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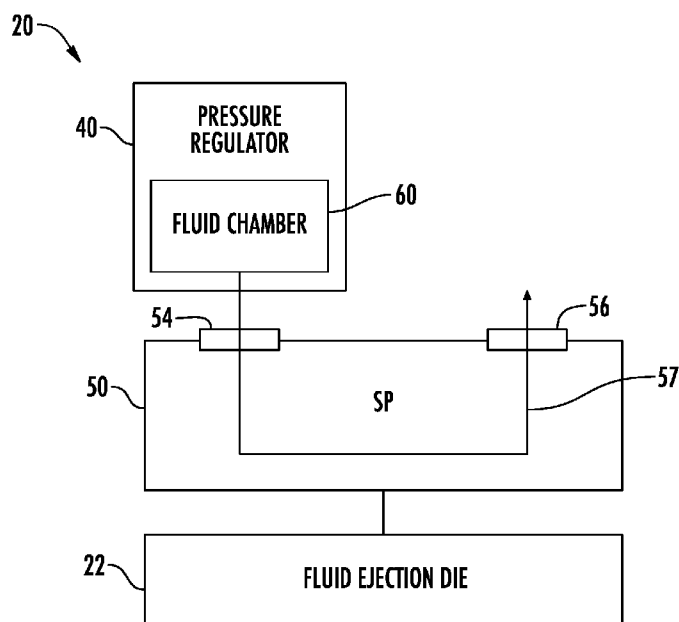


FIG. 1

(57) Abstract: A fluid ejection and circulation apparatus may include a fluid ejection die, a pressure regulator comprising a fluid chamber and a standpipe. The standpipe may be between the fluid chamber and the fluid ejection die. The standpipe may include a first port connected to the fluid chamber and proximate a first end of the fluid ejection die and a second port proximate a second end of the fluid ejection die, the first port and the second port being connected by a first above die circulation path.

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STANDPIPE CIRCULATION

BACKGROUND

[0001] Fluid ejection apparatus are used to selectively eject droplets of fluid. Many fluid ejection apparatuses include a standpipe to deliver fluid to a fluid ejection die and to warehouse air or other gases that may be generated during fluid ejection.

The BRIEF DESCRIPTION OF THE DRAWINGS

[0002] FIG. 1 is a schematic diagram illustrate portions of an example fluid ejection and circulation apparatus.

[0003] FIG. 2 is a flow diagram of an example fluid circulation method.

[0004] FIG. 3 is a schematic diagram illustrating portions of an example fluid ejection and circulation apparatus.

[0005] FIG. 4 is a schematic diagram illustrating portions of an example fluid ejection and circulation apparatus.

[0006] FIG. 5A is a sectional view illustrating portions of an example fluid ejection and circulation apparatus.

[0007] FIG. 5B is a sectional view illustrating portions of an example fluid ejection and circulation apparatus.

[0008] FIG. 6 is a sectional view of the fluid ejection and circulation apparatus of FIG. 5B taken along line 6-6.

[0009] FIG. 7 is a fragmentary sectional view of a portion of an example pressure regulator of the apparatus of FIGS. 5A and 5B.

[00010] FIG. 8 is a perspective view illustrating portions of the example pressure regulator of FIG. 7.

[00011] FIG. 9 is a perspective view illustrating an example lever and valve seat of the pressure regulator of FIG. 7.

[00012] FIG. 10 is a sectional view of the fluid ejection and circulation apparatus of FIGS. 5A and 5B as part of a fluid ejection and circulation system operating in a circulation mode.

[00013] FIG. 11 is a bottom view of a portion of the fluid ejection and circulation apparatus of FIG. 10.

[00014] FIG. 12 is a perspective view illustrating portions of an example fluid ejection and circulation apparatus.

[00015] FIG. 13 is a bottom view illustrating portions of the example fluid ejection and circulation apparatus of FIG. 12.

[00016] Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements. The FIGS. are not necessarily to scale, and the size of some parts may be exaggerated to more clearly illustrate the example shown. Moreover, the drawings provide examples and/or implementations consistent with the description; however, the description is not limited to the examples and/or implementations provided in the drawings.

DETAILED DESCRIPTION OF EXAMPLES

[00017] Disclosed are example fluid ejection and circulation apparatus, systems and methods that use a standpipe for circulating fluid to inhibit settling of fluid suspended particles. The example apparatus, systems and methods comprise a standpipe having two ports that are connected to one another by above die circulation path that facilitate circulation of fluid through

and across the standpipe without the fluid being directed to the associated fluid ejection die. Such circulation of the fluid may inhibit settling of fluid suspended particles, enhancing fluid ejection performance and facilitating use of fluids having heavier particles and/or a higher concentration of particles.

[00018] For example, in implementations where the example fluid ejection circulation apparatus and methods are used to selectively eject droplets of printing fluid, such as ink, the apparatus and methods facilitate the use of pigment-based inks having a higher concentration of pigments and/or heavier, possibly metallic, pigments. Pigment-based inks tend to be more efficient, durable and permanent as compared to dye-based inks. Such pigments may be especially beneficial in the composition of a white ink, wherein the heavier metallic pigments and/or higher concentration of such pigments provide the white ink with a greater opacity and/or brightness. With such inks, the circulation of the fluid reduces settling of the pigments, enhancing printing performance and/or prolonging life of the fluid ejection device. Without such circulation, pigment settling may block ink flow and clogged nozzles, especially during periods of storage or nonuse of printing apparatus.

[00019] The disclosed fluid ejection and circulation apparatus may provide macro recirculation. Such macro recirculation utilizes a pressure regulator that finally controls the port pressure of the fluid flowing to the fluid ejection device. Such macro recirculation continually refreshes the fluid, reducing air and particulate levels near the fluid ejection device. As a result, fluid ejection or printing reliability is enhanced.

[00020] In some implementations, the two ports of the standpipe are connected to fluid chambers of different pressure regulators. When in a circulation mode, fluid is passed through a first one of the regulators, through a first port of the standpipe into the standpipe. The fluid is then circulated through or along the standpipe to the second port of the standpipe. Fluid is

then discharged from the second standpipe through the second port and into the second pressure regulator.

[00021] In one implementation, when in the circulation mode, the fluid is pumped into and through the first one of the regulators and through the first port of the standpipe into the standpipe. At the same time, the fluid within the standpipe is drawn or pulled (by pump or pressure differential) out the second port of the standpipe and through the second pressure regulator. In one implementation, the second pressure regulator may include a regulator port and a valve that selectively opens and closes the regulator port based upon a pressure within the fluid chamber of the second pressure regulator. During the fluid circulation mode, the valve is actuated to open the regulator port of the second pressure regulator regardless of the current pressure within the fluid chamber of the second pressure regulator, facilitating the discharge of fluid from the second pressure regulator.

[00022] In one implementation, the second pressure regulator has a regulator port and a valve that selectively opens and closes the regulator port based upon inflation level of a compliant chamber within a fluid chamber of the second pressure regulator. During the circulation mode, rather than being connected to atmosphere as during fluid ejection, the compliant chamber is instead connected to an inflator that inflates the compliant chamber to cause the valve to open the regulator port to facilitate the discharge of the fluid from the second regulator through the regulator port.

[00023] In some implementations, the fluid ejection and circulation apparatus, systems and methods circulate fluid through and along to side-by-side standpipes, wherein each of the side-by-side standpipes services a distinct portion of fluid ejection device of the fluid ejection die or dies. Each of the side-by-side standpipes has two ports: a first port for the inflow circulating fluid; and a second port for the outflow of circulating fluid when the apparatus system and methods are in the circulation mode. In one implementation, the

first two ports of the two standpipes are both connected to the fluid chamber of a first pressure regulator while the second two ports of the second two standpipes are both connected to the fluid chamber of a second pressure regulator.

[00024] In one implementation, fluid is pumped or otherwise supplied to both standpipes by both pressure regulators during a fluid ejection mode. In contrast, when in the fluid circulation mode, fluid is pumped otherwise supplied to both standpipes through one of the pressure regulators and is withdrawn or discharged from both standpipes through the other of the pressure regulators.

[00025] In each of the disclosed apparatus, systems and methods, the circulation paths are through the standpipe, or along multiple side-by-side standpipes, may be separated from the fluid ejection die, serviced by the standpipe(s), by an intervening manifold or die carrier which delivers fluid from the standpipe(s) to the fluid ejection die. In each of the disclosed apparatus, systems and methods, additional circulation paths may be provided to further reduce particle settling. For example, fluid circulation loops or paths may be additionally provided within the fluid ejection die itself. In implementations where the standpipe(s) are separated from the fluid ejection die and intervening manifold or die carrier, fluid circulation loops or paths may be formed in the manifold or die carrier or between the bonding material or an adhesive material joining the manifold/die carrier and the fluid ejection die.

[00026] Disclosed is an example fluid ejection and circulation apparatus may include a fluid ejection die, a pressure regulator comprising a fluid chamber and a standpipe. The standpipe may be between the fluid chamber and the fluid ejection die. The standpipe may include a first port connected to the fluid chamber and proximate a first end of the fluid ejection die and a second port proximate a second end of the fluid ejection die, the first port and the second port being connected by an above die circulation path.

[00027] Disclosed is an example fluid ejection and circulation system that may include a fluid ejection die, a first pressure regulator, a second pressure regulator, a first standpipe and a second standpipe. The first pressure regulator may include a first fluid chamber having a first regulator port, a first pressure sensing member that changes in response to pressure changes in the first fluid chamber and a first valve to selectively open and close the first regulator port in response to the first pressure sensing member. The second pressure regulator may include a second fluid chamber having a second regulator port, a second pressure sensing member that changes in response to pressure changes in the second fluid chamber and a second valve to selectively open and close the second regulator port in response to the second pressure sensing member. The first standpipe has a first port connected to the first fluid chamber and a second port connected to the second fluid chamber. The second standpipe has a third port connected to the first fluid chamber and a second port connected to the second fluid chamber.

[00028] In one implementation, the above described first and second pressure sensing members comprises compliant chambers within the first and second fluid chambers, respectively. In such implementations, the apparatus may be employed as part of a larger system comprising a fluid source, a first pump connected to the first fluid chamber, a second pump connected to the second fluid chamber, an inflator connected to the second compliant chamber and a controller. The controller may comprise a processing unit and instruction contained in a non-transitory computer-readable medium, wherein the instructions cause the processing unit to actuate the system between an ejection mode and a circulation mode. In the ejection mode, the first pump pumps fluid from the fluid source to the first fluid chamber and the second pump pumps fluid from the fluid source to the second fluid chamber. In the circulation mode, the first pump pumps fluid from the fluid source to the first

fluid chamber, the inflator inflates the second compliant chamber to open the second valve and the second pump pulls fluid from the second fluid chamber.

[00029] Disclosed is an example fluid circulation method that may comprise supplying fluid from a pressure regulator to a standpipe opposite a fluid ejection die through a first port of the standpipe and circulating fluid across the standpipe to and through a second port of the standpipe.

[00030] FIG. 1 schematically illustrates portions of an example fluid ejection and circulation apparatus 20 for the controlled ejection of fluid, wherein the fluid may be circulated within the apparatus to further mix particles suspended within the fluid to reduce settling of the particles. Apparatus 20 provides macro circulation by circulating the fluid within the standpipe without the fluid being directed to an underlying fluid ejection die. Apparatus 20 comprises fluid ejection die(s) 22, pressure regulator 40 and standpipe 50.

[00031] Fluid ejection die(s) 22 comprises a fluid ejection die that supports multiple fluid ejection devices. A portion of the fluid ejection devices may be directly serviced by the standpipe 50. Such “servicing” refers to the supplying of fluid to the fluid ejection devices and the warehousing of air or other gases that may result from fluid ejection by the fluid ejection devices. In one implementation, fluid ejection die(s) 22 include fluid feed slots or fluid feed holes that deliver fluid being supplied by the standpipe 50 to fluid ejection chambers. Fluid actuators within the respective ejection chambers displace fluid to eject fluid through corresponding orifices or nozzles.

[00032] In one implementation, the fluid actuator may comprise a thermal resistor which, upon receiving electrical current, heats to a temperature above the nucleation temperature of the solution so as to vaporize a portion of the adjacent solution or fluid to create a bubble which displaces fluid through the orifice. In other implementations, the fluid actuator may comprise other forms of fluid actuators. In other implementations, the

fluid actuator may comprise a fluid actuator in the form of a piezo-membrane based actuator, an electrostatic membrane actuator, mechanical/impact driven membrane actuator, a magnetostrictive drive actuator, an electrochemical actuator, and external laser actuators (that form a bubble through boiling with a laser beam), other such microdevices, or any combination thereof.

