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MIXED REGIME PASSIVE VALVE

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

1) Field of the Invention

[0003] The present invention relates to a passively actuated valve and, more particularly, to a passively actuated flap valve and method of use for the retrieval of gas from a mixed flow of liquid and gas.

2) Description of the Prior Art

[0004] A mixed stream of liquid and gas can flow over a surface. The gas and liquid may have different fluid densities thereby, causing the force generated on the surface over which the flow occurs to be different for the gas and the liquid. It is desired to separate the gas from the liquid in the flow and to retrieve the gas through a vertically arranged bore opening up to the surface over which the flow occurs. As the gas is

retrieved through the bore, it is also desired that liquid does not enter through the bore.

[0005] Previous examples of gas and liquid mitigation and separation include actively controlled devices positioned on the surface over which a mixed flow of liquid and gas occurs. An actively controlled device such as a valve is actuated based on an output of a sensor. The sensor senses the flow of liquid or gas and during the flow of gas and in absence of liquid, the actuator can open the valve to extract the gas from the surface.

[0006] Also, centrifugal devices are used to separate gas from liquid during a mixed flow of liquid and gas. However, as recognized herein, the use of sensors, actively controlled devices, and/or centrifugal devices add complexity to the system. Furthermore, such systems may include many working parts which are not suitable for removing gas from external flows.

SUMMARY OF INVENTION

[0007] A valve system for gas extraction is provided with a vertically arranged bore having a central axis and a pivotable flap valve coupled to the bore at a pivot axis with the pivot axis offset from the central axis of the bore. The flap valve includes a higher mass on a first, shorter side of the pivot axis. A top surface of the flap valve on the shorter side of

the pivot axis is inclined above a horizontal plane when the flap valve is closed. In this way, a valve system is adapted to open during flow of a mixed stream of liquid and gas such that the valve system is effectively used to extract gas from the mixed flow.

[0008] More specifically, the valve is a pivotable butterfly valve that opens selectively during an absence of the dynamic force of liquid flow over an external side of the valve. The valve is coupled to the bore at a pivot axis that is axially offset from a central axis of the bore; thereby, dividing the valve into a shorter, first section and a longer, second section along the pivot axis. The mass of the valve is unequally distributed on each side of the pivot axis with the mass being higher on the shorter section. The internal side of the valve facing the bore is subjected to a vacuum.

[0009] As liquid flows over the valve in a certain direction, the hydrodynamic forces of the flowing liquid can force the valve to remain in a closed position. The location of the center of gravity of the valve relative to the offset pivot point ensures that the valve remains closed during flow of liquid over the valve even in the presence of the internal vacuum.

[0010] As gas flows over the valve, the closing forces are reduced and in the presence of the internal vacuum, the unequal mass distribution about the offset pivot axis allows the flap of the valve to tilt in one direction; thereby, opening the valve and allowing gas to enter the bore. The valve can again close when flow of liquid over the valve resumes.

[0011] The particular weight offset described, works as oriented with gravity pointed down. Should the valve be used upside down; the weight offset would have to be changed such that the valve is naturally closed. This weight movement can be eliminated with a light torsion spring over pivot shaft, which could keep the valve flap closed regardless of orientation. Orientation options are important based on internal versus external flow and where the gas tends to collect in a pipe (internal flow) versus on a body (external flow). By using a tactile, self-sensing valve, gas can be selectively separated and extracted from a mixed flow of gas and liquid. Features of the valve such as the offset pivot point and uneven distribution of mass on the valve allow opening and closing of the valve based on presence of dynamic forces on the valve caused only during a liquid flow. The technical effect of using a self-sensing and a passively actuated valve is that complexity of the gas retrieval system involving actively controlled devices,

and/or centrifugal devices is reduced. The reduction of complexity results in reducing the cost of the system while maintaining sufficient precision of measurements.

[0012] It should be understood that the summary above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. It is not meant to identify key or essential features of the claimed subject matter, the scope of which is defined uniquely by the claims that follow the detailed description. Furthermore, the claimed subject matter is not limited to implementations that solve any disadvantages noted above or in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Features of illustrative embodiments may be understood from the accompanying drawings in conjunction with the description. The elements in the drawings may not be drawn to scale. Some elements and/or dimensions may be enlarged or minimized for the purpose of illustration and understanding of the disclosed embodiments wherein:

[0014] **FIG. 1** is a perspective view of a valve system in a closed position in accordance with an embodiment of the present invention;

[0015] **FIG. 2** is a perspective view of the valve system of **FIG. 1** in an open position;

[0016] **FIG. 3** is a top view of the valve system of **FIG. 1** in the closed position;

[0017] **FIG. 4** is a top view of the valve system of **FIG. 2** in the open position;

[0018] **FIG. 5** is a cross-sectional view of the valve system of **FIG. 3** in the closed position;

[0019] **FIG. 6** is a cross-sectional view of the valve system of **FIG. 4** in the open position;

[0020] **FIG. 7** is another cross-sectional view of the valve system of **FIG. 3** in the closed position;

[0021] **FIG. 8** is a another cross-sectional view of the valve system of **FIG. 4** in the open position; and

[0022] **FIG. 9** is a flow-chart illustrating an example method that can be implemented to passively operate the valve system.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The following description relates to a passively actuated valve system used for the retrieval of gas from a stream of a liquid and gas mixture flowing over the valve system.

[0024] In the invention, a valve system **100** is provided in which the system includes a bore, as shown in **FIG. 1** and **FIG. 2**,

over which gas is retrieved. During the flow of gas over a valve **102,** a flap of the valve is tilted to one side exposing the bore to the gas flow, as shown in the top views of the valve system **100** from a closed position in **FIG. 3** to an open position in **FIG. 4.**

[0025] The valve **102** includes a pivot axis that is axially off-centered toward one side as shown in a first set of crosssectional views of the valve in **FIG. 5** and **FIG. 6.** A second set of cross-sectional views of the bore including the valve **102** are shown in **FIG. 7** and **FIG. 8.** **FIG. 9** shows an example method of passive operation of the valve.

[0026] **FIG. 1** is a perspective view of a valve **102** in a closed position and **FIG. 2** is a perspective view of the valve in an open position. In the figures, the flap valve **102** is positioned over and coupled in alignment with a bore such that a stream of a gas-liquid mixture can flow over the valve in a direction shown by arrow **A.** The bore can open up to a surface that is exposed to a mixed stream of gas-liquid.

