x-axis). In some embodiments, more than one intra-chamber active mixer **1802** may be utilized in a pressure chamber **412**. In FIG. **21**G, a pair **2130** of intra-chamber active mixers **1802** may be connected to opposing vertical sides walls **1822**/**2123**. In FIG. **21**H, a pair **2130** of intra-chamber active mixers **1802** may be connected to opposing vertical sides walls **2124**-**2125**. In FIG. **21**I, four intra-chamber active mixers **1802** may be connected to vertical sides walls **1822** and **2123**-**2125**. A technical benefit of each configuration in FIGS. **21**A-**21**I is that print fluid is mixed within a pressure chamber **412** to restore homogeneity of the print fluid. Multiple intra-chamber active mixers **1802** may be implemented for different ink types (e.g., higher viscosity inks, or heavily loaded inks).

To implement an intra-chamber active mixers **1802** in a pressure chamber **412**, a chamber plate **805** as disclosed above (see FIG. **8**) may be etched or patterned with one or more intra-chamber active mixers **1802**. FIG. **22** illustrates chamber plate **805** in an illustrative embodiment. Zoom window **2200** illustrates a magnified view of a chamber opening **854** on chamber plate **805**. Chamber opening **854** is an opening etched or cut into chamber plate **805**, and has side walls **2206**-**2209**. In an embodiment, chamber opening **854** is etched or patterned with one or more cantilevers **1902** of an intra-chamber active mixer **1802** projecting inward from chamber plate **805** into the chamber opening **854**. This etching controls or defines the length **1950** and width **1952** of cantilever **1902**. In an embodiment, cantilever **1902** may be partially etched on chamber plate **805** to control or define the thickness **1954** of cantilever **1902** (shown by hashing). Each chamber opening **854**-**855** on chamber plate **805** may be patterned in a similar manner. Although one cantilever **1902** is shown projecting from side wall **2206** in FIG. **22**, chamber plate **805** may be etched or patterned in a similar manner to form one or more intra-chamber active mixers **1802** as illustrated in FIGS. **21**A-**21**I. One technical benefit is intra-chamber active mixers **1802** may be patterned using existing lithography processes, and the dimensions of a cantilever **1902** may be accurately controlled with etching and/or partial etching processes.

FIG. **23** is a flow chart illustrating a method **2300** of operating a printhead **104** with an intra-chamber active mixer **1802** in an illustrative embodiment. The steps of method **2300** will be described with reference to a printhead **104** having jetting channels **402** as in FIG. **18**, but those skilled in the art will appreciate that method **2300** may be performed by other printheads. For each jetting channel **402**, a print fluid is received in the pressure chamber **412** of the jetting channel **402** (step **2302**). The free end **1906** of a cantilever **1902** oscillates to mix the print fluid in the pressure chamber **412** (step **2304**). For example, when an actuator **416** fires in response to jetting pulses, pressure waves are created in the pressure chamber **412** that cause jetting of droplets from its corresponding nozzle **306**. The pressure waves in the print fluid drive the free end **1906** of cantilever **1902** to oscillate or vibrate. This acts as a micro-stirrer that stirs the print fluid locally within the pressure chamber **412**. One technical benefit is the print fluid is mixed within the pressure chamber **412** to restore homogeneity of the print fluid.

Intra-Channel Fluid Mixer

In an embodiment, one or more intra-channel fluid mixers may be implemented in jetting channels **402**. FIG. **24** is a perspective view of a jetting channel **402** with an intra-channel fluid mixer **2402** in an illustrative embodiment. The diaphragm **410** has been removed in FIG. **24**. In an embodiment, an intra-channel fluid mixer **2402** is disposed at a channel fluid passage **521** that fluidly couples the pressure chamber **412** with a manifold **511**. An intra-channel fluid mixer **2402** comprises a structural element within a jetting channel **402** configured to cause a circular rotation or motion of print fluid that flows between the pressure chamber **412** and the manifold **511**. The circular rotation or motion of print fluid creates a vortex that mixes the print fluid. As illustrated in FIG. **24**, jetting channel **402** (and other jetting channels **402** of printhead **104**) may comprise flow-through jetting channels **540**. Thus, intra-channel fluid mixer **2402** may be configured to cause circular rotation or motion of non-jetted print fluid that flows from pressure chamber **412** to a manifold through channel fluid passage **521**. However, intra-channel fluid mixer **2402** may be disposed at different locations of a jetting channel **402**, or may be used with a non-flow through type of jetting channel **402**. One technical benefit of implementing an intra-channel fluid mixer **2402** is the print fluid is mixed within a jetting channel **402** to restore homogeneity of the print fluid. Other jetting channels **402** may have a similar configuration with an intra-channel fluid mixer **2402** as shown in FIG. **24**.