[00033] In one implementation, fluid ejection die(s) 22 may be generally formed from a silicon material upon which the fluid actuators are formed and upon which a layer or multiple layers of material, such as SU8 is deposited to form the fluid ejection chambers and nozzle orifices. In other implementations, the fluid ejection die(s) 22 may have different constructions or may be formed from other materials.

[00034] Pressure regulator 40 regulates the pressure of fluid being supplied through standpipe 50 to fluid ejection die(s) 22. Pressure regulator 40 comprises pressurized fluid chamber 60 which is fluidly connected to standpipe 50. In some implementations, pressure regulator 40 may comprise a compliant chamber within the fluid chamber 60 and connected to atmosphere, wherein the shape or size of the compliant chamber varies in response to changes in its inflation level which changes in response to the pressure within fluid chamber 60. In such implementations, a valve opens and closes a port through which fluid is supplied to fluid chamber 60 in response to the size or shape/inflation level of the compliant chamber. In some implementations, the size, shape or positioning of the compliant chamber or a wall of the compliant chamber is sensed, wherein a controller actuates the valve based on such sensed values. In another implementation, the valve is actuated by a lever which engages the compliant chamber.

[00035] In one implementation, pressure regulator 40 maintains fluid backpressure in the fluid ejection devices of the fluid ejection die 20 within a narrow range below atmospheric levels in order to avoid depriming of the

nozzle or nozzles (leading to drooling or fluid leaking) while optimizing fluid ejection device pressure conditions for fluid ejection or printing. During non-operational periods, this pressure is maintained statically by surface tension of fluid in the nozzle. In some implementations, the pressure regulator 40 may operate by using a formed metal spring (not shown) to apply a force to an area of flexible or compliant film or chamber that is open to the atmosphere, thereby establishing a negative internal pressure for fluid containment in the apparatus 20. A lever (not shown) on a pivot point connects the metal spring assembly to a valve (not shown) that opens and closes port 66 such that deflection of the spring can either open or close the valve by mating it to a valve seat.

[00036] During operation in a fluid ejection mode, fluid flows through standpipe 50 to fluid ejection die(s) 22. Fluid is expelled from the apparatus 20, which evacuates fluid from the pressure-controlled fluid containment system of the regulator 40. When the pressure in the regulator 40 reaches the backpressure set point established through design choices for spring force (i.e., spring constants K) and flexible film area, a valve may open to fluid to be delivered from a pump connected to the port of the pressure regulator. Once a sufficient volume of fluid is delivered, the spring expands and closes the valve. The regulator 40 operates from fully open to fully closed (i.e., seated) positions. Positions in between the fully open and fully closed positions modulate the pressure drop through the regulator valve itself, causing the valve to act as a flow control element.

[00037] Standpipe 50 directs fluid from pressure regulator 60 to fluid ejection die(s) 22. Standpipes 50 further warehouse air or gas released from the fluid are generated during the ejection of fluid by fluid ejection die(s) 22. In one implementation, the fluid from pressure regulator 40 is first passed through a filter prior to reaching standpipe 50. In one implementation, standpipe 50 is directly bonded to an upper surface of fluid ejection die(s) 22. In another implementation, standpipe 50 is indirectly connected to fluid

ejection die(s) 22 by an intervening structure or multiple intervening structures, such as a manifold or die carrier that further distributes the fluid to and along the fluid ejection die(s).

[00038] Standpipe 50 extends between fluid chamber 60 and fluid ejection die(s) 22. Standpipe 50 comprises an elongate vertical chamber through which fluid flows and having a volume for warehousing air and gas. Standpipe 50 services a portion of the fluid ejection devices of fluid ejection die (s) 22. Standpipe 50 comprises ports 54, 56, both of which are spaced from and above fluid ejection die(s) 22.

[00039] Port 54 is fluidically connected to fluid chamber 60 such as a fluid may flow into or out of fluid chamber 60 through port 54. In a fluid ejection mode during which fluid is ejected by the fluid ejection devices of fluid ejection die(s) 22 fluid may flow from fluid chamber 60 through port 54 into standpipe 50. In a fluid circulation mode during which fluid is directed from port 54 to port 56, fluid may flow from fluid chamber 60 through port 54 into standpipe 50.

[00040] Port 56 is spaced from port 54. In one implementation, port 54 is on a first side of an axial midpoint of standpipe 50 while port 56 is on a second side of the axial midpoint of standpipe 50. Port 56 facilitates the discharge of fluid from standpipe 50 in a direction away from fluid ejection die 22 when apparatus 20 is in the fluid circulation mode during which fluid is not being ejected by fluid ejection die 22. In some implementations, fluid is supplied into standpipe 50 through port 56 during the fluid ejection mode. Ports 54 and 56 are connected by above-die circulation path as indicated by arrow 57. The provided above-die circulation path enhances the performance of apparatus 20 and potentially lengthens the life of apparatus 20.

[00041] FIG. 2 is a flow diagram of an example fluid circulation method 100 for circulating fluid in a fluid ejection apparatus to reduce sedimentation of particles within the fluid. Method 100 may be carried out while in apparatus is

in a circulation mode during which fluid is not being ejected by a fluid ejection die. Method 100 reduces sedimentation to enhance the performance and/or prolong the life of the fluid ejection apparatus. Although method 100 is described in the context of being carried out by apparatus 20, it should be appreciated that method 100 may likewise be carried out with any of the apparatus and system described hereafter or with other similar apparatus and systems.

[00042] As indicated by block 104, pressure regulator 40 supplies fluid to standpipe 50 opposite fluid ejection die(s) 22 through port 54 of standpipe 50. As indicated by block 108, the fluid within standpipe 50 is circulated along a majority of the length of standpipe 50 prior to reaching port 56 through which fluid is discharged from standpipe 50 in the fluid circulation mode. In one implementation, the fluid is circulated through the second port away from fluid ejection die(s) 22. In one implementation, fluid is directed through port 56 to a fluid chamber of a second pressure regulator and out of the second pressure regulator to a fluid source for subsequent recirculation. In one implementation, the fluid from the fluid source may be pumped into the pressure regulator 40 while a fluid is pulled or drawn out of the second pressure regulator and out of standpipe 50 through port 56.

[00043] FIG. 3 schematically illustrates portions of an example fluid circulation and circulation apparatus 220. Similar apparatus 20, apparatus 220 provides macro circulation by circulating fluid along a standpipe without the fluid being directed to an underlying fluid ejection die. Apparatus 220 comprises fluid ejection die 222, pressure regulators 40-1, 40-2 and standpipe 50 (described above).

[00044] Fluid ejection die 222 is similar to fluid ejection die(s) 22 described above. Fluid ejection die 222 is illustrated in more detail in FIG. 3 as specifically including a series of individual fluid ejection devices 224 (a portion of which are illustrated). Each of the fluid ejection devices 224 may

include a fluid ejection chamber having an orifice or nozzle and an associated fluid actuator (described above) that displaces fluid to eject fluid through the nozzle. In the example illustrated, the fluid ejection devices 224 are supplied with fluid by fluid delivery passages 223 in the form a fluid feed slot or a series of fluid feed holes that extend through die 222 and through which fluid from standpipe 250 flows. As illustrated in broken lines, in some implementations, an additional die carrier or manifold 225 may be positioned between fluid ejection die 222 and standpipes 250, wherein the die carrier or manifold delivers fluid from the standpipes 250 to the slots 224 and/or fluid feed holes 226. In some implementations, the intermediate die carrier manifold may itself include corresponding slots or fluid feed holes 226.

[00045] Pressure regulators 40-1 and 40-2 are each similar pressure regulator 40 described above. Each of pressure regulators 40 comprises a fluid chamber 60. Fluid chamber 60 of pressure regulator 40-1 is directly or indirectly connected to port 54 of standpipe 50. Fluid chamber 60 of pressure regulator 40-2 is directly or indirectly connected to port 56 of standpipe 50. Although not illustrated, a filter may be provided between each of the pressure regulators and standpipe 54 filtering the fluid flowing between the pressure regulators 40 and standpipe 50. As described above, pressure regulators 40 may include additional components which control the pressure of fluid within fluid chamber 60 which further control the pressure of fluid being supplied to the fluid ejection devices of fluid ejection die 222.

[00046] During a fluid ejection mode, fluid is ejected by the fluid ejection devices 224 of fluid ejection die 222. In one implementation, pressure regulator 40-1 supplies fluid through port 54 to standpipe 50 which further delivers a fluid through slot fluid delivery passage 223 to the fluid ejection devices of die 222. Similarly, pressure regulator 40-2 may supply fluid through port 56 to standpipe 50 which further delivers the fluid through fluid delivery passages 223 to the fluid ejection devices of die 222 that are serviced

by fluid feed holes 226. In the fluid ejection mode, ports 54 and 56 both serve as inlet ports by which fluid is supplied into standpipe 50.

[00047] During a fluid circulation mode, fluid is not ejected by fluid ejection devices 224, but is instead circulated through and across standpipe 50 along a path above fluid ejection die 223, ultimately flowing away from fluid ejection die 223 without being ejected. As indicated by arrow 257, fluid is pumped into fluid chamber 60 of pressure regulator 40-1 and further through port 54 into standpipe 50. As fluid ejection device 224 are not ejecting fluid, the fluid flows along the length of standpipe 50. At the same time, fluid is further being drawn or pulled from standpipe 50 through port 56 and through fluid chamber 60 of pressure regulator 40-2. The pulling or withdrawal of fluid by an external pump or pressure differential establishes the fluid circulation path shown, indicated by arrow 257. Such circulation stirs or agitates particles within the fluid to inhibit settling of particles within the fluid. The withdrawn fluid may be separately returned or recirculated back through pressure regulator 40-1 and standpipe 52 fluid ejection die 222 for subsequent use and ejection. During such circulation along the path indicated by arrows 257, fluid is not being ejected by fluid ejection die 222 such that a majority, if not substantially all, of the fluid flowing through standpipe 50 leaves standpipe 50 through port 56.

[00048] In one implementation, apparatus 220 is further operable in a reverse flow circulation mode. In the reverse flow circulation mode, fluid is directed through and along standpipe 50 in an opposite direction to the direction indicated by arrow 257. In particular, fluid is pumped to or delivered to the standpipe 50 from pressure regulator 40-2 and through port 56. The fluid then flows along and across the standpipe 50 to the port 54. In the reverse flow circulation mode, fluid may be pumped, pulled or drawn out of standpipe 50 through port 54 and through fluid chamber 60 of pressure regulator 40-1. In one implementation, the fluid may be made available for subsequent recirculation through apparatus 220. During such reverse direction fluid circulation, fluid is not being ejected by fluid ejection die 222

such that a majority, if not substantially all, of the fluid flowing through standpipe 50 leaves standpipe 50 through port 54.

[00049] As further shown by broken lines, in some implementations, additional circulation paths may be provided to further reduce particle settling. For example, fluid circulation loops or paths 290 may be additionally provided within the fluid ejection die itself. In implementations where the standpipe(s) are separated from the fluid ejection die by an intervening manifold or die carrier 225, fluid circulation loops or paths 292 may be formed in the manifold or die carrier or between the bonding material or an adhesive material 294 joining the manifold/die carrier 225 and the fluid ejection die 222.

[00050] FIG. 4 schematically illustrates portions of an example fluid ejection and circulation apparatus 320. FIG. 4 illustrates a top sectional view of its standpipes and underlying fluid ejection die while schematically illustrating its pressure regulators. Similar apparatus 20 and 220, apparatus 320 provides macro circulation by circulating fluid between and across two standpipes without the fluid being directed to an underlying fluid ejection die. Apparatus 320 is similar to apparatus 220 except that apparatus 320 comprises fluid ejection die 322 and multiple side-by-side standpipes 350-1 and 350-2 (collectively referred to as standpipes 350) overlying a fluid ejection die 322. Those remaining components or structures of apparatus 320 which correspond to components or structures of apparatus 220 are numbered similarly.

