

US010385741B2

(12) **United States Patent**  
**Petridis et al.**

(10) **Patent No.:** **US 10,385,741 B2**  
(45) **Date of Patent:** **Aug. 20, 2019**

(54) **OIL SYSTEM WITH CLOG RESISTANT OIL FILTER**

*B01D 2201/605* (2013.01); *F01M 2001/023* (2013.01); *F01M 2001/0238* (2013.01); *F01M 2001/0246* (2013.01)

(71) Applicant: **Ford Global Technologies, LLC**,  
Dearborn, MI (US)

(58) **Field of Classification Search**  
CPC .. *F01M 1/10*; *F01M 1/02*; *F01M 1/16*; *F01M 2001/023*; *F01M 2001/0238*; *F01M 2001/0246*; *B01D 35/005*; *B01D 35/30*; *F16N 39/06*  
See application file for complete search history.

(72) Inventors: **Anthemios Petridis**, Bishop's Stortford (GB); **Gautam Chatterji**, Basildon (GB)

(73) Assignee: **Ford Global Technologies, LLC**,  
Dearborn, MI (US)

(56) **References Cited**

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

U.S. PATENT DOCUMENTS

2006/0104823 A1 5/2006 Hunter et al.  
2013/0251570 A1 9/2013 Tanasuca et al.  
(Continued)

(21) Appl. No.: **15/873,821**

FOREIGN PATENT DOCUMENTS

(22) Filed: **Jan. 17, 2018**

EP 2918799 A1 9/2015  
JP H0777174 A 3/1995

(65) **Prior Publication Data**

US 2018/0202330 A1 Jul. 19, 2018

OTHER PUBLICATIONS

(30) **Foreign Application Priority Data**

Jan. 19, 2017 (GB) ..... 1700951.5

Intellectual Property Office of the United Kingdom, Combined Search and Examination Report Issued in Application No. GB1700951.5, dated Mar. 13, 2017, South Wales, 7 pages.  
(Continued)

(51) **Int. Cl.**

*F01M 1/10* (2006.01)  
*B01D 35/30* (2006.01)  
*F01M 1/02* (2006.01)  
*F01M 1/16* (2006.01)  
*B01D 35/00* (2006.01)  
*F16N 13/04* (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... *F01M 1/10* (2013.01); *B01D 35/005* (2013.01); *B01D 35/30* (2013.01); *F01M 1/02* (2013.01); *F01M 1/16* (2013.01); *F16N 13/04* (2013.01); *F16N 13/10* (2013.01); *F16N 39/06* (2013.01); *B01D 2201/302* (2013.01);