FIGS. **25**A-**25**D illustrate an intra-channel fluid mixer **2402** in illustrative embodiments. FIG. **25**A is a perspective view of an intra-channel fluid mixer **2402**, which includes an inlet/outlet segment **2510** (i.e., a first inlet/outlet segment), a cylindrical mixing chamber **2512**, and another inlet/outlet segment **2514** (i.e., a second inlet/outlet segment). In an embodiment, inlet/outlet segment **2510** is disposed at one side **2516** of mixing chamber **2512**, and inlet/outlet segment **2514** is disposed generally at an opposite side **2517** of mixing chamber **2512** (i.e., along the y-axis). Segments **2510** and **2514** are referred to as "inlet/outlet" or "I/O" segments as print fluid may flow into or out of mixing chamber **2512** through either of segments **2510** and **2514** depending on the direction of flow of print fluid through a jetting channel **402**. If a flow is only in one direction, segment **2510** may be referred to as an inlet segment, and segment **2514** may be referred to as an outlet segment. Mixing chamber **2512** is a cavity having a generally cylindrical shape **2519**, and the dimensions of mixing chamber **2512** may be a diameter **2546** in the range of about 70-90 micrometers, and a height **2548** in the range of about 60-120 micrometers. FIG. **25**B is a plan view of intra-channel fluid mixer **2402**, which illustrates a flow of print fluid in one direction. Inlet/outlet segment **2510** is configured to receive a flow of print fluid (e.g., non-jetted print fluid from a pressure chamber **412** of a jetting channel **402**). The print fluid flows from inlet/outlet segment **2510** into mixing chamber **2512**. Due to the structure of mixing chamber **2512**, a turbulent flow is created within mixing chamber **2512**. For example, the volume **2540** of mixing chamber **2512** may be larger than the volume **2542** of inlet/outlet segment **2510** or inlet/outlet segment **2514** (see FIG. **25**A). Also, the cylindrical shape **2519** of mixing chamber **2512** causes a circular rotation or motion of print fluid within mixing chamber **2512**. The circular rotation or motion of print fluid creates a vortex **2518** as the print fluid revolves around an axis **2520**. FIG. **25**C is a perspective view of intra-channel fluid mixer **2402**, which further shows the vortex **2518** created within mixing chamber **2512** as the print fluid revolves around axis **2520**. In FIGS. **25**B-**25**C, the print fluid circulating within mixing chamber **2512** exits through inlet/outlet segment **2514** (e.g., toward a manifold). The print fluid exiting mixing chamber **2512** is mixed via the turbulent flow created within mixing chamber **2512**, which has a technical benefit of restoring homogeneity of the print fluid. When intra-channel fluid mixer **2402** is implemented in a channel fluid passage **521** as illustrated in FIG. **24**, the print fluid may be mixed as/before the print fluid exits the jetting channel **402** (for a flow in one direction) or may be mixed as the print fluid enters the jetting channel **402** (for a flow in a reverse direction).

In an embodiment, inlet/outlet segment **2510** may be offset (e.g., horizontally offset) from mixing chamber **2512** to induce rotation of the print fluid within mixing chamber **2512** as illustrated in FIG. **25**B. For example, the center **2530** of inlet/outlet segment **2510** (i.e., along the x-axis) may be offset from a center **2532** of mixing chamber **2512**. At the same time, inlet/outlet segment **2514** may be generally centered with respect to mixing chamber **2512**. For example, the center **2534** of inlet/outlet segment **2514** (i.e., along the x-axis) may be generally aligned with the center **2532** of mixing chamber **2512**. In an embodiment, inlet/outlet segment **2514** may be offset (e.g., horizontally offset) from mixing chamber **2512**. FIG. **25**D is a plan view of intra-channel fluid mixer **2402**. For example, the center **2534** of inlet/outlet segment **2514** (i.e., along the x-axis) may be offset from the center **2532** of mixing chamber **2512**. In an embodiment, inlet/outlet segment **2510** may be vertically offset from inlet/outlet segment **2514** as illustrated in FIG. **25**C. For example, the center **2530** of inlet/outlet segment **2510** (i.e., along the y-axis) may be offset from the center **2534** of inlet/outlet segment **2514**. Each of these configurations has a technical benefit of causing a circular rotation or motion of print fluid within mixing chamber **2512**.