[0027] A top rim **104** of a cylindrical bore **106** lining the valve **102** includes a radially symmetric circular circumference. The inner surface (wall) of the bore **106** includes alternating arcuate and flat sections. Two opposing arcuate sections **108**

and **110** alternate between two opposing flat sections **112** and **114.**

[0028] A first ramp **116** (as shown in **FIG. 5** and **FIG. 6**) is positioned between the rim **104** and the arcuate section **110.** A second ramp **118** is positioned between the rim **104** and the arcuate section **108.** A restraining lip **120** runs along the arcuate section **108** below the second ramp **118.** The retraining lip **120** may span more than 180° angle from one pivot point to another along the arcuate section **108.**

[0029] The valve **102** includes a flap **122** or valve body coupled to the bore **106** at pivot points **124** on opposite sides of the cylindrical bore. The line joining pivot points **124** on opposite sides of the bore **106** forms a pivot axis **126** about which the valve **102** is coupled to the bore. The flap **122** is free to move about the pivot axis **126.** As an example, the flap **122** can oscillate in a range of 30-60° about the pivot axis **126.**

[0030] The pivot axis **126** is axially off-centered relative to a central axis **B-B'** of the bore **106.** The pivot axis **126** is shifted to the right relative to the central axis **B-B',** such as towards the arcuate section **110** of the bore **106.**

[0031] The flap **122** can be divided into two segments such as two throttle blades along the pivot axis **126.** The two segments include a shorter segment **128** on a first side of the pivot axis

126 between the pivot axis **126** and the arcuate section **110** and a longer segment **130** on a second side of the pivot axis between the pivot axis and the arcuate section **108.**

[0032] The mass of the flap **122** is distributed unequally on each side of the pivot axis **126.** The first side of the flap **122** may be lighter relative to the second side of the flap.

[0033] In the closed position of the valve **102,** as seen in **FIG. 1** and **FIG. 3,** the flap **122** covers the entire opening of the bore **106.** The longer segment **130** of the flap **122** is angled downward into the bore **106.** An arcuate edge of the longer segment **130** rests against the restraining lip **120.** In the closed position of the valve **102,** the longer segment **130** of the flap **122** is tilted into the bore **106.**

[0034] As an example shown in **FIG. 5,** the tilting of the longer segment **130** can form a first angle, α, of 10 - 45° between a plane of the rim **104** of the bore **106** and a top surface of the longer segment of the flap.

[0035] The shorter segment **128** may be further divided into a first portion **132** and a second portion **134.** The first portion **132** of the first segment **128** is a flat portion with flat sides flush with the first flat section **112** and a second flat section **114,** respectively, of the inner surface of the bore **106** on each side. The top surface of the second portion **134** of the first

segment **128** is inclined upwards above a horizontal plane of the rim **104** of the bore **106.** A peripheral portion **136** of the flap adjoins the top inclines outward above the horizontal plane of the rim **104** of the bore **106.**

[0036] An upper surface **138** of the flap **122** is in face sharing contact with a gas-liquid flow; the gas-liquid mixture flowing along the direction of the arrow **"A"** (left to right of the valve **102**) from the longer segment **130** towards a first segment of the flap. As an example, when the bore **106** with the valve **102** coupled to it is moving through water from left to right, water can flow over the valve in the direction shown by the arrow **A.** As further elaborated with relation to **FIG. 5,** when the water flows over the valve **102,** it forces the valve closed, while in absence of the flow of water then the valve can open.

[0037] In the open position of the valve **102,** as seen in **FIG. 2** and **FIG. 4,** the flap **122** opens partially to allow fluids to enter the bore via an opening **150.** The opening **150** spans across a first portion of the bore **106** while the remaining, second, portion of the bore remains covered by flap **122.** In the open position, the longer segment **130** of the flap **122** tilts within the bore **106** while the first segment **128** protrudes outward from

the horizontal plane of the rim **104** of the bore. The tilting of the flap **122** occurs along the pivot axis **126**.

[0038] As an example shown in **FIG. 6**, the tilting of the longer segment **130** can form a second angle, β, between a horizontal plane of the rim **104** of the bore **106** and a top surface of the longer segment **130** of the flap **122**. In the example, β is a right angle of 90°.

[0039] A lower surface **160** of the flap **122** includes an angular section **162** joining the peripheral portion **136** to a hemispherical section **164**. In the open position, the angular section **162** and hemispherical section **164** protrude outward from the horizontal plane of the rim **104** of the bore **106**.

[0040] **FIG. 5** shows a first cross-sectional view and **FIG. 7** shows a third cross-sectional view of the valve **102** in the open position. **FIG. 6** shows a second cross-sectional view and **FIG. 8** shows a fourth cross-sectional view of the valve **102** in the closed position.

[0041] The first and second cross-sectional views of **FIG. 5** and **FIG. 6** are taken along the arcuate sections **108** and **110** such as along the direction arrow **A**. The third and fourth cross-sectional views of **FIG. 7** and **FIG. 8** are taken along the flat section **112** and the flat section **114** such as along the pivot axis **126**. Therefore, the first cross-sectional views of **FIG. 5**

and **FIG. 6** shows a plane perpendicular to that of the cross-sectional views of **FIG. 7** and **FIG. 8.**

[0042] The cross-sectional views provide further details of the lower surface **160** of the flap **122** of the valve **102.** The longer segment **130** of the flap **122** is elliptical shaped with a rounded wall **170** (angled towards the upper surface **138**) joining the upper surface and the lower surface. The hemispherical section **164** ends in a cylindrical portion **166** with a flat lower surface **168.** The lower surface of the longer segment **130** of the flap **122** is joined to the cylindrical portion **166** via an arcuate section **172** framing the pivot point **124.**

[0043] In the closed position, the angular section **162** joining the peripheral portion **136** to the hemispherical section **164** is in face sharing contact with a second ramp **118** between the rim **104** and the arcuate section **110.** In the open position, the cylindrical portion **166** is in face sharing contact with the arcuate section **110.** Due to the large surface area of contact between the cylindrical portion **166** and the arcuate section **110,** the valve **102** does not get stuck in the open position. Also, during opening of the valve **102,** as the cylindrical portion **166** hits the arcuate section **110** of the bore, the flap **122** is stopped from rotating about the pivot axis **126.**

[0044] The uneven distribution of mass about the pivot axis **126** is caused by the presence of the heavier hemispherical section **164** on the arcuate section **108** of the flap **122.** The lower surface of the elliptical shaped longer segment **130** of the flap **122** includes a round cutout **180** to further lower the mass on the longer segment and adjust the mass on both sides of the pivot axis **126.**

[0045] During a first operating condition, the valve is passively opened by rotating the flap **122** about the off-centered pivot axis **126** in a first direction in a presence of internal vacuum to allow flow of gases into the cylindrical bore **106**, and during a second operating condition, the valve is passively opened by rotating the flap about the off-centered pivot axis in a second, opposite, direction in presence or absence of internal vacuum to block liquids from entering the bore. The first condition includes a flow of only gases over a surface contacting the valve **102** in the presence of the internal vacuum, and the second condition includes a flow of liquids over the surface by applying dynamic force on the valve.