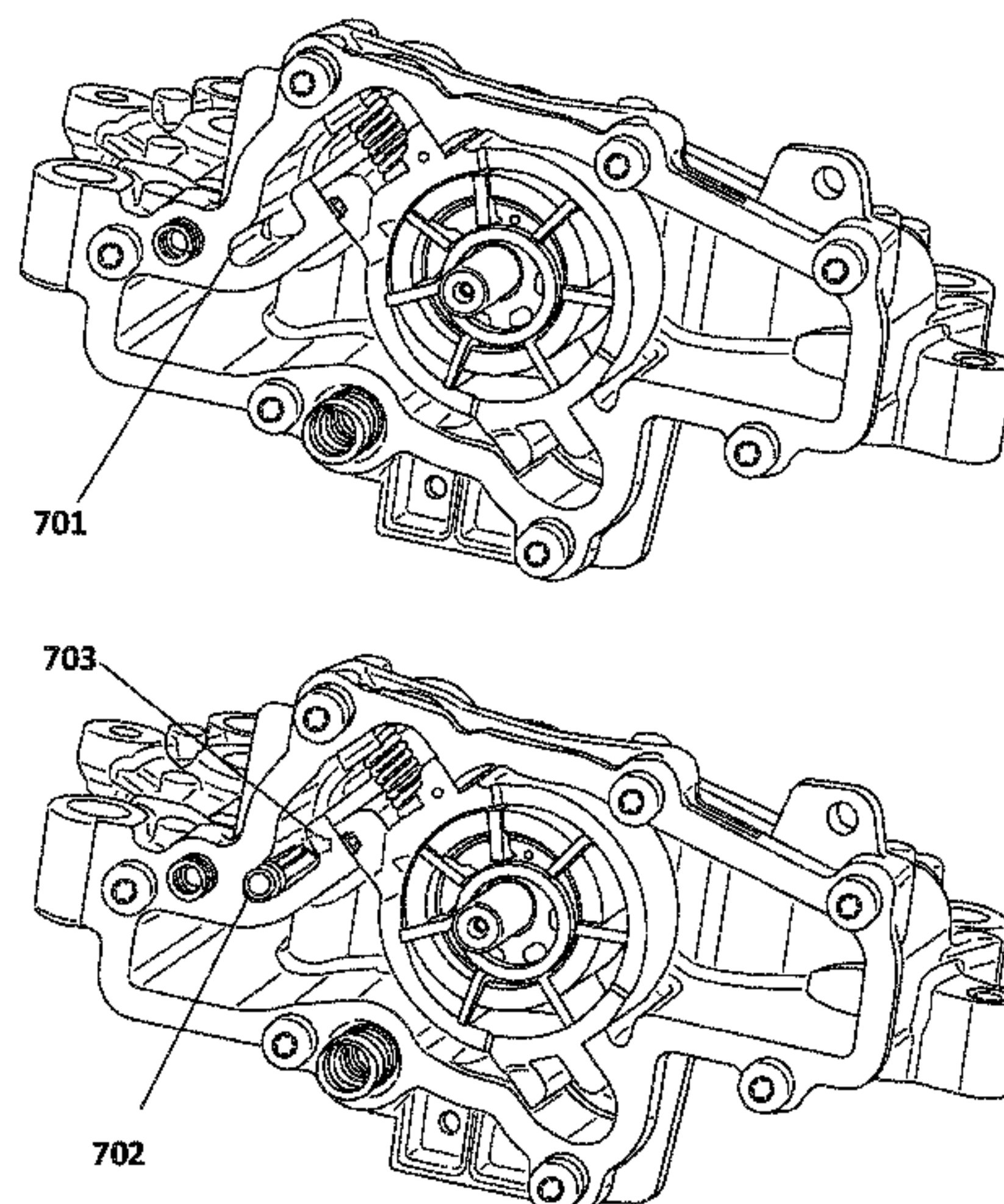
*Primary Examiner* — Jacob M Amick

(74) *Attorney, Agent, or Firm* — Julia Voutyras; McCoy Russell LLP

(57) **ABSTRACT**

Systems are provided for an oil system including a filter with a large surface area. In one example, a system may include an oil filter with a prismatic shape. This shape may include a filter surface area greater than an inlet area of an oil port and the filter surface area may also be located a distance away from the oil port.

**20 Claims, 12 Drawing Sheets**



- (51) **Int. Cl.**  
*F16N 13/10* (2006.01)  
*F16N 39/06* (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0255617 A1\* 10/2013 Kawamata ..... F04B 7/00  
123/188.9  
2015/0218983 A1 8/2015 Watanabe et al.

OTHER PUBLICATIONS

European Patent Office, Extended European Search Report Issued in  
Application No. 18152048.7, dated Jun. 8, 2018, Germany, 8 pages.