Intra-channel fluid mixer **2402** as described above may be referred to as a passive fluid mixer, and it does not contain elements or features that actively move to stir the print fluid in mixing chamber **2512**. Mixing is performed by the circular rotation or motion of print fluid in the mixing chamber **2512**. Although examples of intra-channel fluid mixer **2402** were shown in FIGS. **25**A-**25**D, other structures or designs may be considered herein.

In an embodiment, chamber plates **804-805** as shown in FIG. **8** may be etched or otherwise patterned to form intra-channel fluid mixer **2402**. FIG. **26** illustrates chamber plate **804** in an illustrative embodiment. As described above, chamber plate **804** is a substantially flat or planar sheet of material, and thus has opposing planar surfaces **910-911**. Planar surface **910** faces toward the discharge surface **220** of the printhead **104**, while planar surface **911** faces toward housing **230**. Zoom window **2600** illustrates a magnified view of a chamber opening **844** and a channel connector opening **846** of chamber plate **804**. Chamber opening **844** is an elongated opening etched or cut into chamber plate **804**, and channel connector opening **846** is an opening etched or cut into chamber plate **804** between chamber opening **844** and the longitudinal centerline **841** of chamber plate **804**. In an embodiment, chamber plate **804** further includes a partially-etched segment **2602** that extends part way from chamber opening **844** toward channel connector opening **846**. To form partially-etched segment **2602**, chamber plate **804** is partially etched from planar surface **910** to an etching depth less than the thickness of chamber plate **804**. For example, partially-etched segment **2602** may comprise a "half-etch" where the etching depth is about half the thickness of chamber plate **804**. Thus, partially-etched segment **2602** does not form a hole through chamber plate **804**. Partially-etched segment **2602** includes a rectangular segment **2604** that begins at chamber opening **844** and extends along a length **2620** (i.e., along the y-axis) toward channel connector opening **846**. A width **2632** (i.e., along the x-axis) of rectangular segment **2604** may correspond with a width **932** of chamber opening **844**. Partially-etched segment **2602** further includes a disc-like or circular segment **2606** that begins at rectangular segment **2604** and extends along a length **2622** (i.e., along the y-axis) toward channel connector opening **846**. A diameter **2626** (i.e., along the x-axis) of circular segment **2606** is larger than the width **2632** of rectangular segment **2604**, and may be in the range of about 70-90 micrometers. Rectangular segment **2604** of partially-etched segment **2602** forms an inlet/outlet segment **2510** of an intra-channel fluid mixer **2402**, and circular segment **2606** forms at least part of a mixing chamber **2512** of an intra-channel fluid mixer **2402**. A partially-etched segment **2602** may be etched between each chamber opening **844-845** and channel connector opening **846-847** of chamber plate **804** in a similar manner. One technical benefit is intra-channel fluid mixer **2402** may be patterned using existing lithography processes.

FIG. **27** illustrates chamber plate **805** in an illustrative embodiment. As described above, chamber plate **805** is a substantially flat or planar sheet of material, and thus has opposing planar surfaces **1010-1011**. Planar surface **1010** faces toward the discharge surface **220** of the printhead **104**, while planar surface **1011** faces toward housing **230**. Zoom window **2700** illustrates a magnified view of a chamber opening **854** and a channel connector feature **856** of chamber plate **805**. Chamber opening **854** is an opening etched or cut into chamber plate **805**, and channel connector feature **856** comprises a partially-etched segment **2702** etched into chamber plate **805** between chamber opening **854** and the longitudinal centerline **851** of chamber plate **805**. To form partially-etched segment **2702**, chamber plate **805** is partially etched from planar surface **1011** to an etching depth less than the thickness of chamber plate **805**. For example, partially-etched segment **2702** may comprise a "half-etch" where the etching depth is about half the thickness of chamber plate **805**. Thus, partially-etched segment **2702** does not form a hole through chamber plate **805**. Partially-etched segment **2702** includes a rectangular segment **2704** that extends along a length **2720** (i.e., along the y-axis) between the longitudinal centerline **851** of chamber plate **805** and chamber opening **854**. Partially-etched segment **2702** further includes a disc-like or circular segment **2706** that begins at rectangular segment **2704** and extends along a length **2722** (i.e., along the y-axis) toward chamber opening **854**. A diameter **2726** (i.e., along the x-axis) of circular segment **2706** is larger than the width **2732** of rectangular segment **2704**, and may be in the range of about 70-90 micrometers. Rectangular segment **2704** of partially-etched segment **2702** forms an inlet-outlet segment **2514** of an intra-channel fluid mixer **2402**, and circular segment **2706** forms at least part of a mixing chamber **2512** of an intra-channel fluid mixer **2402**. A partially-etched segment **2702** may be etched between each chamber opening **854-855** and channel connector feature **856-857** of chamber plate **805** in a similar manner. One technical benefit is intra-channel fluid mixer **2402** may be patterned using existing lithography processes.