[0046] In an open position of the valve **102**, if a liquid flow resumes, the valve can close upon the liquid hitting the protruded face of the arcuate section **108** of the shorter segment **128** and the hydrodynamic forces can maintain the valve in the

closed position. Furthermore, in the open position, backwards flow of liquid (such as in a direction opposite to the direction shown by the arrow **A**) is stopped from entering the bore by the protruding hemispherical section **164**. In the closed position of the valve, backwards flow of liquid (such as in a direction opposite to the direction shown by arrow **A**) is stopped by the inclined arcuate shorter segment **128**. The peripheral portion **136** of the flap **122** protruding out of horizontal plane of the rim **104** of the bore **106** averts undesired backflow of liquid into the bore.

[0047] As one example, if a bubble comes in contact with the valve **102**, the bubble can expand and collapse over the valve. The liquid in the bubble can be averted from entering the bore while the gas can be sucked in.

[0048] **FIG. 9** shows an example method **500** for operating a self-sensing, passive, modified butterfly or flap valve (such as the valve **102**) coupled to a bore (such as the bore **106**). The valve covers the entire opening of the bore. The bore opens to a surface on which a mixed stream of liquid and gas flows in one direction.

[0049] At step **502**, vacuum (a lower than atmospheric pressure) is applied on an internal side of the bore to facilitate actuation of the valve and suction of gas into the

bore. At step **504,** a liquid (such as water) flows over the flap valve covering the bore. As the liquid flows over, a dynamic force is generated on a top surface of the valve.

[0050] At step **506,** the hydrodynamic force generated due to the flow of liquid causes the valve to close even in the presence of internal vacuum. Closing of the valve includes a flap or valve body (such as flap **122**) of the valve to rotate clockwise about the pivot axis (such as axis **126**) and flatten over the opening of the bore.

[0051] At the closed position, the flap is not planer with the horizontal plane of the rim of the bore as a second segment of the flap (such as the longer segment **130**) on a second side of the pivot axis is tilted into the bore and a top surface of a first segment of the flap (such as the shorter segment **128**) is inclined above the horizontal plane of the rim. The second segment of the flap rests on a restraining lip (such as the restraining lip **120**) along an arcuate inner surface of the bore. The valve can also remain closed in the absence of the internal vacuum (lower pressure).

[0052] At step **508,** flow of liquid over the valve is stopped and only gas (such as air) flows over the valve. In the absence of the hydrodynamic force over the valve; at step **510,** the valve is opened due to the internal vacuum and the unequal mass

distribution about the offset pivot axis. The heavier mass on the shorter side of the flap causes the flap of the valve to rotate counter-clockwise about its pivot axis, thereby opening the valve.

[0053] Opening the valve includes a exposing a portion of an opening of the bore to the gas flow. At the open position, the opening of the bore is partially exposed to the gas flow while a portion of the opening is covered. The internal vacuum in the bore, sucks in the gas flowing over the valve, thereby extracting gas from the mixed liquid-gas flow. Again, if liquid flow resumes over the valve, the dynamic forces of liquid will cause the valve to close, thereby restricting liquid from entering the bore.

[0054] In this way, a passively actuated valve coupled at an opening of a passage can be used to effectively extract gases from a mixed stream of liquid and gas flowing over s surface. The valve can be closed by exerting hydrodynamic forces generated by a flow of the liquid over a flap of the valve, and the valve can be subsequently opened by suspending the flow of the liquid over the flap and applying vacuum within the passage. A gas flowing over the valve is routed into the passage via the open valve.

[0055] The particular weight offset described works as oriented with gravity pointed down and as shown in the figures supporting the present invention. In a variant of the embodiment and should the valve be used upside down; the weight offset would have to be changed such that the valve is naturally closed. This weight movement can be eliminated with a light torsion spring over the pivot shaft, which could keep the valve flap closed regardless of orientation.

[0056] The invention has been described with references to specific embodiments. While particular values, relationships, materials, and steps have been set forth for purposes of describing concepts of the present disclosure, it will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the disclosed embodiments without departing from the spirit or scope of the basic concepts and operating principles of the invention as broadly described.

MIXED REGIME PASSIVE VALVE

ABSTRACT OF THE DISCLOSURE

A system for gas extraction is provided with a flap valve coupled to a bore with a pivot axis offset from an axis of the bore. The valve includes a higher mass on a shorter side of the pivot axis. A valve surface on the shorter side is inclined above a horizontal plane when the valve closes. The valve opens during liquid and gas flow to extract gas from the flow. As liquid flows over the valve, the valve is forced to close. The center of gravity of the valve relative to the offset pivot point ensures that the valve remains closed during liquid flow. As gas flows over the valve, closing forces are reduced and under internal vacuum, the mass distribution about the offset pivot axis allows the flap of the valve to tilt; opening the valve and allowing gas to enter the bore.