\* cited by examiner

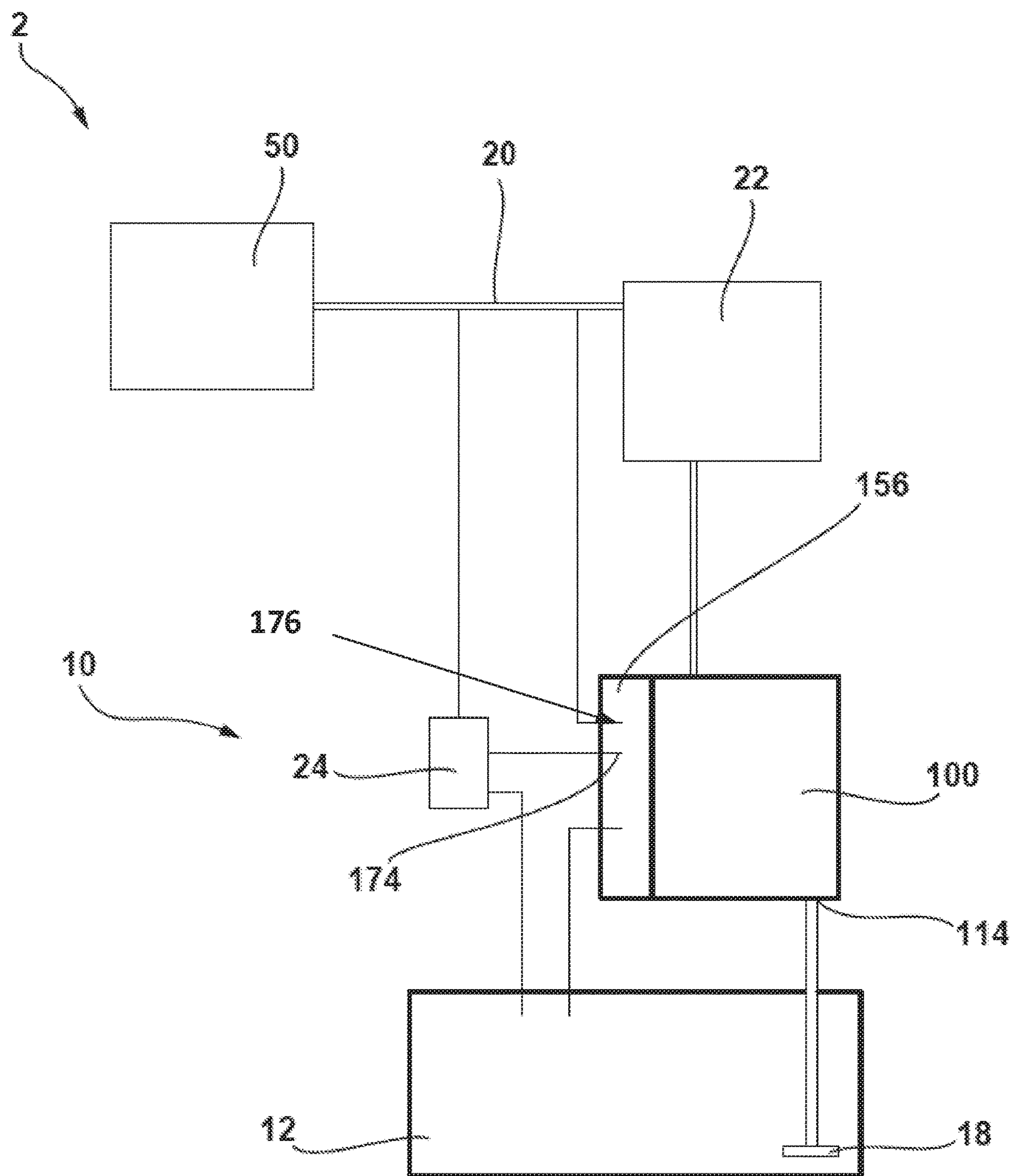


FIG. 1