The configuration of plate stack **232** in FIGS. **26-27** is provided as an example, and other configurations as considered herein.

FIG. **28** is a flow chart illustrating a method **2800** of operating a printhead **104** with an intra-channel fluid mixer **2402** in an illustrative embodiment. The steps of method **2800** will be described with reference to a printhead **104** having jetting channels **402** as in FIG. **24**, but those skilled in the art will appreciate that method **2800** may be performed by other printheads.

For method **2800**, intra-channel fluid mixer **2402** receives a print fluid (e.g., non-jetted print fluid) that flows between a pressure chamber **412** and a manifold through channel fluid passage **521** (step **2802**). For example, inlet/outlet segment **2510** (see FIG. **25**A) may receive a flow of print fluid from a pressure chamber **412** of a jetting channel **402**. Intra-channel fluid mixer **2402** causes a circular rotation of the print fluid (step **2804**). For example, the print fluid may flow from inlet/outlet segment **2510** into mixing chamber **2512**, as shown in FIGS. **25**B-**25**C. Mixing chamber **2512** causes a circular rotation or motion of the print fluid, and creates a vortex **2518** as the print fluid revolves around an axis **2520** (optional step **2810**). The print fluid is then conveyed from the intra-channel fluid mixer **2402** along the channel fluid passage **521** (step **2806**). For example, the print fluid circulating within mixing chamber **2512** exits through inlet/outlet segment **2514** (e.g., toward a manifold), as shown in FIGS. **25**B-**25**C. One technical benefit is the print fluid is mixed within the jetting channel **402** to restore homogeneity of the print fluid.

Embodiments above for the intra-channel passive mixers **1302**, the intra-chamber active mixers **1802**, and intra-channel fluid mixer **2402** were described with reference to a flow-through printhead **504** such as shown in FIGS. **5**A and **6**A-**6**B. However, one or more of the intra-channel passive mixers **1302**, the intra-chamber active mixers **1802**, and the intra-channel fluid mixer **2402** may be implemented in a different flow-through printhead while retaining the technical benefits noted above. Further, one or more of the intra-channel passive mixers **1302**, the intra-chamber active mixers **1802**, and the intra-channel fluid mixer **2402** may be implemented in a non-flow-through printhead while retaining the technical benefits noted above. FIG. **29** is a cross-section of a flow-through printhead **2904** in an illustrative embodiment. Printhead **2904** has a similar configuration as described above with jetting channels arranged in one or more rows. However, the flow-through jetting channels **2902** have a different configuration than described above. For example, a jetting channel **2902** includes a first channel fluid passage **2920** that fluidly couples a pressure chamber **412** to a manifold **2910**, and includes a second channel fluid passage **2921** that fluidly couples the pressure chamber **412** to another manifold **2911**. In this configuration, print fluid may flow into and out of the pressure chamber **412** via channel fluid passage **2920** and channel fluid passage **2921** in different lengthwise directions (i.e., along the y-axis) of a jetting channel **402**, instead of in the same lengthwise direction as in FIG. **6**B. For example, print fluid may flow from manifold **2910** into the pressure chamber **412** through channel fluid passage **2920** (i.e., from left to right), and non-jetted print fluid may flow out of the pressure chamber **412** into manifold **2911** through channel fluid passage **2921** in the opposite direction (i.e., from right to left). A flow-through printhead **2904** such as this may implement intra-channel passive mixers **1302**, intra-chamber active mixers **1802**, and/or intra-channel fluid mixer **2402** as described above.