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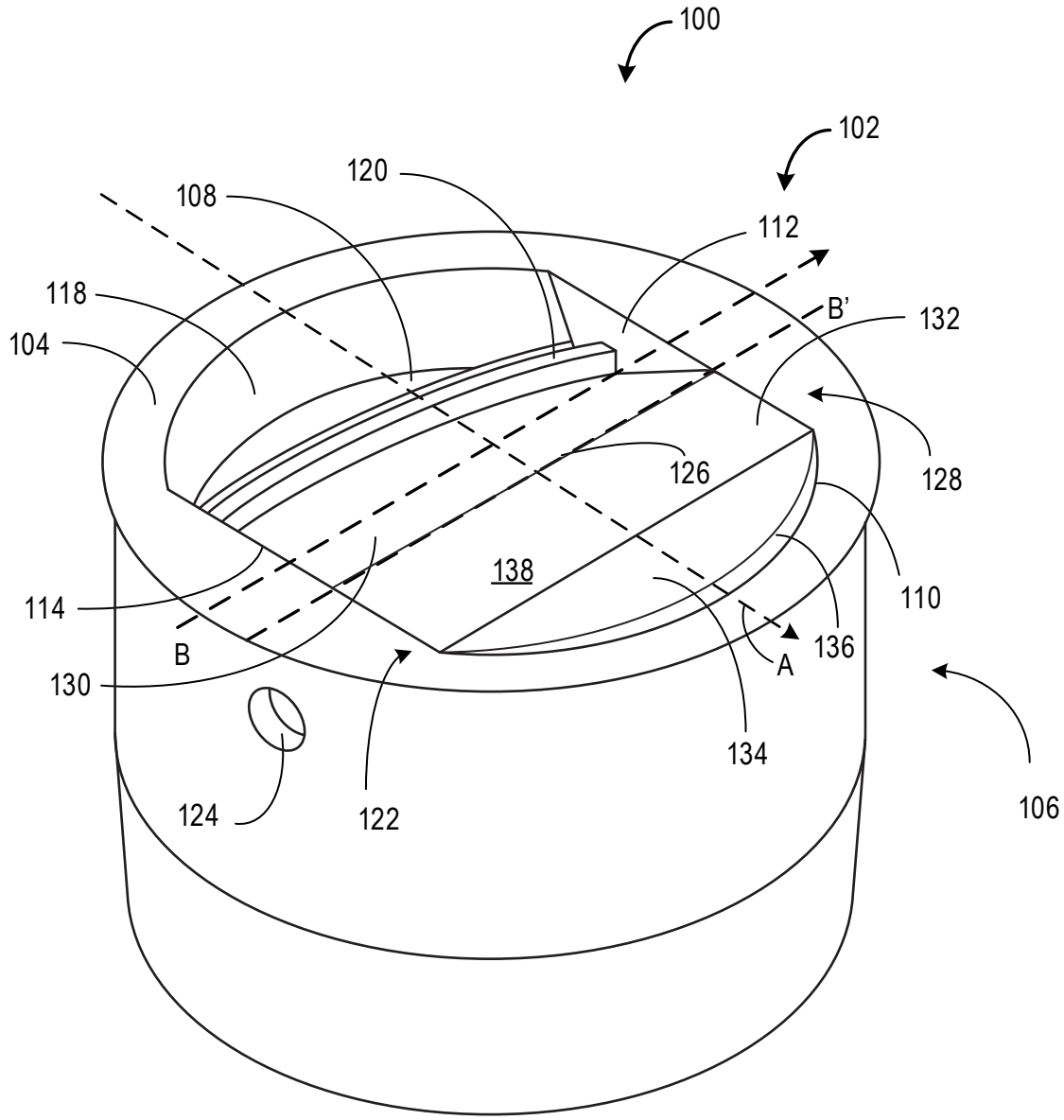