[00051] Fluid ejection die 322 is similar to fluid ejection die 222 described above except that fluid ejection die 322 is illustrated as specifically including a fluid supply slot 324 and a series of fluid feed holes 326 which extend through die 222 which supply fluid to associated fluid ejection devices 224 (shown in FIG. 3 and described above). In the example illustrated, fluid supply slot 324 is serviced by standpipe 350-1 while fluid feed holes 326 are serviced by standpipe 350-2. Such fluid passages through die 322 are illustrated as different examples by which fluid may be passed through die 322. It should be appreciated that die 322 may replace fluid feed

holes 326 with another slot similar to slot 324 or may replace slot 324 with fluid feed holes similar to fluid feed holes 326. The relative size, spacing and extent of slot 324 and fluid feed holes 326 may be varied depending upon such factors as the density of the fluid ejection devices provided in die 322. In some implementations, an additional die carrier or manifold, such as manifold/die carrier 225 shown in FIG. 3, may be positioned between fluid ejection die 322 and standpipes 350, wherein the die carrier or manifold delivers fluid from the standpipes 350 to the slots 324 and/or fluid feed holes 326. In some implementations, the intermediate die carrier manifold may itself include corresponding slots or fluid feed holes 226 (shown in FIG. 3).

[00052] Standpipes 350-1, 350-2 are each similar to standpipe 50 described above. Standpipe 350-1 comprises an elongate channel or passage through which fluid flows to the underlying fluid slot 324. Standpipe 350-1 further includes an upper vertical volume for warehousing air and gas released from the fluid such as during fluid ejection. Standpipe 350-1 comprises fluid ports 354-1 and 356-1. Ports 354-1 and 356-1 are similar reports 54 and 56, respectively, described above. Ports 354-1 and 356-1 are spaced apart proximate to opposite in regions of standpipe 350-1 to form a fluid circulation passage across a majority of standpipe 350-1 above slot 324.

[00053] Standpipe 350-2 extends alongside of and substantially parallel to standpipe 350-1. Standpipe 350-2 is separated from standpipe 350-1 by an intervening imperforate wall 355. In some implementations, wall 355 may be formed by multiple walls, layers or panels. Standpipe 350-2 comprises fluid ports 354-2 and 356-2. Ports 354-2 and 356-2 are similar reports 54 and 56, respectively, described above. Ports 354-2 and 356-2 are spaced apart proximate to opposite in regions of standpipe 350-2 to form a fluid circulation passage across a majority of standpipe 350-2 above fluid feed holes 326. Because ports 354-1 and 354-2 are located proximate to end 357 while ports 356-2 and 356-2 are located proximate to end 358, fluid circulation along at least a majority if not substantially an entire length of standpipes 350 is promoted. Because such circulation is generally linear as a result of the

narrower path provided by wall 355, and because divider wall 355 bisects the total volume of standpipes 350, the velocity of fluid flow across such standpipes 350 is higher, stirring, mixing or agitating the parts to a greater extent to reduce settling.

[00054] As indicated by broken lines, in some implementations, apparatus 320 may additionally comprise filters 328-1 and 328-2 (collectively referred to as filters 328). Filters 328 comprise porous panels, layers or membranes through which fluid flows, wherein filters 328 remove certain particles or contaminants. Filters 328-1 filters the fluid flowing between fluid chamber 60 of pressure regulator 40-1 to ports 354-1 and 354-2. Filters 328-2 filters a fluid flowing between fluid chamber 60 and ports 356-1 and 356-2. In some implementations, one or both of filters 328 may be omitted.

[00055] During a fluid ejection mode, fluid is ejected by the fluid ejection devices of fluid ejection die 322. In one implementation, pressure regular 40-1 supplies fluid through filter 328-1 and through port 354-1 to standpipe 350-1 which further delivers a fluid through slot 324 to the fluid ejection devices of die 322 that are serviced by slot 324. Pressure regulator 40-2 may additionally supply fluid through filter 328-2 and through port 354-2 to standpipe 350-2 which further delivers a fluid through fluid feed holes 326 to the fluid ejection devices of die 322 that are serviced by fluid feed holes 326. Similarly, pressure regular 40-2 supplies fluid through filter 328-2 and through port 356-1 to standpipe 350-1 which further delivers a fluid through slot 324 to the fluid ejection devices of die 222 that are serviced by slot 324. Pressure regulator 40-2 may further supply fluid through filter 328-2 and through port 356-2 to standpipe 350-2 which further delivers a fluid through fluid feed holes 326 to the fluid ejection devices of die 322 that are serviced by fluid feed holes 326. In the fluid ejection mode, ports 356-1 and 356-2 both serve as inlet ports by which fluid is supplied into standpipes 350.

[00056] During a fluid circulation mode, fluid is not ejected by fluid ejection devices, but is instead circulated in and out of standpipes 350 using the double-ended parallel circulation paths. As indicated by arrows 359, fluid may be pumped to or delivered to the first standpipe 350-1 from pressure regulator 40-1 and through port 354-1. The fluid then flows along and across the first standpipe 350-1 to part 356-1. Thereafter, the fluid flows from port 356-1 across filter 328-2 into fluid chamber 60 of pressure regular 40-2. The fluid may then be discharged from fluid chamber 60 of pressure regulator 40-2. In one implementation, the fluid is pulled or drawn by a pump or vacuum from fluid chamber 60 of pressure regular 40-2, where it is available for subsequent recirculation through apparatus 320. During such circulation along the path indicated by arrows 359, fluid is not being ejected by fluid ejection die 322 such that a majority, if not substantially all, of the fluid flowing through standpipe 350-1 leaves standpipe 250-1 through port 356-1.

[00057] In a similar fashion, during the fluid circulation mode, as indicated by arrows 361, fluid may be pumped to or delivered to the second standpipe 350-2 from pressure regulator 40-1 and through port 354-2. The fluid then flows along and across the first standpipe 350-2 to port 356-2. Thereafter, the fluid flows from port 356-2 across filter 328-2 into fluid chamber 60 of pressure regular 40-2. The fluid may then be discharged from fluid chamber 60 of pressure regulator 40-2. In one implementation, the fluid is pulled or drawn by a pump or vacuum from fluid chamber 60 of pressure regular 40-2, where it is available for subsequent recirculation through apparatus 320. During such circulation along the path indicated by arrows 261, fluid is not being ejected by fluid ejection die 322 such that a majority, if not substantially all, of the fluid flowing through standpipe 350-1 leaves standpipe 350-2 through port 356-2.

[00058] In one implementation, apparatus 320 is further operable in a reverse flow circulation mode. In the reverse flow circulation mode, fluid is directed through and along standpipes 350 in an opposite direction to the direction indicated by arrows 359 and 361. In particular, fluid is pumped to or

delivered to the standpipes 350 from pressure regulator 40-2 reports 356-1, 356-2. The fluid then flows along and across the standpipes 350 to the port ports 354-1, 354-2, respectively. The fluid then flows through port 354-1, 354-2 of standpipes 350 into fluid chamber 60 of pressure regulator 40-1. The fluid may then be discharged from fluid chamber 60 of pressure regulator 40-1. In one implementation, the fluid is pulled or drawn by a pump or vacuum from fluid chamber 60 of pressure regular 40-1, where it is available for subsequent recirculation through apparatus 320. During such circulation, fluid is not being ejected by fluid ejection die 322 such that a majority, if not substantially all, of the fluid flowing through standpipes 350 leaves standpipes 350 through ports 354-1, 354-2.

[00059] As further indicated by broken lines, in some implementations, pressure regulators 40-1 and 40-2 may specifically comprise a pressure sensing members (PS) 362-1, 362-2 (collectively referred to as pressure sensing members 362) and valve mechanisms or valves 364-1, 364-2 (collectively referred to as valves 364). Pressure sensing members 362 detect, sense or otherwise react to changes in pressure within their respective fluid chambers 60. Valves 364 comprise mechanism to selectively open and close respective regulator ports 366-1, 366-2 (collectively referred to as ports 366) in response to or based upon the pressure within the respective fluid chamber 60, as indicated by pressure sensing members 362.

[00060] In one implementation, pressure sensing members 362 comprises compliant chambers, such as flexible panels along a side of the interior of fluid chamber 60 or bags within the fluid chambers 60 that are connected to atmosphere when apparatus 320 is in a fluid ejection mode such that the size, shape or positioning of the compliant chamber changes based upon the current ejection of fluid in the pressure levels within the respective fluid chamber 60. In such an implementation, valves 364 open and close the respective ports 366 based upon the current state of the compliant chamber. For example, in one implementation, each valve is operably coupled to its respective fluid chamber by a spring biased lever such that inflation or

deflation of the compression chamber serving as the pressure sensing member 362 causes the lever to apply force to the respective valve 364. In other implementations, movement of a panel or portion of the compliant chamber may be sensed, resulting in signals that cause an actuator to actuate the valve 364 to selectively open and close the respective regulator port 366. In yet other implementations, pressure sensing member 362 may comprise other pressure sensors that detect the pressure within fluid chamber 60, wherein the sensed pressure causes an actuator to adjust estate of the respective valve 364 to selectively open and close or adjust the extent to which regular port 366 is opened or closed.

[00061] In some implementations, when apparatus 320 is in the fluid ejection mode shown and as indicated by arrows 359 and 361, regulator port 366-2 is forced to an open state to allow fluid to be discharged from fluid chamber 60 to complete the fluid circulation loop. In one implementation, valve 364-2 is automatically actuated to open regulator port 366-2. In implementations where pressure sensing member 362 comprises a compliant chamber, the compliant chamber may be inflated or deflated to an inflation state such that valve 364-2 automatically opens regulator port 366-2 during the fluid circulation mode.

[00062] FIGS. 5A and 5B are sectional views illustrating portions of an example fluid ejection and circulation apparatus 420. Apparatus 420 may be in the form of a print or fluid ejection module which may be a removable and replaceable component of a larger overall fluid ejection system. Apparatus 420 comprises fluid ejection die 422, providing an array of fluid ejection devices 424, die carrier 425, filter chambers 427-1, 427-2 (collectively referred to as filter chambers 427), filters 428-1, 428-2 (collectively referred to as filters 428), fluid needles 430-1, 430-2 (collectively referred to as fluid needles 430), pressure regulators 440-1, 440-2 (collectively referred to as pressure regulators 440), standpipes 450-1, 450-2 (collectively referred to as standpipes 450) and cross flow passage 452.

[00063] FIG. 6 is a sectional view illustrating fluid ejection die 422, die carrier 425 and standpipes 450 in greater detail. Fluid ejection die 422 comprises fluid ejection die supporting a series or array of fluid ejection devices 424 (such as the fluid ejection devices described above). In the example illustrated, fluid ejection die 422 comprises a pair of slots or a series of fluid feed holes 432-1, 432-2 through which fluid is supplied to the individual fluid ejection devices 424.

[00064] Die carrier 425 is bonded to die 422 and supports die 422 below standpipes 450-1 and 450-2. In one implementation, the material forming standpipes 450 as a first coefficient of thermal expansion, the material forming die 422 has a second coefficient of thermal expansion and the material forming die carrier 425 has a third coefficient of thermal expansion between that of die 422 and the material standpipes 450. In one implementation, die 422 is formed from silicon whereas the material standpipes 450 is formed from a polymer and the material die carrier 425 is formed from a ceramic or polymer. As shown by FIG. 6, die carrier 425 includes slots 434-1 and 43-2 which supply fluid from standpipes 450-1 and 450-2 to fluid feed holes 432-1 and 422-2, respectively.

[00065] Filters 428 are similar to filters 28 described above. Filter 428-1 filters the fluid supplied from pressure regular 440-1 to filter chamber 437-1 and ultimately to fluid feed holes 432-1 shown in FIG. 6. Filter 428-2 filters fluid supplied from pressure regulator 440-2 to filter chamber 437-2 and ultimately to fluid feed holes 432-2 as shown in FIG. 6. In the example illustrated, filters 428-1 and 428-2 form the floor of the respective fluid chambers of pressure regulator 440-1 and 440-2.

[00066] Pressure regulators 440-1 and 440-2 are substantially identical to one another. Pressure regulators 440-1, 440-2 comprises fluid chambers 460-1, 460-2, compliant chambers 462-1, 462-2, valve 464-1, 464-2. Fluid chambers 460-1, 460-2 contain compliant chambers 462-1, 462-2,

respectively. Fluid chambers 460-1, 460-2 comprises ports 466-1, 466-2, respectively, through which fluid may flow in and out of the respective fluid chambers 460. Fluid chambers 460 contain compliant chambers 462. Fluid flows through fluid chambers 460 to filters 428.

[00067] Compliant chambers 462 each comprise a flexible membrane, pouch, bag or other structure which may change in shape and volume in response to pressure changes within the respective fluid chambers 460. In one implementation, each of compliant chambers 462 may comprise a flexible bag having an interior connected to atmosphere by an atmospheric port 479. Compliant chambers 462 serve as pressure sensing members.