FIG. **30** is a cross-section of a non-flow-through printhead **3004** in an illustrative embodiment. Printhead **3004** has a similar configuration as described above with jetting channels arranged in one or more rows. However, the jetting channels are non-flow-through jetting channels **3002**. For example, a jetting channel **3002** includes a single channel fluid passage **3020** that fluidly couples a pressure chamber **412** to a manifold **3010**. However, there is no return path for non-jetted print fluid to flow out of the pressure chamber **412**. A non-flow-through printhead **3004** such as this may implement intra-channel passive mixers **1302** and/or intra-chamber active mixers **1802** as described above while retaining the technical benefits noted above.

The following clauses and/or examples pertain to further embodiments or examples. Specifics in the examples may be used anywhere in one or more embodiments. The various features of the different embodiments or examples may be variously combined with some features included and others excluded to suit a variety of different applications. Examples may include subject matter such as a method, means for performing acts of the method, at least one machine-readable medium including instructions that, when performed by a machine cause the machine to perform acts of the method, or of an apparatus or system according to embodiments and examples described herein.

Some embodiments pertain to Example 1 that include a printhead comprising a plurality of jetting channels, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid, and one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel.

Example 2 includes the subject matter of Example 1, further comprising a manifold fluidly coupled to the jetting channels, wherein the one or more intra-channel passive mixers project from the one or more vertical side walls of a channel fluid passage that fluidly couples the manifold and the pressure chamber.

Example 3 includes the subject matter of Examples 1 and 2, where the one or more intra-channel passive mixers comprise a pair of the intra-channel passive mixers that project from opposing vertical side walls of the channel fluid passage.

Example 4 includes the subject matter of Examples 1-3, where the pair of the intra-channel passive mixers are aligned across a width of the channel fluid passage.

Example 5 includes the subject matter of Examples 1-4, where the pair of the intra-channel passive mixers are staggered across a width of the channel fluid passage.

Example 6 includes the subject matter of Examples 1-5, where the one or more intra-channel passive mixers project from the one or more vertical side walls of the pressure chamber.

Example 7 includes the subject matter of Examples 1-6, where the one or more intra-channel passive mixers have a generally square or rectangular shape.

Example 8 includes the subject matter of Examples 1-7, where the one or more intra-channel passive mixers have a generally triangular shape.

Example 9 includes the subject matter of Examples 1-8, where the one or more intra-channel passive mixers have a generally shark-fin shape.

Example 10 includes the subject matter of Examples 1-9, where the one or more intra-channel passive mixers have a generally trapezoidal shape.

Example 11 includes the subject matter of Examples 1-10, where the one or more intra-channel passive mixers have a generally rounded shape.

Example 12 includes the subject matter of Examples 1-11, where the jetting channels comprise flow-through jetting channels.

Example 13 includes the subject matter of Examples 1-12, further comprising a jetting apparatus.

Some embodiments pertain to Example 14 that include a printhead comprising a housing and a plate stack attached to the housing that forms a plurality of jetting channels, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid. The plate stack forms one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel.

Example 15 includes the subject matter of Example 14, further comprising a manifold fluidly coupled to the jetting channels, wherein the one or more intra-channel passive mixers project from the one or more vertical side walls of a channel fluid passage that fluidly couples the manifold and the pressure chamber.

Example 16 includes the subject matter of Examples 14-15, where the one or more intra-channel passive mixers project from the one or more vertical side walls of the pressure chamber.

Example 17 includes the subject matter of Examples 14-16, where the one or more intra-channel passive mixers have a generally shark-fin shape.

Example 18 includes the subject matter of Examples 14-17, where the plate stack includes a diaphragm plate that forms diaphragms of the jetting channels, a support plate, a restrictor plate, a first chamber plate and a second chamber plate that form pressure chambers of the jetting channels, and a nozzle plate having nozzle holes that define nozzles of the jetting channels, wherein at least one of the restrictor plate and the first chamber plate form the one or more intra-channel passive mixers.

Example 19 includes the subject matter of Examples 14-18, where the restrictor plate includes restrictor openings, each configured to fluidly couple an individual one of the pressure chambers of the jetting channels with a manifold, wherein a restrictor opening is etched with the one or more intra-channel passive mixers projecting inward from the restrictor plate into the restrictor opening.

Example 20 includes the subject matter of Examples 14-19, where the first chamber plate includes chamber openings that form at least part of the pressure chambers of the jetting channels, wherein a chamber opening is etched with the one or more intra-channel passive mixers projecting inward from the first chamber plate into the chamber opening.