FIG. 1

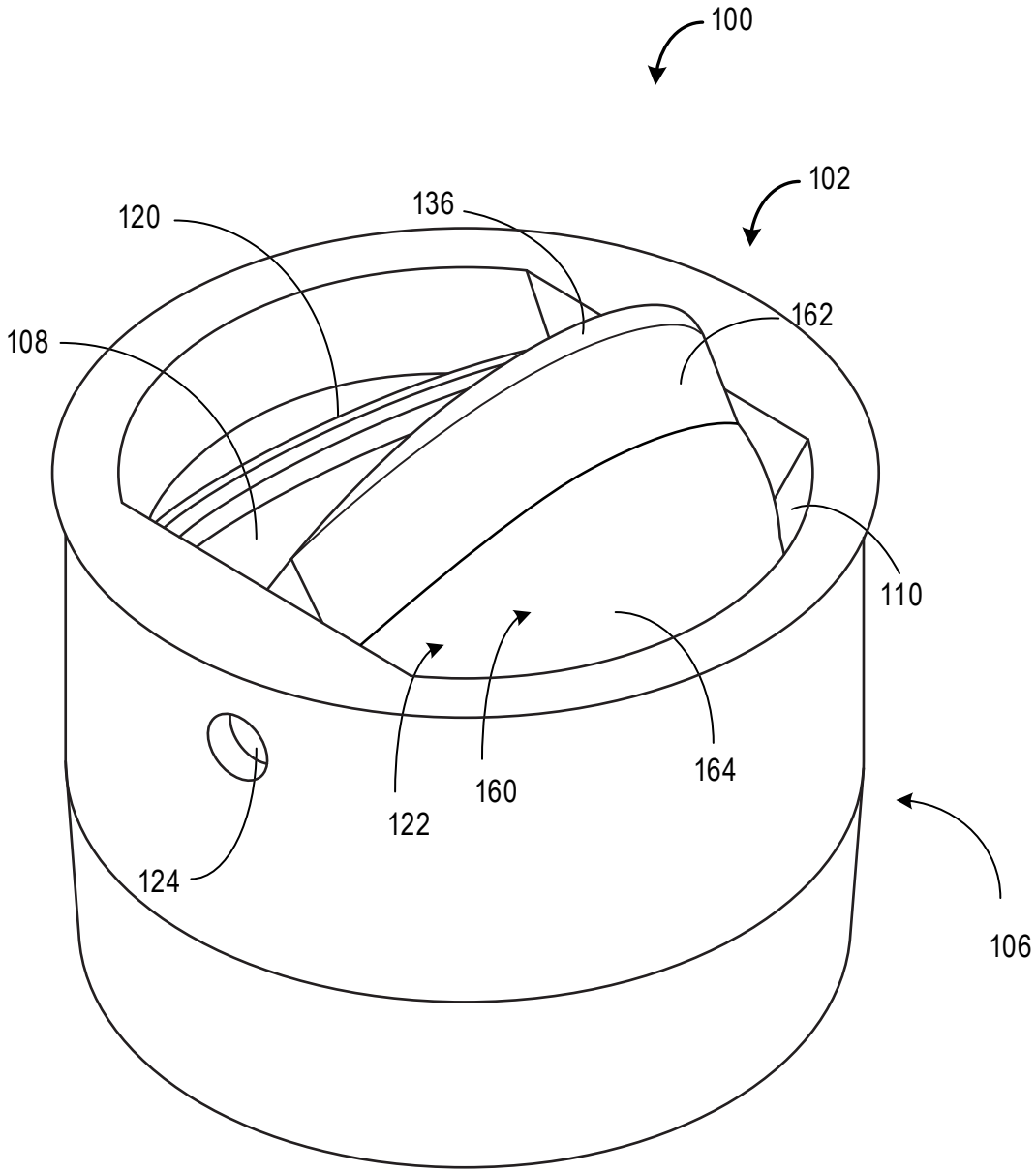


FIG. 2

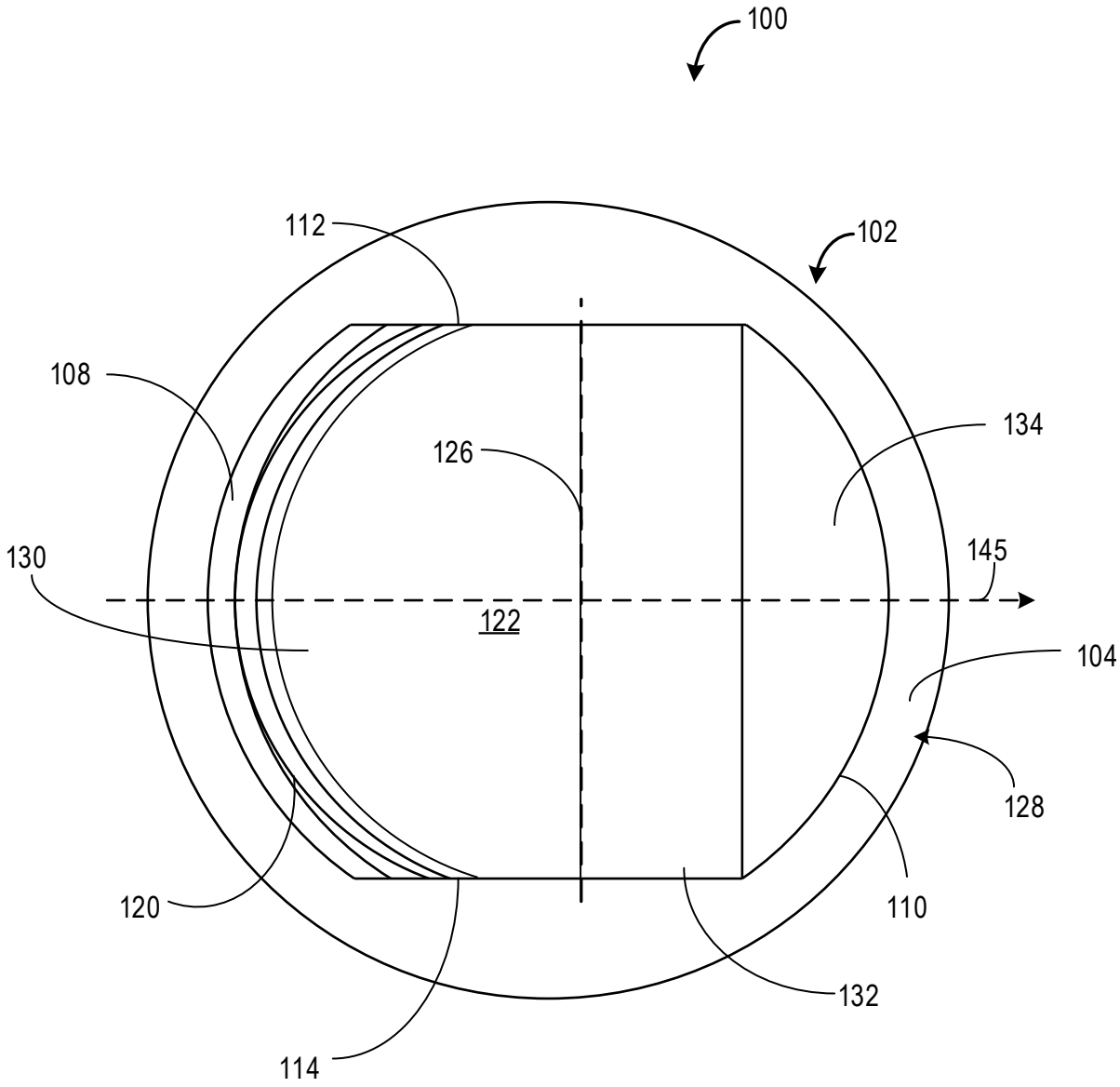