[00068] Valves 464 comprise valve mechanisms that selectively open and close their respective ports 466-1, 466-2 in response to or based upon the inflation level, shape or size of the associated compliant chamber 462 which is itself dependent upon the fluid pressure level within interior of the associated fluid chamber 460. As shown by FIGS. 5A and 5B, each of ports 466 passes through a crown 480 against which a valve seat 482 may bear against to seal the respective port 466. In the example illustrated, the valve seat 482 of each of pressure regulators 440 pivots between port closing or sealing position and a port opening position by use of a lever that engages compliant chamber 462. In one implementation, the valve seat 482 is formed from a resilient a rubber -like material. Examples of such materials include silicon rubbers, fluoro silicate elastomers, or blends thereof.

[00069] FIGS. 7-9 illustrate portions of pressure regulator 440-1 in more detail. As noted above, pressure regular 440-2 is substantially similar to pressure regulator 440-1. As shown by FIG. 7, compliant chamber 462-1 may be in the form of an inflatable bag captured between a pair of levers 484, 486. Levers 484, 486 are resiliently biased towards one another and against compliant chamber 462-1 by a tension spring 487 (shown in FIG. 8). As shown by FIG. 9, lever 486 further supports valve seat 482. Lever 486 pivots

about axles 488 which are pivotally received within the body of apparatus 420 is shown by FIGS. 5A and 5B. Depending upon the inflation level of compliant chamber 462-1, valve seat 482 may be pivoted into sealing engagement with crown 480 or out of sealing engagement with respect to crown 480.

[00070] As shown by FIG. 5A and 5B, standpipes 450 extend side-by-side and parallel to one another above die carrier 425 and above ejection die 422. During fluid ejection, standpipes 450 receive fluid from filter chambers 427-1, 427-2, respectively, after the fluid has passed through filters 428-1 and 428-2, respectively (shown in FIGS. 5A and 5B). In particular, standpipe 450-1 receives fluid from filter chamber 427-1 through a fluid conduit 438-1 terminating at a port 454-1 as seen in FIG. 5A. Standpipe 450-1 may also receive fluid from filter chamber 427-2 through a fluid conduit 439-1 terminating at a port 456-1 as seen in FIG. 5A. Standpipe 450-2 receives fluid from filter chamber 427-1 to a fluid conduit 438-2 terminating at port 454-2. Standpipe 450-2 may also receive fluid from filter chamber 427-2 through a fluid conduit 439-2 terminating at a port 456-2 as seen in FIG. 5B. Standpipes 450-1 and 450-2 are separated by an intervening wall 455.

[00071] FIG. 10 illustrates fluid ejection and circulation apparatus 420 provided as part of a larger fluid ejection and circulation system 500. In addition to apparatus 420, system 500 comprises external fluid source 502, fluid pumps 504-1, 504-2 (collectively referred to as fluid pumps 504), pumps/inflators 506-1, 506-2 (collectively referred to as pumps/inflators 506) and controller 510. External fluid source 502 serves as a reservoir containing fluid to be supplied to each of pressure regulators 440 and ultimately to fluid ejection die 422. Pumps 504 selectively pump fluid from fluid source 502 to fluid chambers 460-1, 460-2 or pull fluid from fluid chambers 460-1, 460-2, respectively, back into fluid source 502. Pumps/inflators 506 are selectively connectable to their respective compliant chambers 462-1 and 462-2. Pump/inflators 506 close off the interior of their respective compliant

chambers 462 from atmosphere and controllably inflate their respective compliant chambers 462 to open the respective valves 464-1 and 464-2.

[00072] Controller 510 actuates system 500 and apparatus 420 between the fluid ejection mode or state in a fluid circulation mode or state. Controller 510 may comprise a processing unit 512 that follows instructions contained in a non-transitory computer-readable medium 514. Following instructions contained in memory 514, processing unit 512 may output control signals to control the operation of pumps 504 and pump/inflators 506 to actuate apparatus 420 between the fluid ejection mode and the fluid circulation mode.

[00073] In the fluid ejection mode, each of the pressure regulators 440 maintains fluid backpressure in the fluid ejection die 422 within a narrow range below atmospheric levels in order to avoid depriming of the nozzles are ejection orifices (leading to drooling or fluid leaking) while optimizing fluid ejection device pressure conditions for fluid ejection or printing. During non-operational periods, this pressure is maintained statically by surface tension of fluid in the ejection orifices. The pressure regulators 440 operate by using spring 487 to apply a force to an area of their respective compliant chambers 462 which are open to the atmosphere through atmospheric ports 478, thereby establishing a negative internal pressure for fluid containment in the apparatus. Lever 486 pivots in response to inflation or deflation of the associated bag 462 to seat or unseat valve seat 482 with respect to the associated crown 480 to seal or open the respective port 466.

[00074] During ejection of fluid, fluid is expelled by fluid ejection die 422 which evacuates fluid from the pressure-controlled fluid containment system of the regulators 440. When the pressure in the respective regulator 440 reaches the backpressure set point established through design choices for spring force (i.e., spring constants K) and flexible film area, the valve seat 482 opens and allows fluid to be delivered from pump 504-1, 504-2 connected to the port 466-1 and four 466-2, respectively. The regulators 440 each operate

from fully open to fully closed (i.e., seated) positions. Positions in between the fully open and fully closed positions modulate the pressure drop through the regulator valve itself, causing the valve mechanism 464 to act as a flow control element.

[00075] In the circulation mode, fluid is not ejected from apparatus 420. FIG. 10 illustrates apparatus 420 in a fluid circulation mode in which fluid is not ejected by fluid ejection devices, but is instead circulated along and across both standpipes 450 in parallel. Controller 510 causes pump/inflators 506-2 to disconnect port 479 of compliant chamber 462-2 from atmosphere and to alternatively inflate compliant chamber 462-2 through port 479 to a point such that valve seat 482 is pivoted out of sealing engagement with crown 480 about port 466-2, opening port 466-2. Controller 510 further outputs control signals causing pump 504-2 to apply a vacuum pressure to pull or draw fluid from fluid chamber 460-2 through the opened port 462-2 and back into fluid source 502 as indicated by arrows 522.

[00076] As indicated by arrows 459, the fluid circulation path is formed wherein fluid is pumped to or delivered from fluid source 502, through needle 430-1 to the first standpipe 450-1 from pressure regulator 440-1 and through port 454-1 into standpipe 450-1 and through port 454-2 into standpipe 450-2. As shown by arrows 470-1 in FIGS. 10 and 11, the fluid then flows along and across the first standpipe 450-1 to the port 456-1. Similarly, as shown by arrows 470-2 in FIGS. 10 and 11, the fluid also flows along and across the first standpipe 450-2 to the port 456-2.

[00077] The fluid flows through ports 456-1 and 456-2 454-2 and up through conduits 439-1 and 439-2, respectively, out of standpipe 450-1 and 450-2. In the example illustrated, the fluid discharged through ports 456 flows across filter 428-2 and into fluid chamber 460-2 of pressure regular 440-2. The fluid may then be discharged from fluid chamber 460-2 of pressure regulator 440-2. In one implementation, the fluid is pulled or drawn by a

pumper vacuum from fluid chamber 460-2 of pressure regular 440-2, where it is available for subsequent recirculation through apparatus 220. During such circulation along the path indicated by arrows 459, 470-1 and 470-2 fluid is not being ejected by fluid ejection die 422 (or is slowed) such that a majority, if not substantially all, of the fluid flowing through standpipes 450 leaves standpipes 450 through ports 456-1, 456-2.

[00078] In the example illustrated, system 500 may provide such circulation in a reverse direction compared to that shown in FIG. 10. To provide such a reverse circulation flow, controller 510 causes pump/inflators 506-1 to disconnect port 479 of compliant chamber 462-1 from atmosphere and to alternatively inflate compliant chamber 462-1 through port 479 to an extent such that valve seat 482 is pivoted out of sealing engagement with crown 480 about port 466-1, opening port 466-1. Controller 510 further outputs control signals causing pump 504-1 to apply a vacuum pressure to pull or draw fluid from fluid chamber 460-1 through the opened port 466-1 and back into fluid source 502, opposite to the direction indicated by arrows 522.

[00079] In the reverse flow circulation mode, fluid is directed through and along standpipes 450 in an opposite direction to the direction indicated by arrows 470-1, 470-2. In particular, fluid is pumped to or delivered to the standpipes 450-1 and 450-2 from pressure regulator 440-2 and through ports 456-1, 456-2, respectively. The fluid then flows along and across the standpipe 450. Thereafter, the fluid flows through ports 454-1 and 454-2 out of standpipes 450-1 and 450-2, respectively. In the example illustrated, the fluid discharged through ports 454-1 and 454-2 flows across filter 228-1 and into fluid chamber 460-1 of pressure regular 440-1. The fluid may then be discharged from fluid chamber 460-1 of pressure regular 440-1 by being pulled or drawn by a pump or vacuum from fluid chamber 460-1 of pressure regular 440-1, where it is available for subsequent recirculation through apparatus 420. During such reverse direction fluid circulation, fluid is not being ejected by fluid ejection die 422 such that a majority, if not substantially

all, of the fluid flowing through standpipes 450 leaves standpipe 450-1 through port 454-1.

[00080] FIGS. 12 and 13 illustrate portions of an example fluid ejection and circulation apparatus 620. FIG. 12 is a perspective view of the two standpipes of apparatus 620. FIG. 13 is a bottom view of the two standpipes of apparatus 620, additionally illustrating the relative positions of fluid ejection dies 422 (shown in broken lines) relative to the above standpipes. Apparatus 620 is similar apparatus 420 except that apparatus 620 comprises standpipes 650-1 and 650-2 (collectively referred to as standpipes 650) in place of standpipe 450-1, 450-2 and supports a series of staggered fluid ejection dies 422. Those remaining components of apparatus 620 are similar to the remaining components of apparatus 420 and are shown in FIGS. 5A, 5B and 6-9. Similar to apparatus 420, apparatus 620 circulates fluid through and across its standpipes in a manner similar to apparatus 320. Apparatus 620 may be used as part of system 500 (shown in FIG. 10) in place of apparatus 420.

[00081] Standpipes 650-1, 650-2 extend alongside one another. Standpipe 650-1 comprises port 654-1 and 656-1 while standpipes 650-2 comprises ports 654-2 and 656-2. Ports 654-1 and 654-2 are connected to filter chamber 437-1 (shown in FIGS. 5A and 5B) and is proximate a first end of standpipes 650 proximate a first end of the intervening wall 655 separating standpipes 650. Ports 654-2 and 656-2 connected to filter chamber 437-2 (shown in FIGS. 5A and 5B) and are at a second opposite end of standpipes 650 proximate a second opposite end of the intervening wall 655.

[00082] Intervening wall 655 extends between standpipes 650 in a serpentine fashion, having a series of S curves 659. The S curves along wall 656 form oppositely directed alternating lobes that facilitate the centering of fluid ejection dies 422-1, 422-2, 422-3, 422-4 and 422-5 (collectively referred to as fluid ejection dies 422) in a staggered, but overlapping fashion along standpipes 650 as shown in FIG. 13. The overlapping staggering

arrangement of dies 422 facilitates fluid ejection across a continuous span. Each of the fluid ejection dies 422 is similar to fluid ejection die 422 described above comprises two fluid delivery passages 432-1, 432-2 in the form of fluid feed slots or fluid feed holes situated on opposite sides of wall 655. For example, fluid delivery passages 432-1 are positioned on a first side of wall 456 opposite to standpipe 650-1 while fluid delivery passages 432-2 are positioned on a second opposite side of wall 456 opposite to standpipe 650-2.

[00083] Similar to apparatus 320 and apparatus 420, apparatus 620 provides enhanced fluid circulation to inhibit particle settling. Such circulation may be enhanced when apparatus 620 is in the fluid circulation mode as described above with respect to the other apparatus.

[00084] Actuation of the above described apparatus 20, 220, 320, 420 and 620 between the ejection mode and the circulation mode may be triggered in various manners. For example, in one implementation, actuation to the fluid ejection mode may automatically occur in response to a fluid ejection or printing command. Actuation to the fluid circulation mode may likewise occur in response to a user input circulation command. In other implementations, actuation to the circulation mode may occur at predetermined or user selected time intervals. In some implementations, time intervals for the triggering or actuation to the fluid circulation mode may be selected based upon the type of fluid being circulated, the age of the fluid being circulated, as well as other characteristics of the apparatus. In some implementations, actuation to the fluid circulation mode may be automatically triggered in response to a sensed sedimentation of particles, a sensed temperature of the fluid within the apparatus or a sensed fluid ejection error or decline in performance. Actuation to the fluid circulation mode may be done by a controller having a processing unit following instruction contained in a non-transitory computer-readable medium, wherein the instructions direct the processing unit to output control signals controlling the pumping or supply of fluid to pressure regulators 40 or from pressure regulators 40.