Example 21 includes the subject matter of Examples 14-20, further comprising a jetting apparatus.

Some embodiments pertain to Example 22 that includes a method comprising operating a printhead comprising a plurality of jetting channels, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, and a nozzle configured to jet a print fluid, and one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel. Operating the printhead comprises conveying a flow of the print fluid along the longitudinal flow path, and disturbing the flow of the print fluid along the longitudinal flow path with the one or more intra-channel passive mixers.

Although specific embodiments were described herein, the scope of the invention is not limited to those specific embodiments. The scope of the invention is defined by the following claims and any equivalents thereof.

What is claimed is:

1. A printhead comprising:

a plurality of jetting channels fluidly coupled to a common manifold, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, a nozzle configured to jet a print fluid, and a channel fluid passage that fluidly couples the common manifold and the pressure chamber; and

one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel, and do not actively move.

2. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers project from the one or more vertical side walls of the channel fluid passage.

3. The printhead of claim **2**, wherein:

the one or more intra-channel passive mixers comprise a pair of the intra-channel passive mixers that project from opposing vertical side walls of the channel fluid passage.

4. The printhead of claim **3**, wherein:

the pair of the intra-channel passive mixers are aligned across a width of the channel fluid passage.

5. The printhead of claim **3**, wherein:

the pair of the intra-channel passive mixers are staggered across a width of the channel fluid passage.

6. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers project from the one or more vertical side walls of the pressure chamber.

7. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers have a generally square or rectangular shape.

8. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers have a generally triangular shape.

9. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers have a generally shark-fin shape.

10. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers have a generally trapezoidal shape.

11. The printhead of claim **1**, wherein:

the one or more intra-channel passive mixers have a generally rounded shape.

12. The printhead of claim **1**, wherein:

the jetting channels comprise flow-through jetting channels.

13. A jetting apparatus comprising:

the printhead of claim **1**.

14. A printhead comprising:

a housing; and

a plate stack attached to the housing that forms a plurality of jetting channels fluidly coupled to a common manifold, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, a nozzle configured to jet a print fluid, and a channel fluid passage that fluidly couples the common manifold and the pressure chamber;

wherein the plate stack forms one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel, and do not actively move.

15. The printhead of claim **14**, wherein:

the one or more intra-channel passive mixers project from the one or more vertical side walls of the channel fluid passage.

16. The printhead of claim **14**, wherein:

the one or more intra-channel passive mixers project from the one or more vertical side walls of the pressure chamber.

17. The printhead of claim **14**, wherein:

the one or more intra-channel passive mixers have a generally shark-fin shape.

18. The printhead of claim **14**, wherein the plate stack includes:

a diaphragm plate that forms diaphragms of the jetting channels;

a support plate;

a restrictor plate;

a first chamber plate and a second chamber plate that form pressure chambers of the jetting channels; and

a nozzle plate having nozzle holes that define nozzles of the jetting channels;

wherein at least one of the restrictor plate and the first chamber plate form the one or more intra-channel passive mixers.

19. The printhead of claim **18**, wherein the restrictor plate includes:

restrictor openings each configured to fluidly couple an individual one of the pressure chambers of the jetting channels with the common manifold;

wherein a restrictor opening is etched with the one or more intra-channel passive mixers projecting inward from the restrictor plate into the restrictor opening.

20. The printhead of claim **18**, wherein the first chamber plate includes:

chamber openings that form at least part of the pressure chambers of the jetting channels;

wherein a chamber opening is etched with the one or more intra-channel passive mixers projecting inward from the first chamber plate into the chamber opening.

21. A jetting apparatus comprising:

the printhead of claim **14**.

22. A method comprising:

operating a printhead comprising:

a plurality of jetting channels fluidly coupled to a common manifold, wherein each jetting channel of the plurality includes a diaphragm, a pressure chamber, a nozzle configured to jet a print fluid, and a channel fluid passage that fluidly couples the common manifold and the pressure chamber; and

one or more intra-channel passive mixers that project from one or more vertical side walls of the jetting channel into a longitudinal flow path of the print fluid along a length of the jetting channel, and do not actively move;

wherein the operating comprises:

conveying a flow of the print fluid along the longitudinal flow path; and

disturbing the flow of the print fluid along the longitudinal flow path with the one or more intra-channel passive mixers.

* * * * *