FIG. 3

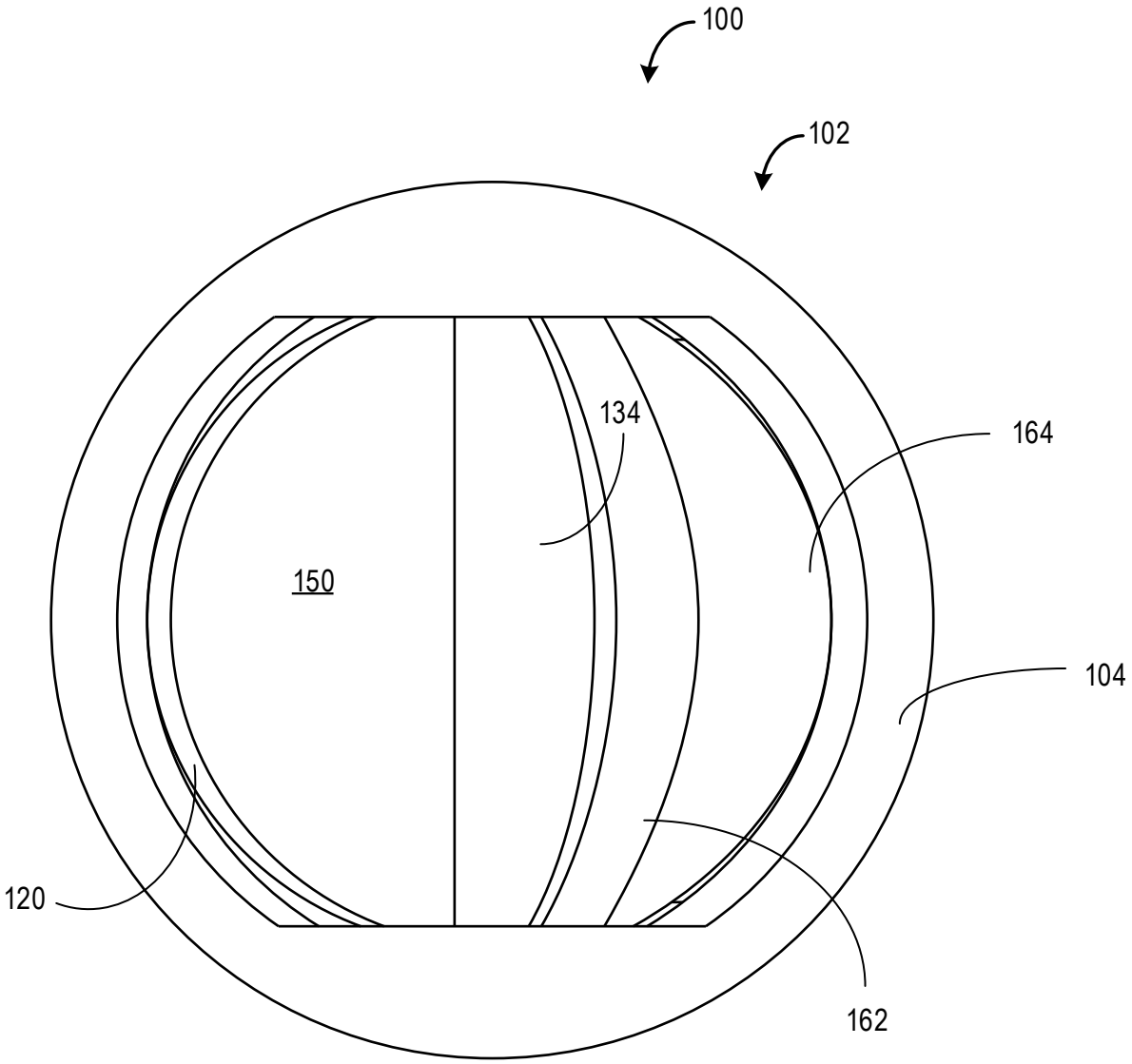
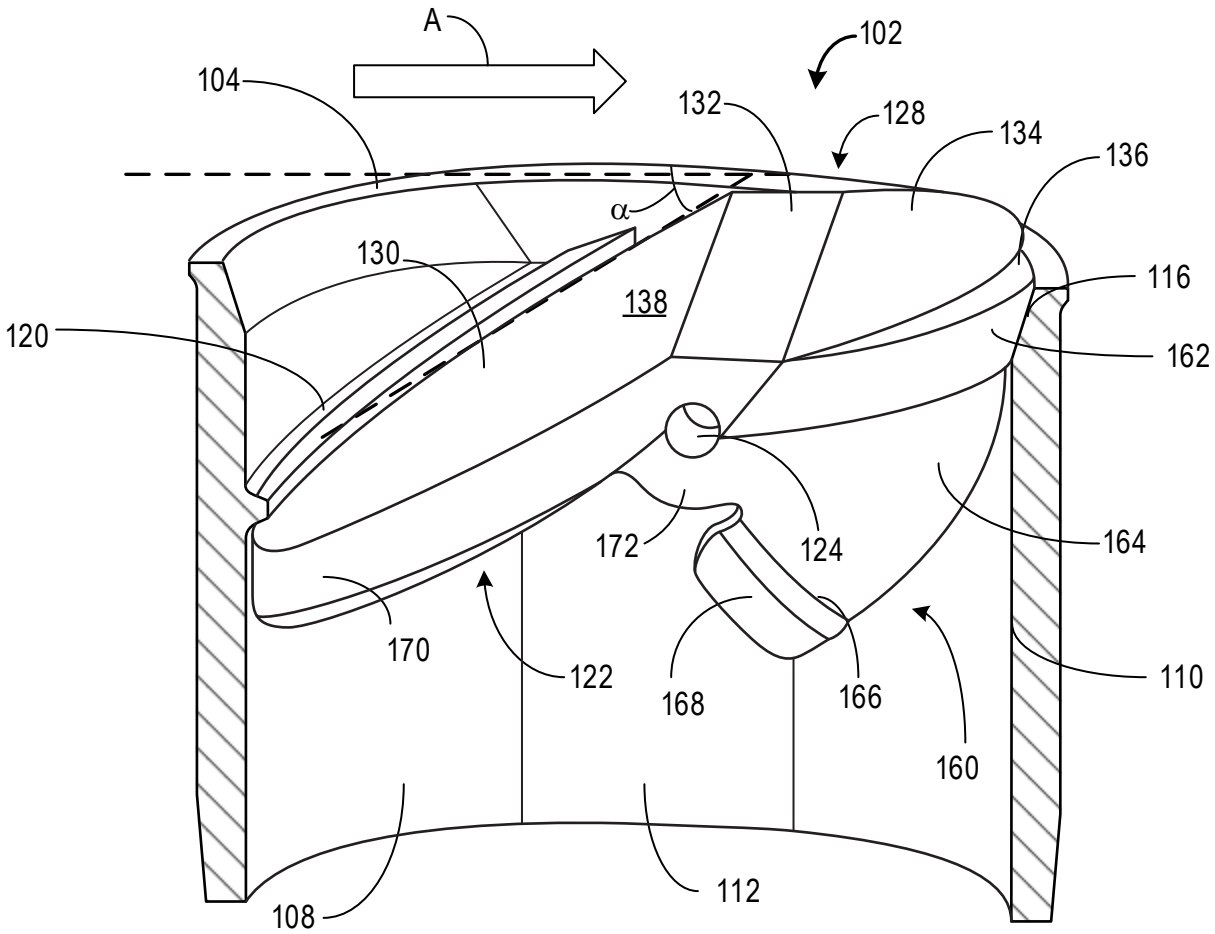