[00085] Although the present disclosure has been described with reference to example implementations, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example implementations may have been described as including features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example implementations or in other alternative implementations. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example implementations and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements. The terms “first”, “second”, “third” and so on in the claims merely distinguish different elements and, unless otherwise stated, are not to be specifically associated with a particular order or particular numbering of elements in the disclosure.

WHAT IS CLAIMED IS:

- 1 1. A fluid ejection and circulation apparatus comprising:
2 a fluid ejection die;
3 a pressure regulator comprising a fluid chamber;
4 a standpipe between the fluid chamber and the fluid
5 ejection die, the standpipe comprising:
6 a first port connected to the fluid chamber and
7 proximate a first end of the fluid ejection die; and
8 a second port proximate a second end of the fluid
9 ejection die, the first port and the second port being
10 connected by a first above die circulation path.
- 1 2. The fluid ejection and circulation apparatus of claim 1 further
2 comprising a second pressure regulator having a second fluid chamber, wherein
3 the second port is connected to the second fluid chamber and wherein the
4 apparatus is operable in a circulation mode during which fluid is pumped through
5 the first pressure regulator through the first port into the standpipe and is pulled
6 from the standpipe through the second port through and out of the second
7 pressure regulator.
- 1 3. The fluid ejection and circulation apparatus of claim 1 further
2 comprising:
3 a filter chamber; and
4 a filter between the filter chamber and the pressure
5 regulator, wherein the standpipe comprises:
6 a top wall opposite to and spaced from the filter by the filter
7 chamber;

8 a first conduit extending from the filter chamber towards the
9 fluid ejection die to the first port; and

10 a second conduit extending from the second port.

1 4. The fluid ejection and circulation apparatus of claim 1 further
2 comprising:

3 a second regulator;

4 a second filter chamber; and

5 a second filter between the second filter chamber and the second
6 regulator, wherein the second conduit extends to the second filter
7 chamber.

8 5. The fluid ejection and circulation apparatus of claim 1 further
9 comprising:

10 a second standpipe between the fluid chamber and
11 the fluid ejection die, the second standpipe comprising:

12 a third port connected to the fluid chamber and
13 proximate the first end of the fluid ejection die; and

14 a fourth port proximate the second end of the fluid
15 ejection die, the third port and the fourth port being
16 connected by a second above die circulation path.

1 6. The fluid ejection and circulation apparatus of claim 5 further
2 comprising a second pressure regulator having a second fluid chamber, wherein
3 the second port and the fourth port are each connected to the second fluid
4 chamber and wherein the apparatus is operable in a circulation mode during
5 which fluid is pumped through the first pressure regulator through the first port
6 and the third port into the standpipe and the second standpipe, respectively, and

7 is pulled from the standpipe and the second standpipe through the second port
8 and the fourth port, respectively, through and out of the second pressure
9 regulator.

1 7. The fluid ejection and circulation apparatus of claim 1 further
2 comprising a die carrier between the fluid ejection die and the first standpipe, the
3 die carrier having a fluid passage extending from the first standpipe to the fluid
4 ejection die.

1 8. The fluid ejection and circulation apparatus of claim 5, wherein the
2 fluid ejection die is formed from a first material having a first coefficient of thermal
3 expansion, wherein portions of the first standpipe are formed from a second
4 material having a second coefficient of thermal expansion and wherein the die
5 carrier contacts the portions of the first standpipe and the fluid ejection die, the
6 die carrier being formed from a third material having a third coefficient of thermal
7 expansion between the first coefficient of thermal expansion and the second
8 coefficient of thermal expansion.

1 9. A fluid ejection and circulation system comprising:

2 a fluid ejection die;

3 a first pressure regulator comprising:

4 a first fluid chamber having a first regulator port;

5 a first pressure sensing member that changes in
6 response to pressure changes in the first fluid chamber; and

7 a first valve to selectively open and close the chamber
8 port in response to the first pressure sensing member;

9 a second pressure regulator comprising:

10 a second fluid chamber having a second regulator
11 port;

12 a second pressure sensing member that changes in
13 response to pressure changes in the second fluid chamber;
14 and

15 a second valve to selectively open and close the
16 second regulator port in response to the second pressure
17 sensing member;

18 a first standpipe having a first port connected to the first fluid
19 chamber and a second port connected to the second fluid chamber;

20 a second standpipe having a third port connected to the first
21 fluid chamber and a fourth port connected to the second fluid
22 chamber.

1 10. The fluid ejection and circulation apparatus of claim 9 further
2 comprising a die carrier having a first fluid passage extending to the fluid ejection
3 die and a second fluid passage extending to the fluid ejection die, wherein the
4 first circulation path extends between the first standpipe and the die carrier and
5 wherein the second circulation path extends between the second standpipe and
6 the die carrier.

1 11. The fluid ejection and circulation system of claim 9, wherein the first
2 port is proximate a first end of the first standpipe and wherein the second port is
3 proximate a second end of the first standpipe, opposite the first end.

1 12. The fluid ejection and circulation system of claim 9, wherein the
2 first and second pressure sensing members comprise first and second
3 compliant chambers, respectively, the system further comprising:

4 a fluid source;

5 a first pump connected to the first fluid chamber;

6 a second pump connected to the second fluid chamber;

7 an inflator connected to the second compliant chamber; and

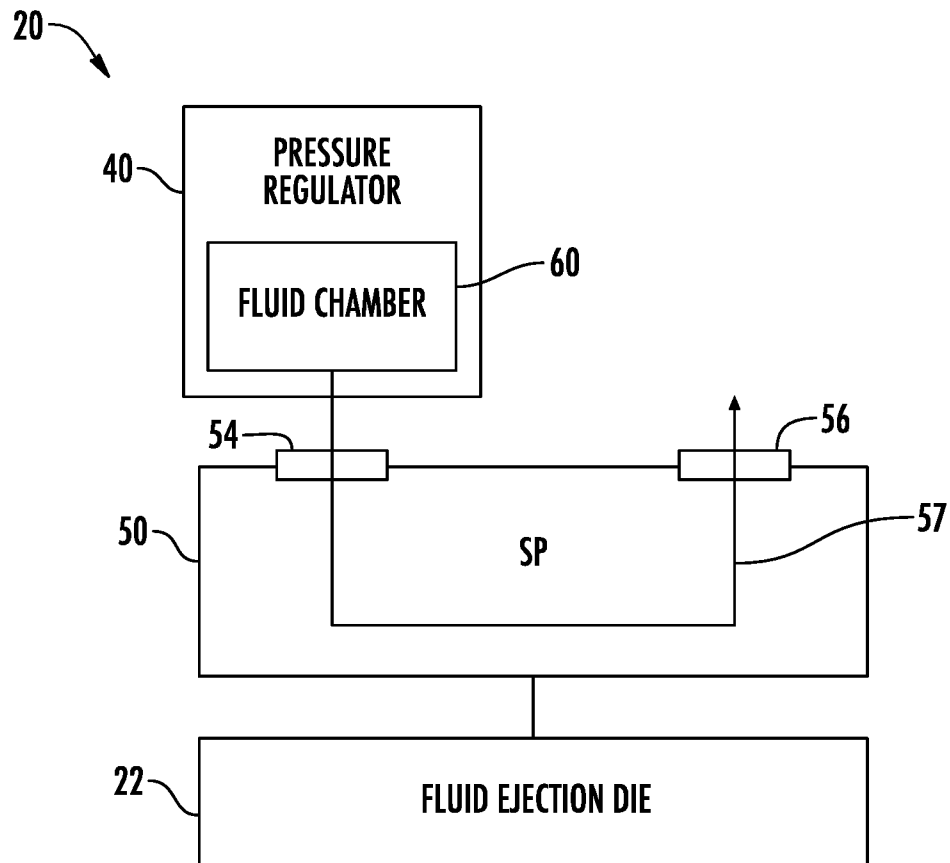
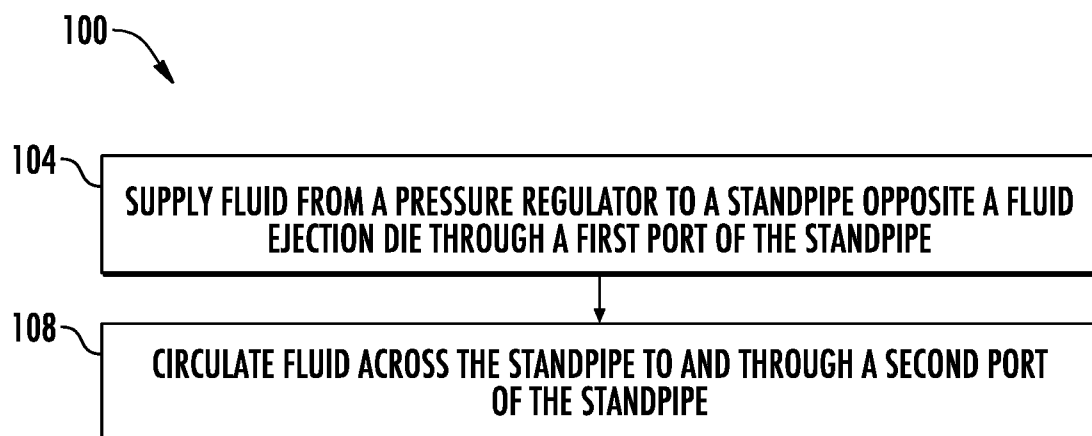
8 a controller to actuate the system between an ejection mode
9 and a circulation mode, wherein:

10 in the ejection mode, the first pump pumps fluid from the fluid
11 source to the first fluid chamber and the second pump pumps fluid from
12 the fluid source to the second fluid chamber, and

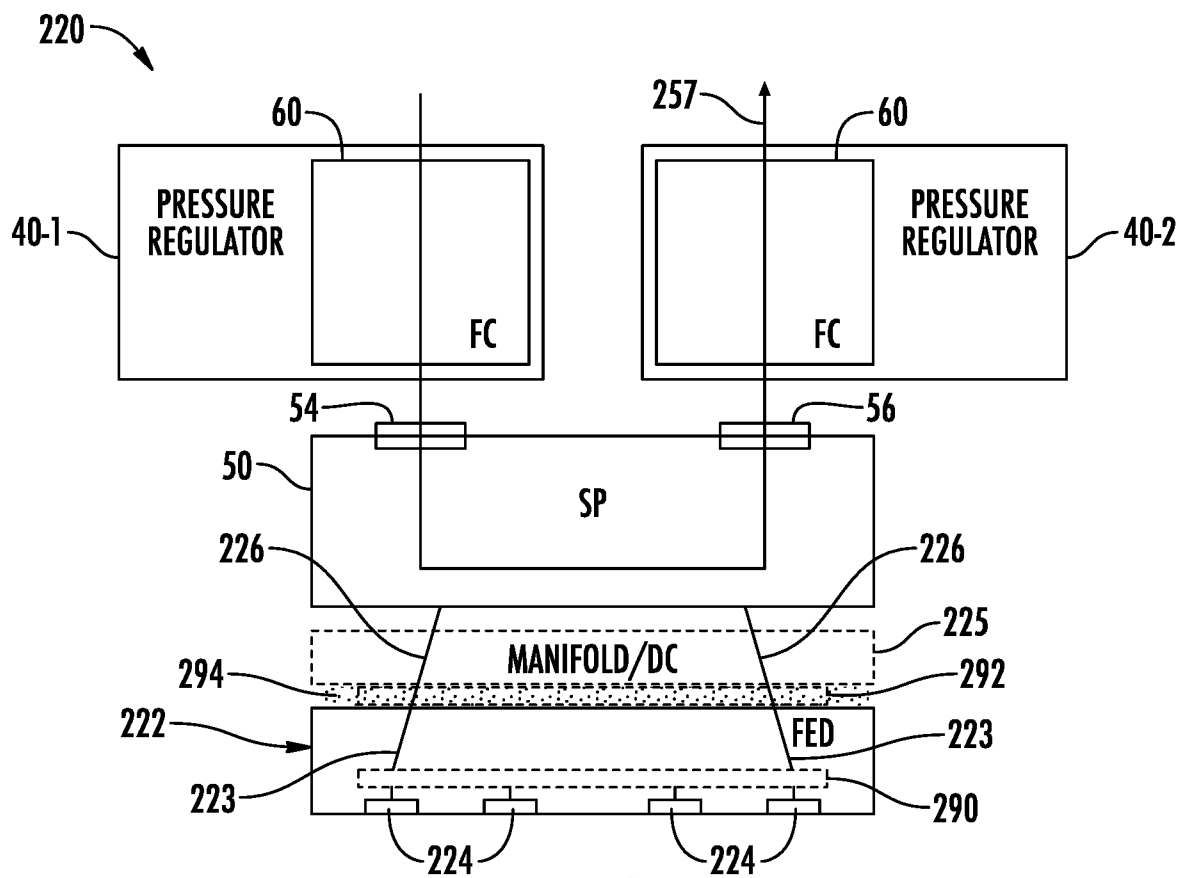
13 in the circulation mode, the first pump pumps fluid from the fluid
14 source to the first fluid chamber, the inflator inflates the second
15 compliant chamber to open the second valve and the second pump
16 pulls fluid from the second fluid chamber.

- 1 13. A method comprising:
- 2 supplying fluid from a pressure regulator to a
- 3 standpipe opposite a fluid ejection die through a first port of
- 4 the standpipe; and
- 5 circulating fluid across the standpipe to and through a
- 6 second port of the standpipe.
- 1 14. The method of claim 13 further comprising:
- 2 supplying fluid from the pressure regulator to a second
- 3 standpipe opposite the fluid ejection die through a first port of the
- 4 second standpipe;
- 5 circulating fluid across the second standpipe to a second
- 6 port of the second standpipe.
- 1 15. The method of claim 13 comprising:
- 2 circulating fluid from the standpipe through the second port
- 3 into a second pressure regulator; and
- 4 pulling the fluid that has been circulated into the second
- 5 pressure regulator from the standpipe out of the second pressure
- 6 regulator.

1/11

**FIG. 1****FIG. 2**

2/11

**FIG. 3**

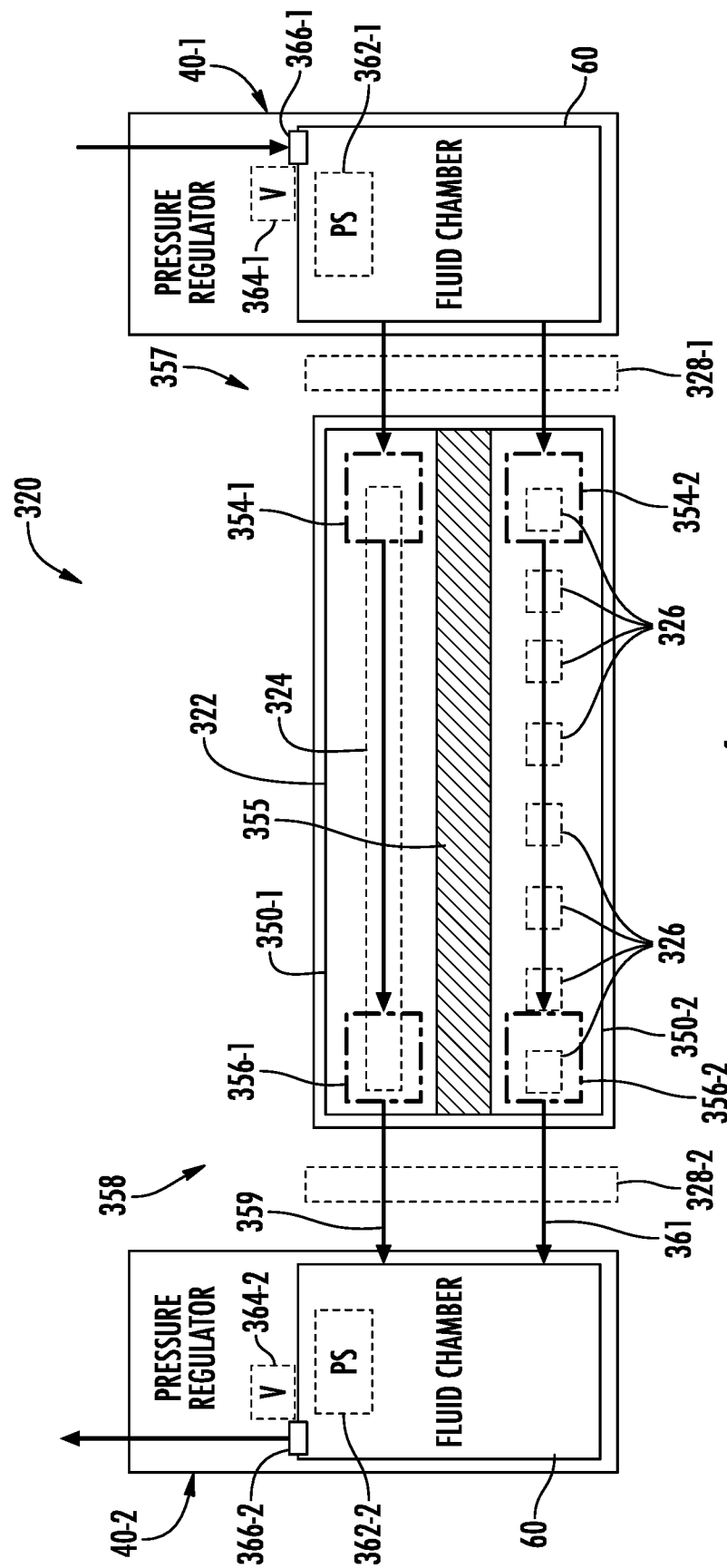


FIG. 4

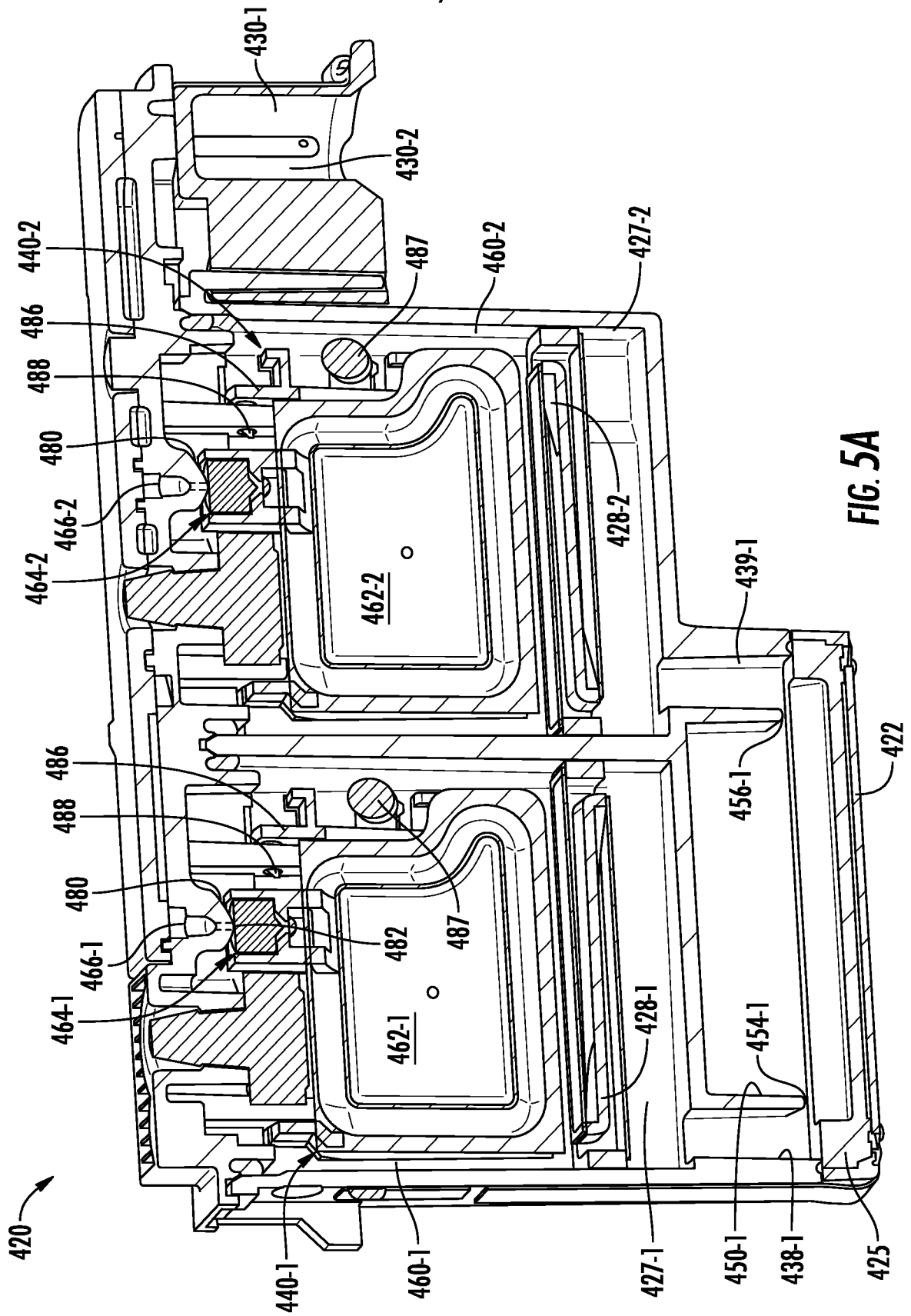
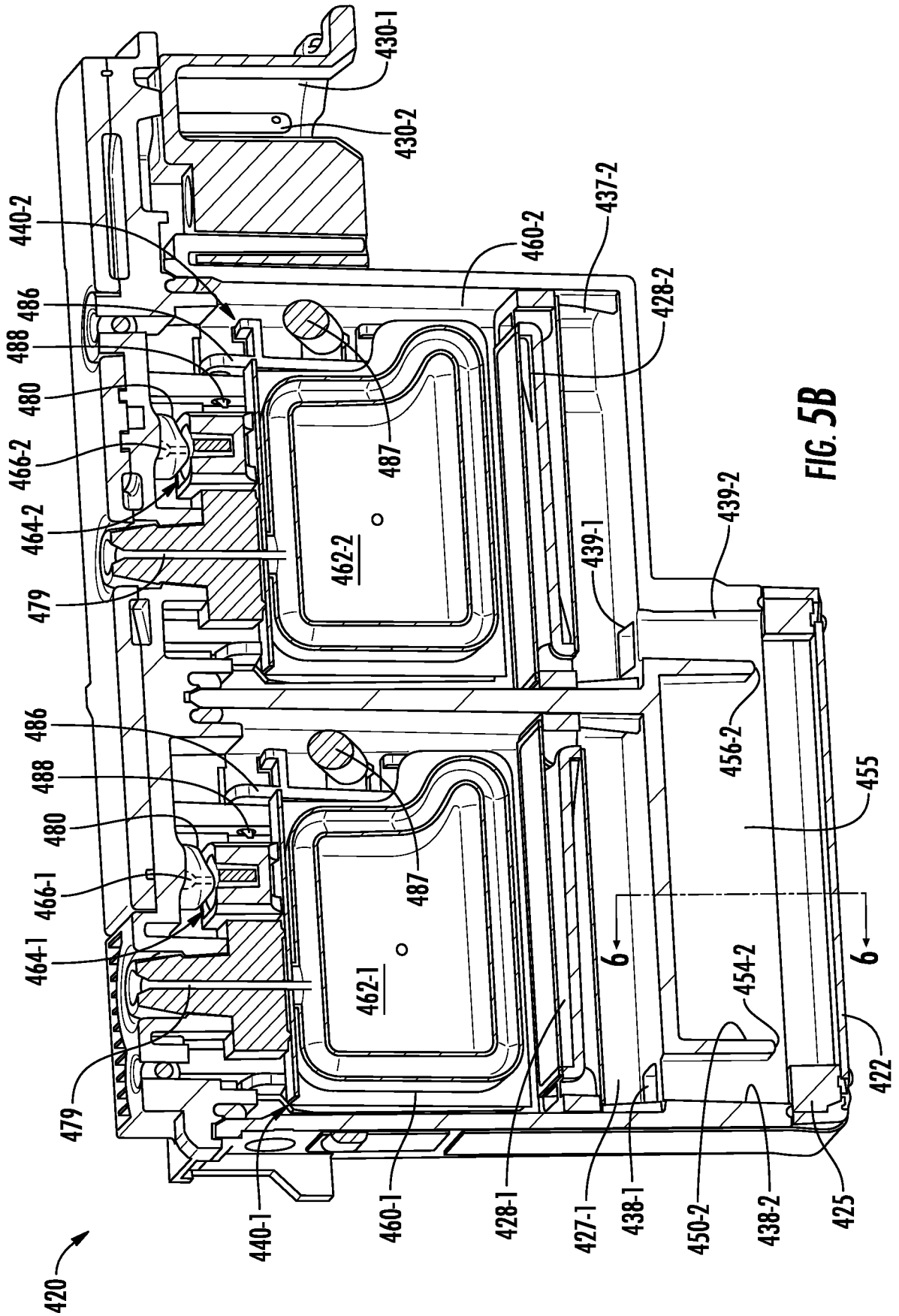
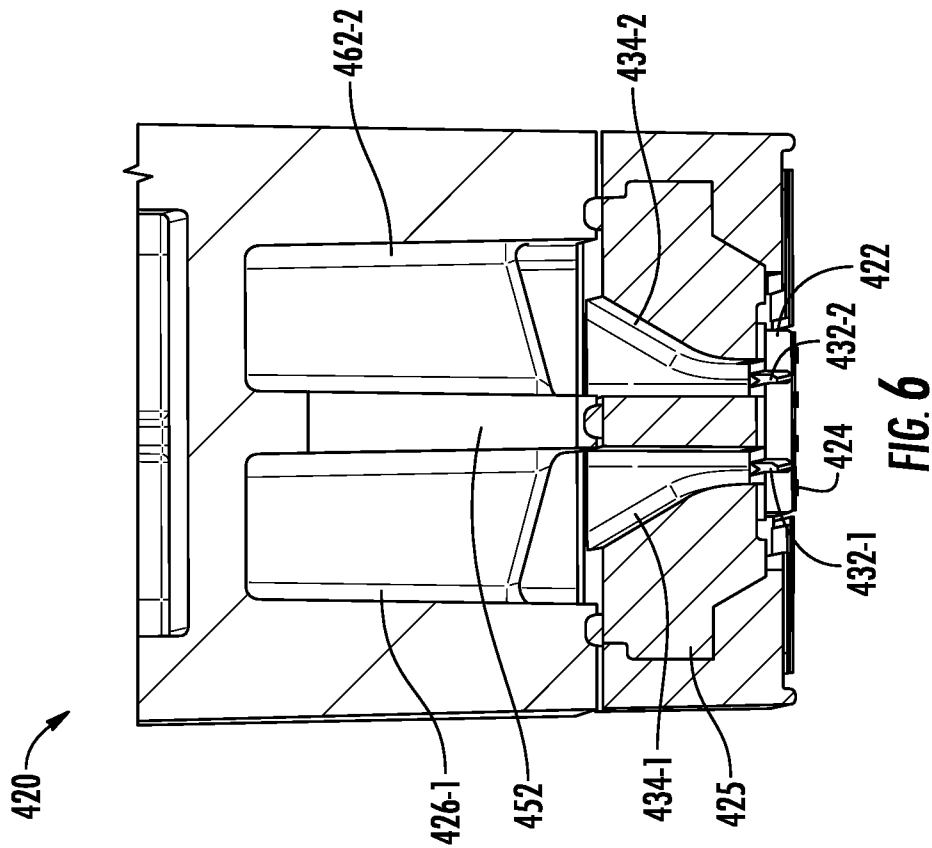
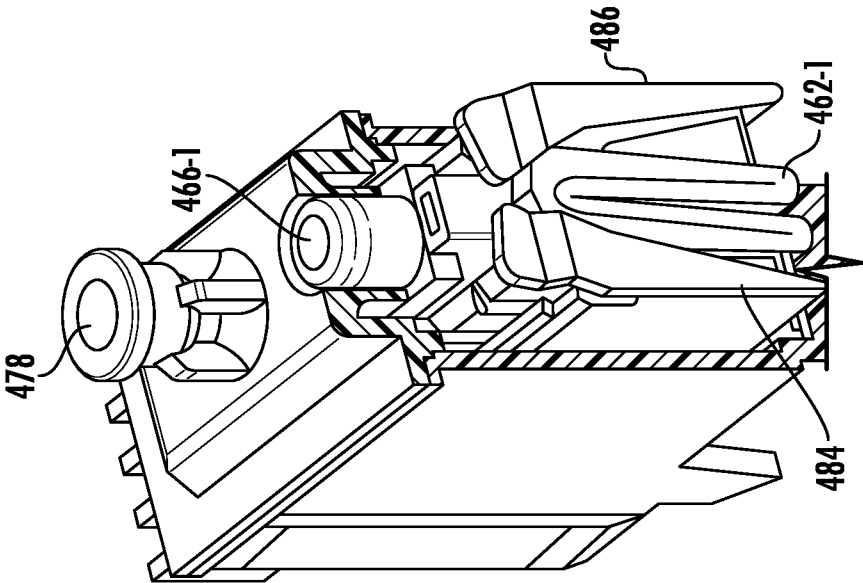
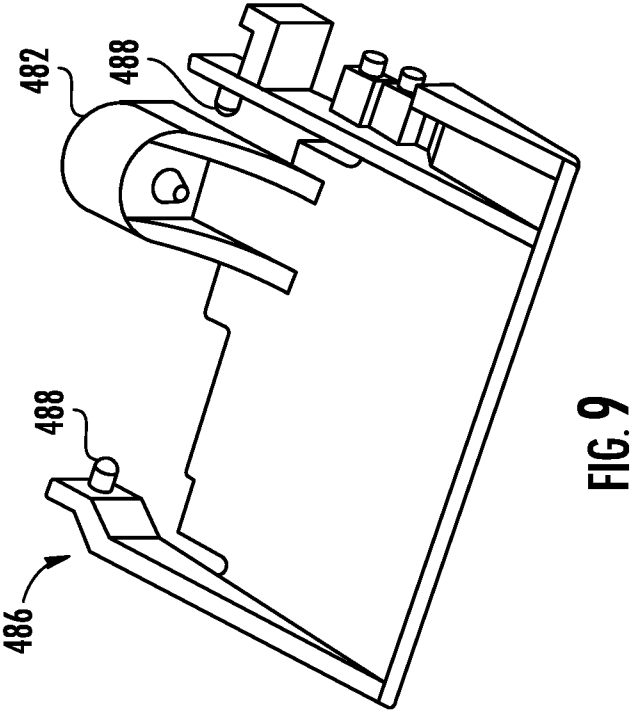
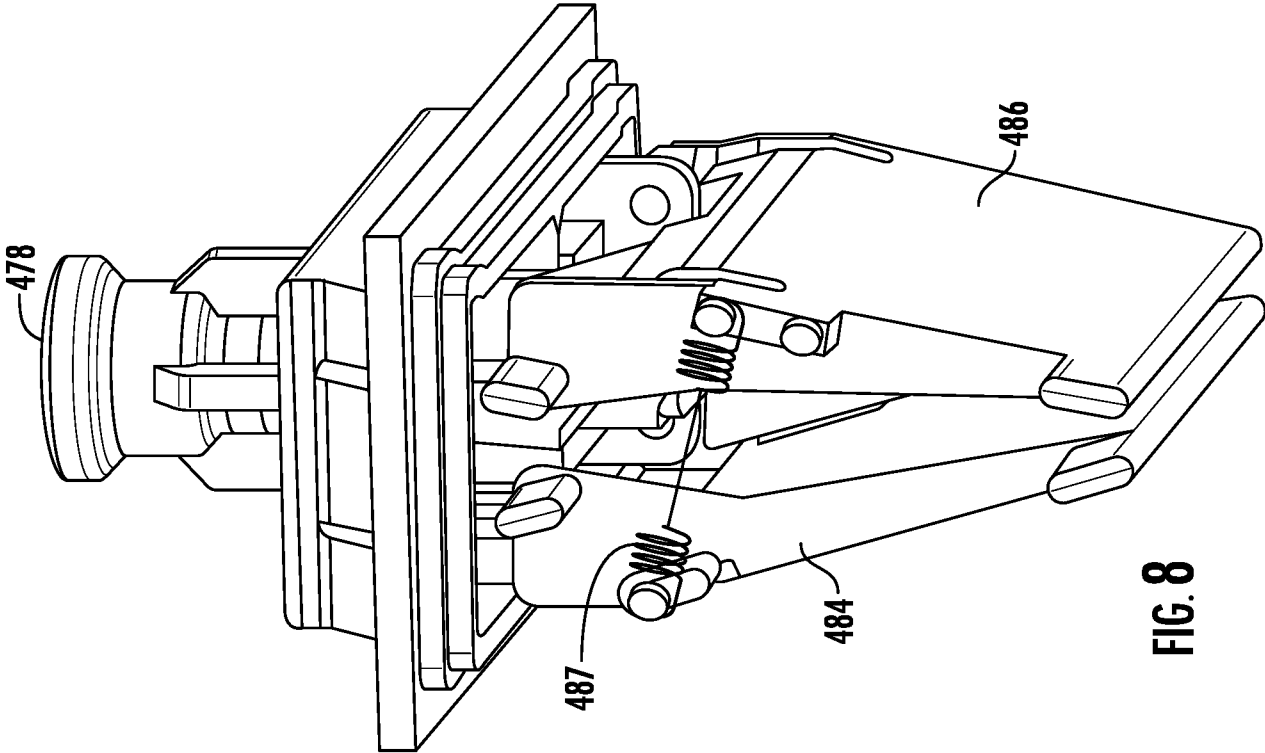