FIG. 4


A
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160
108
112

FIG. 5

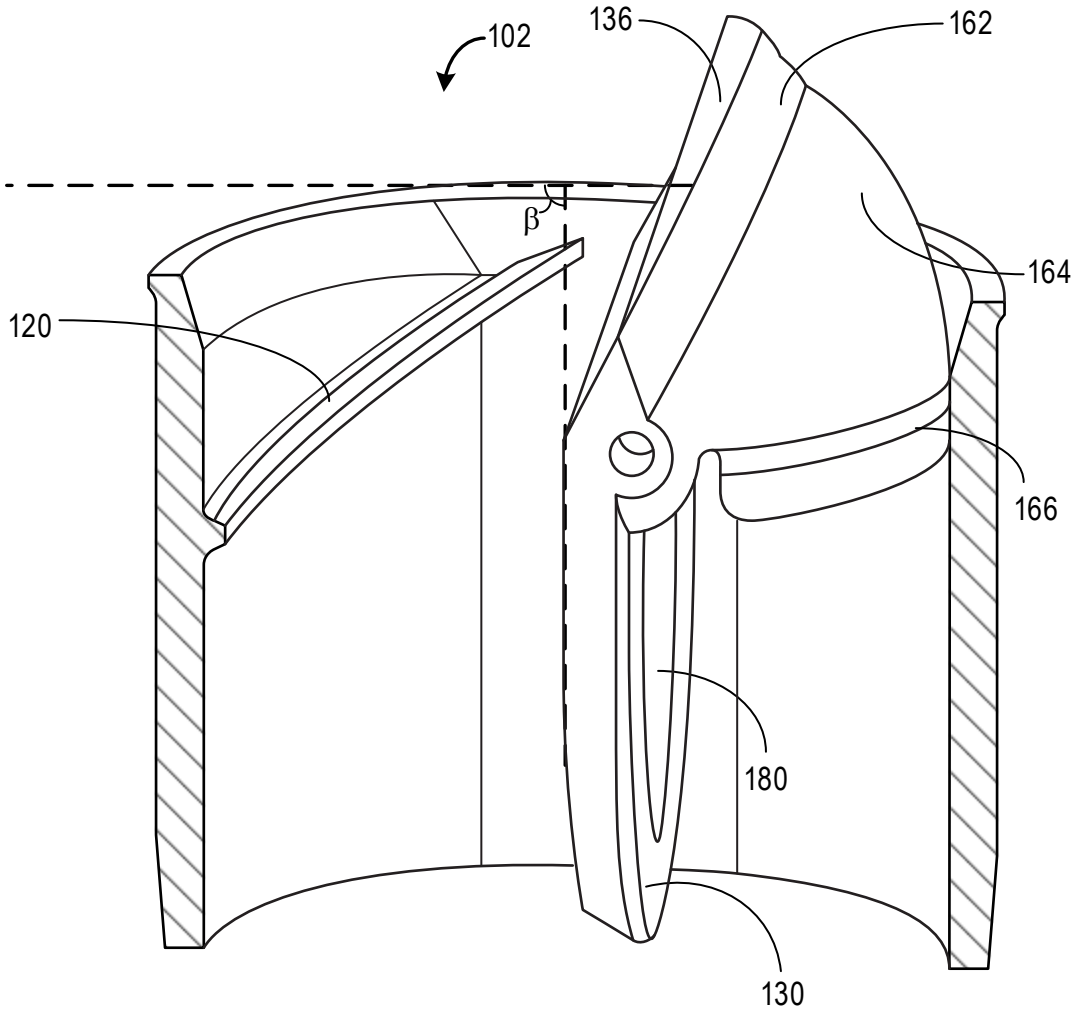

FIG. 6

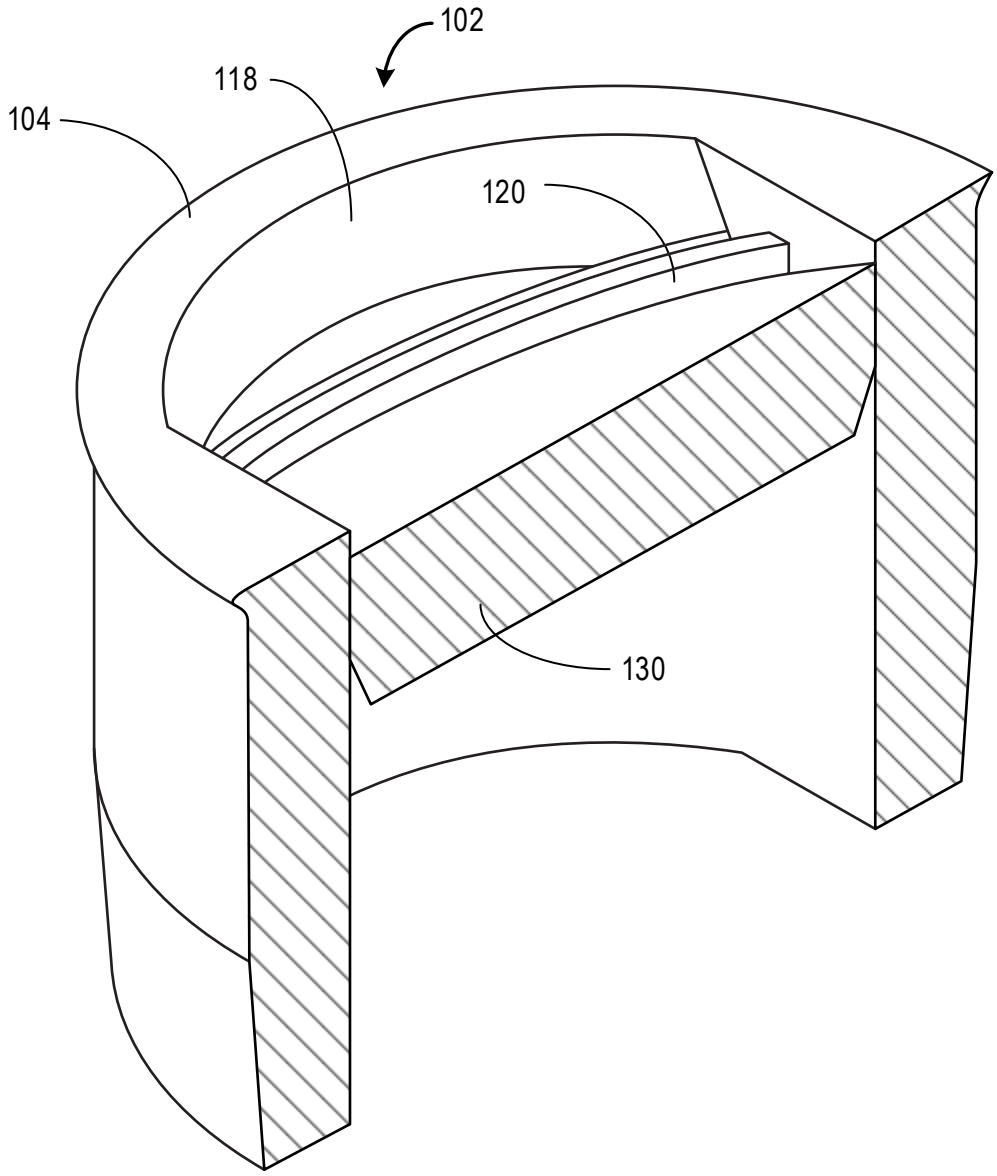

FIG. 7

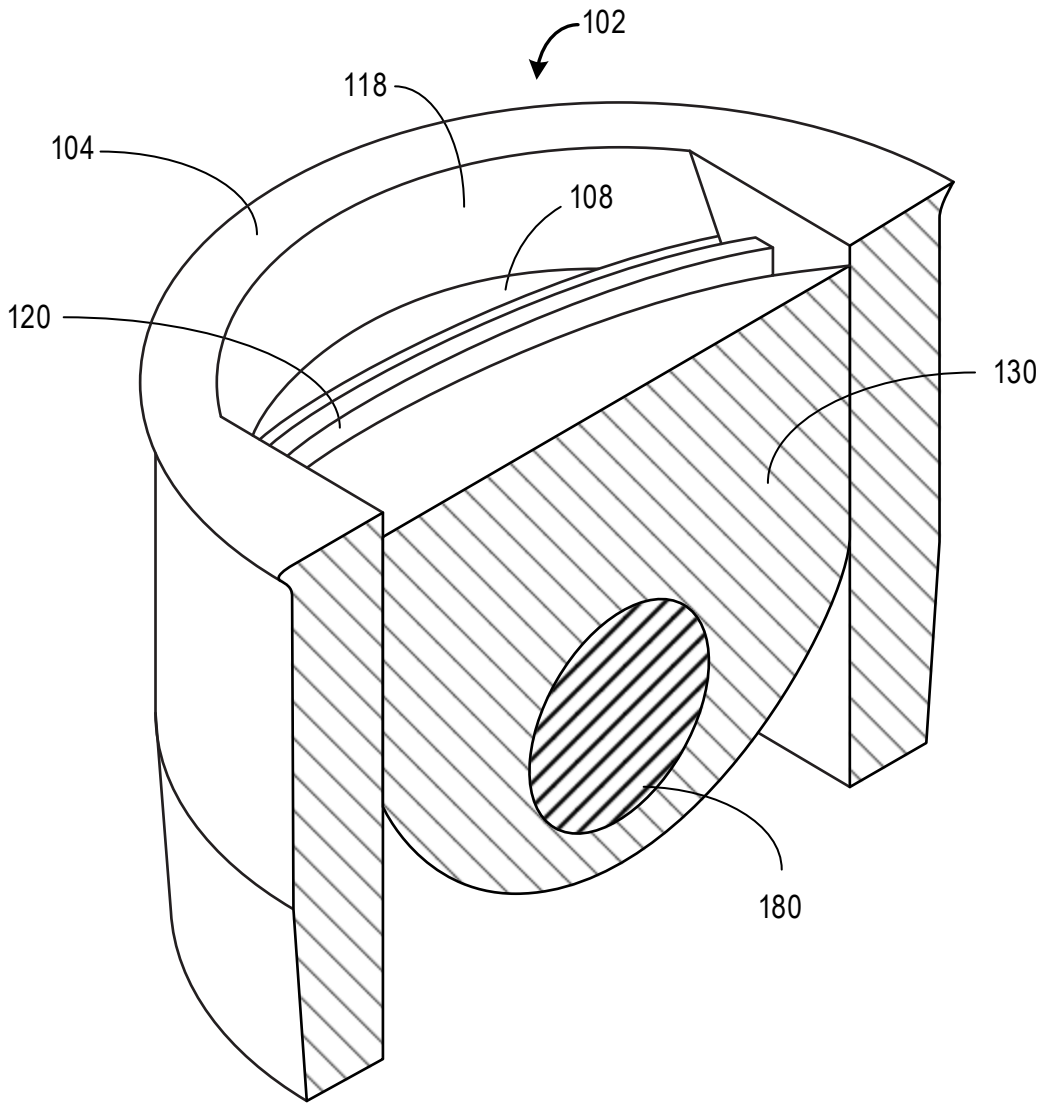

FIG. 8

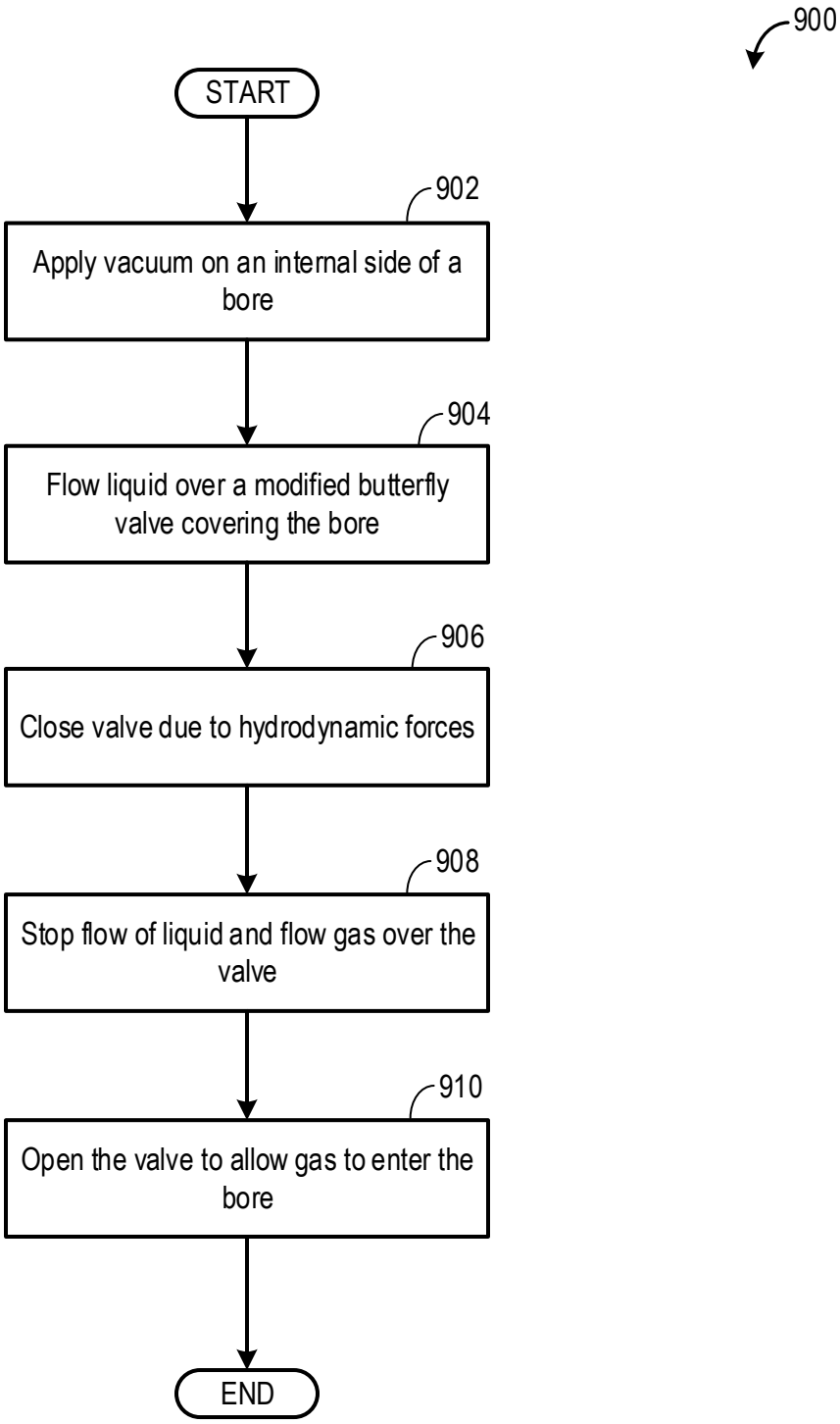
900
START
902
Apply vacuum on an internal side of a bore
904
Flow liquid over a modified butterfly valve covering the bore
906
Close valve due to hydrodynamic forces
908
Stop flow of liquid and flow gas over the valve
910
Open the valve to allow gas to enter the bore
END

FIG. 9