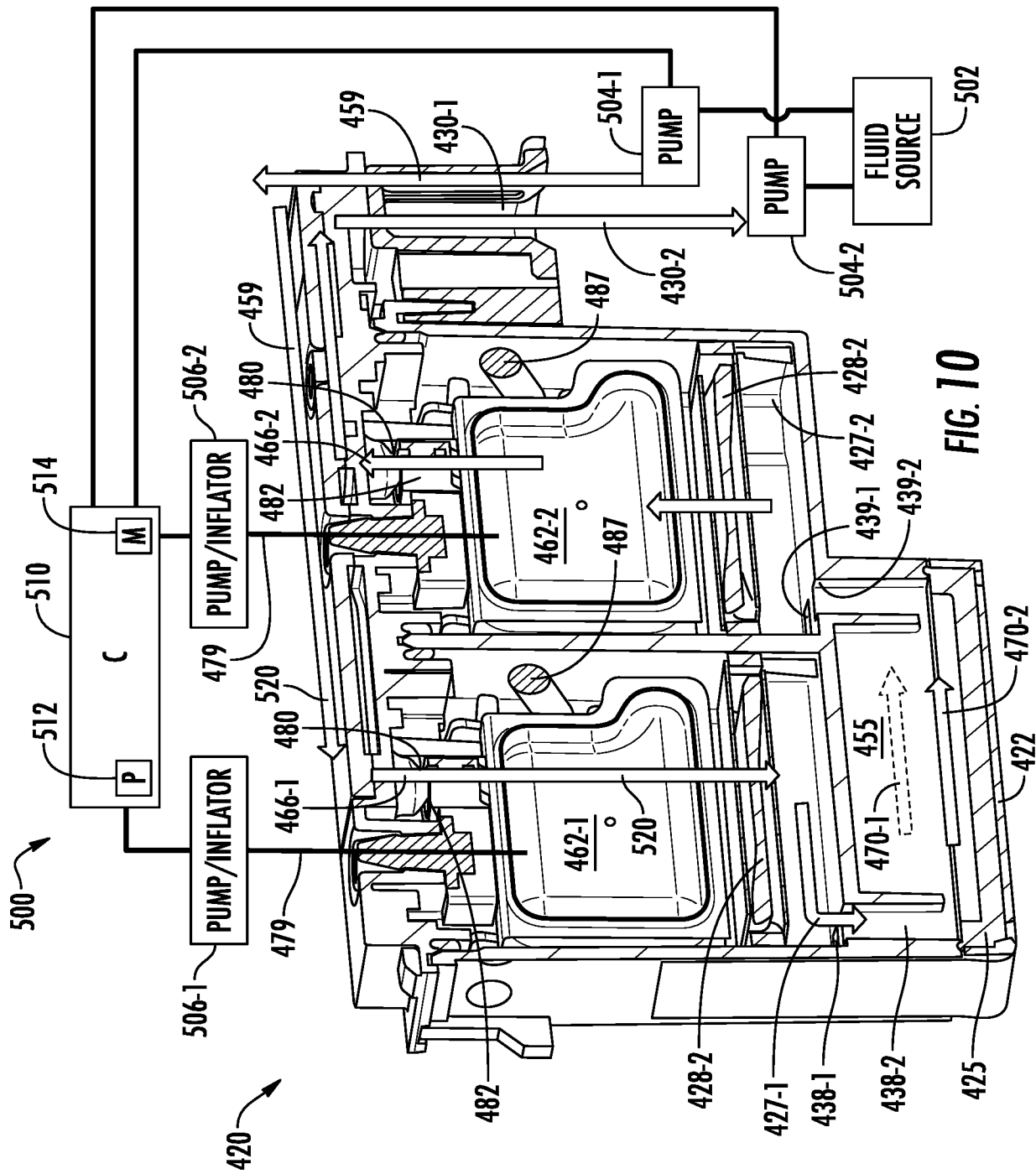
FIG. 5A

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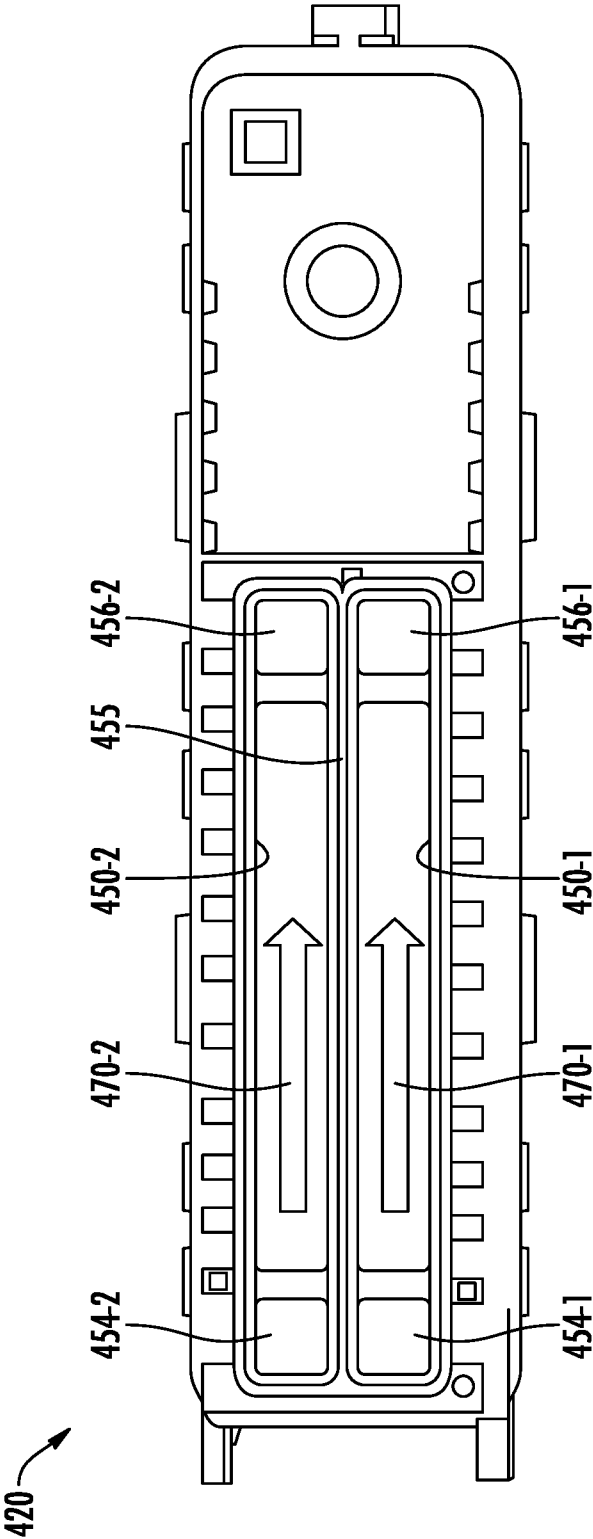
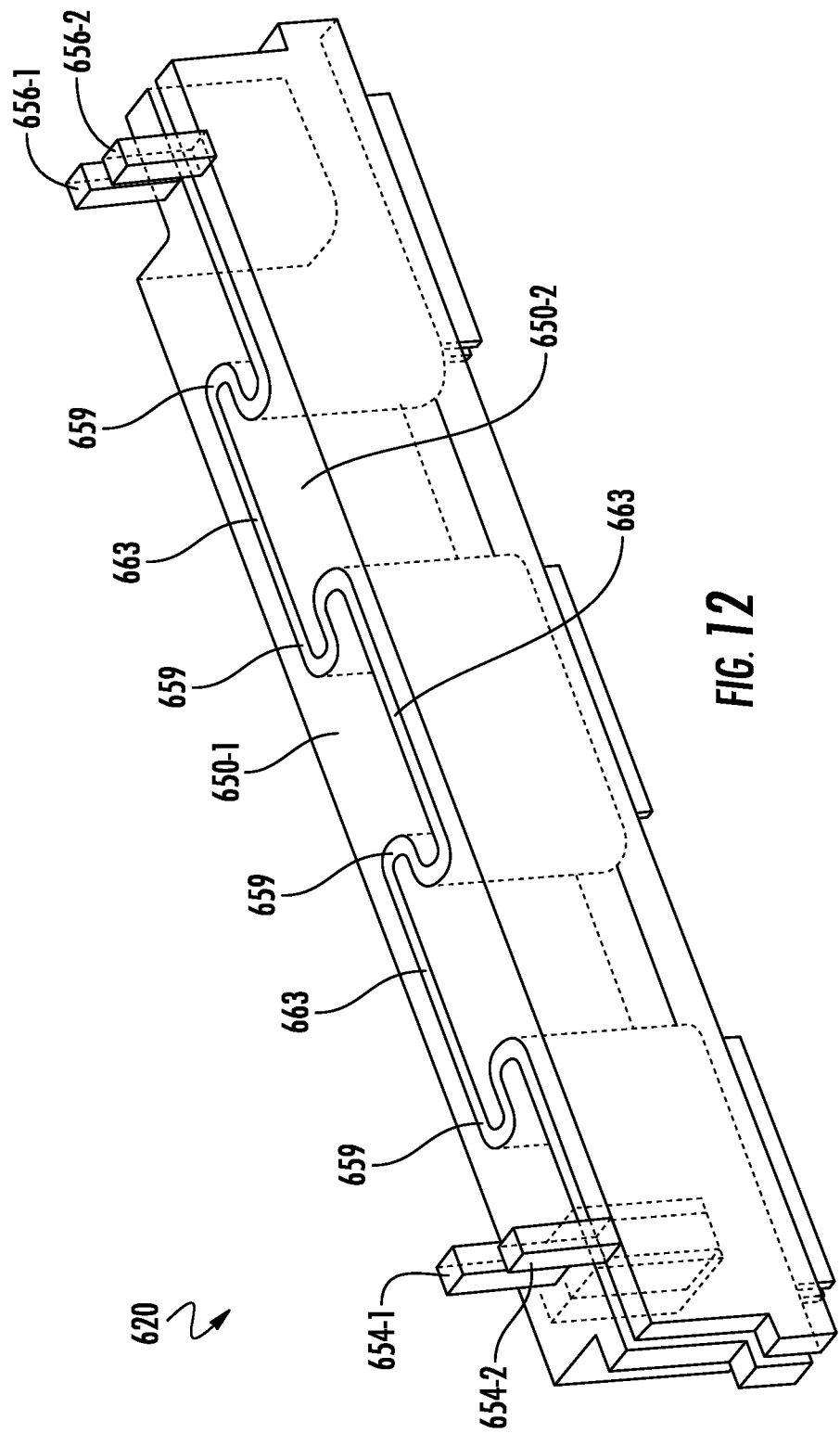


FIG. 11



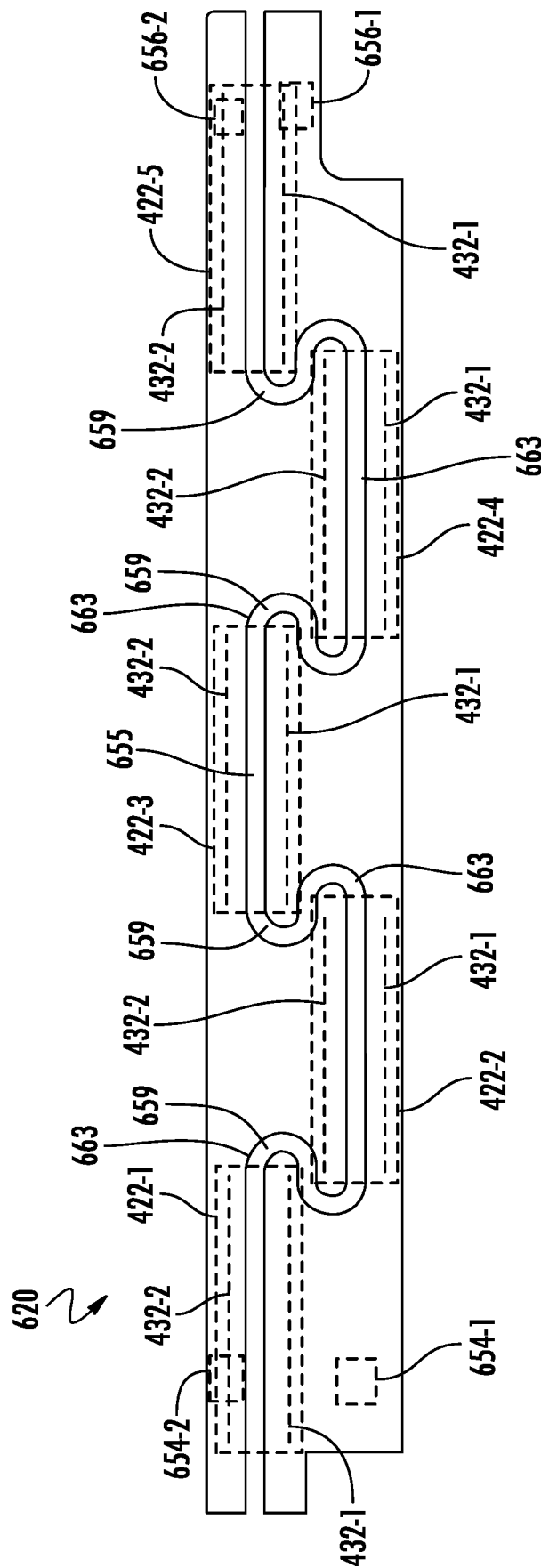


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2019/030082

A. CLASSIFICATION OF SUBJECT MATTER												
B41J 2/175 (2006.01) B41J 2/18 (2006.01) B41J 2/19 (2006.01) B41J 2/20 (2006.01)												
According to International Patent Classification (IPC) or to both national classification and IPC												
B. FIELDS SEARCHED												
Minimum documentation searched (classification system followed by classification symbols)												
B41J 2/00-2/525												
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched												
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)												
PatSearch (RUPTO Internal), USPTO, PAJ, Espacenet, Information Retrieval System of FIPS												
C. DOCUMENTS CONSIDERED TO BE RELEVANT												
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.										
Y	US 2014/0043404 A1 (FUJIFILM CORPORATION) 13.02.2014, fig. 7A-C, paragraphs [0116] - [0127]	1, 2, 4, 5, 7, 9-11, 13-15										
A		3, 6, 8, 12										
Y	WO 2012/054017 A1 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P. et al.) 26.04.2012, fig. 1, 2, paragraphs [0022] - [0025]	1, 2, 4, 5, 7, 9-11, 13-15										
Y	US 9162453 B2 (HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.) 20.10.2015, fig. 10, col. 11, line 22 - col. 12, line 25	4										
A	CN 106079902 B (FUJIFILM DIMATIX INC.) 10.04.2018	1-15										
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.												
* Special categories of cited documents: <table border="0"> <tr> <td>“A” document defining the general state of the art which is not considered to be of particular relevance</td> <td>“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>“E” earlier document but published on or after the international filing date</td> <td>“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>“O” document referring to an oral disclosure, use, exhibition or other means</td> <td>“&” document member of the same patent family</td> </tr> <tr> <td>“P” document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			“A” document defining the general state of the art which is not considered to be of particular relevance	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	“E” earlier document but published on or after the international filing date	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	“O” document referring to an oral disclosure, use, exhibition or other means	“&” document member of the same patent family	“P” document published prior to the international filing date but later than the priority date claimed	
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Date of the actual completion of the international search		Date of mailing of the international search report										
04 December 2019 (04.12.2019)		23 January 2020 (23.01.2020)										
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37		Authorized officer P. Bystrov Telephone No. 8(495) 531-64-81										