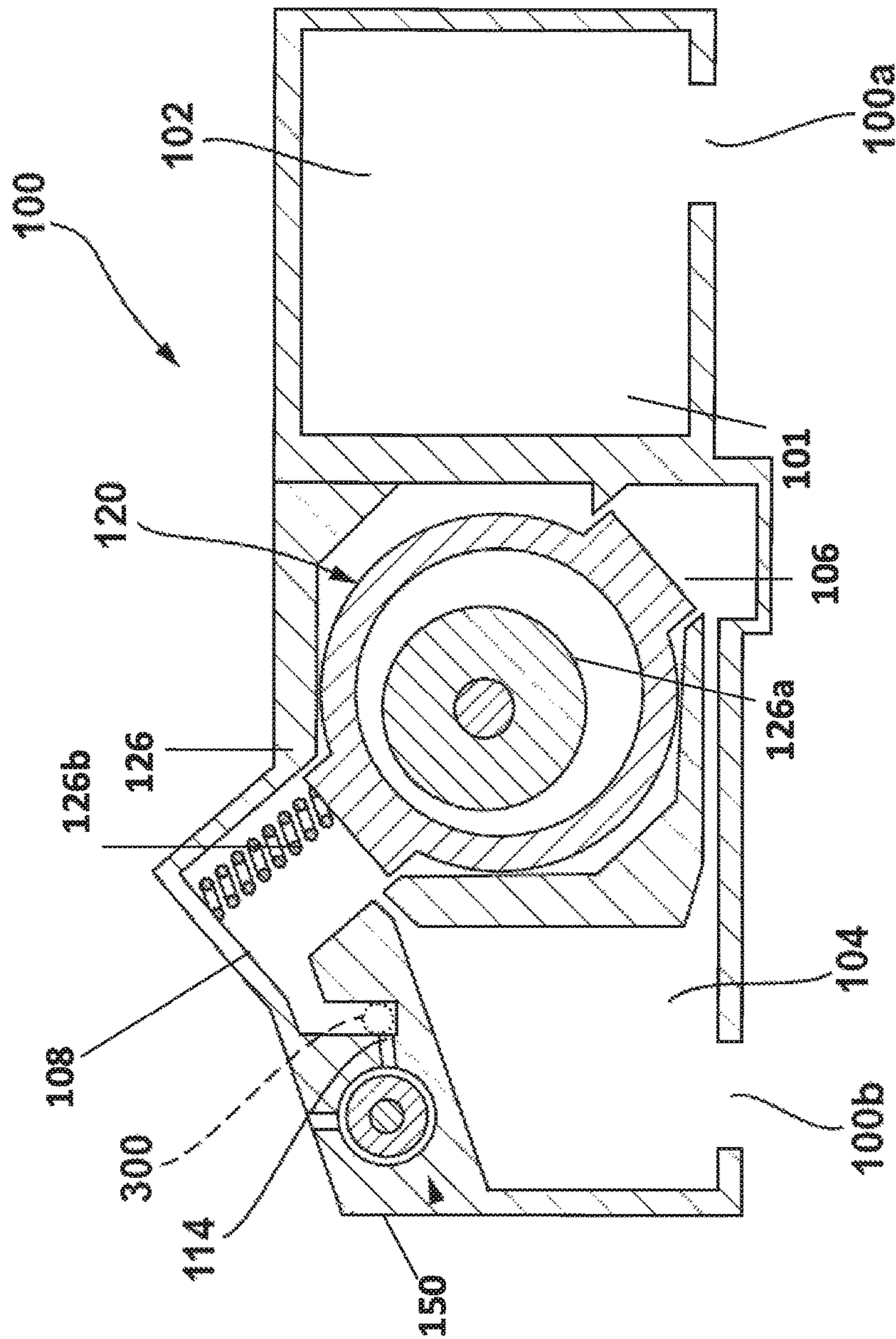


FIG. 2A



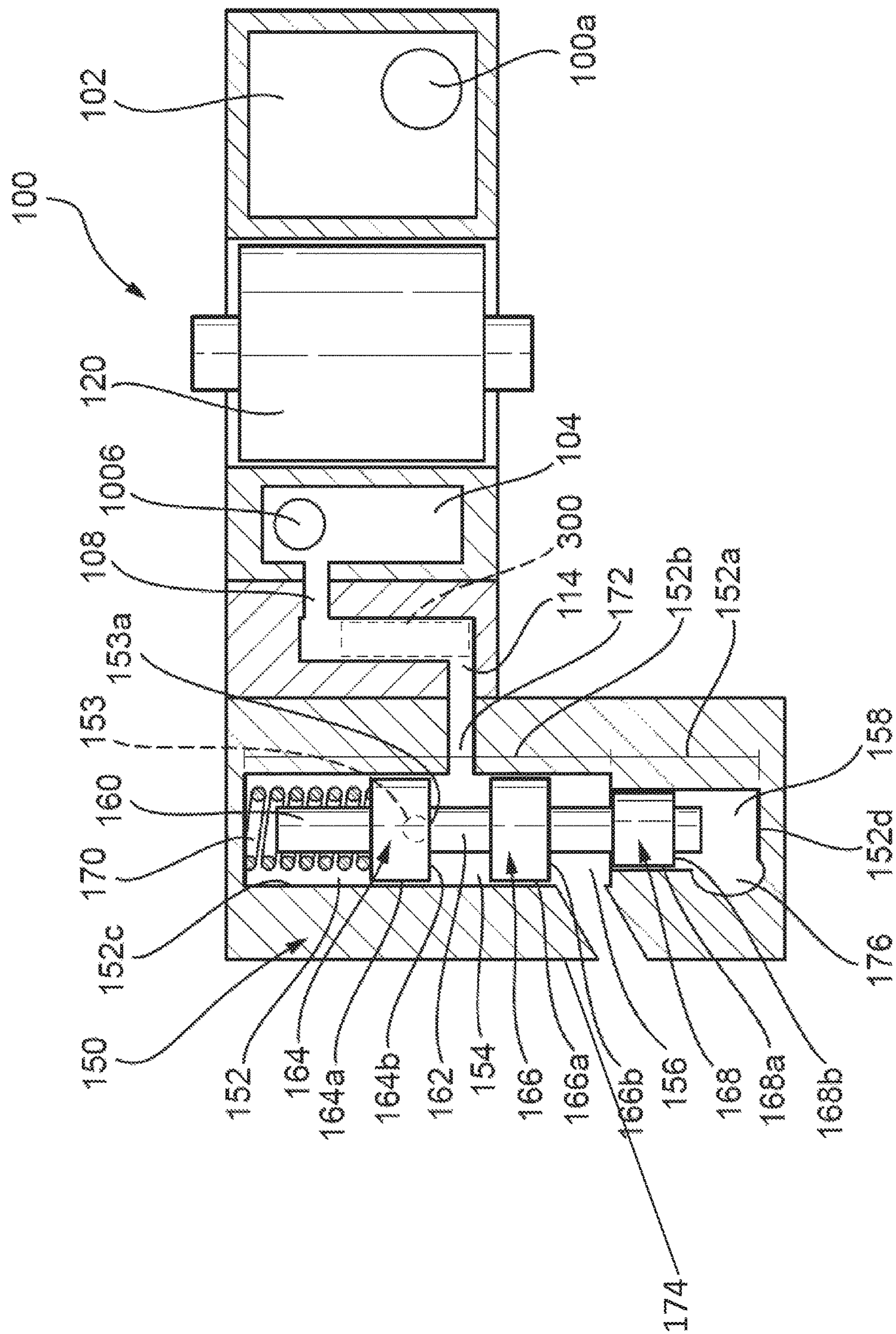


Fig. 2B

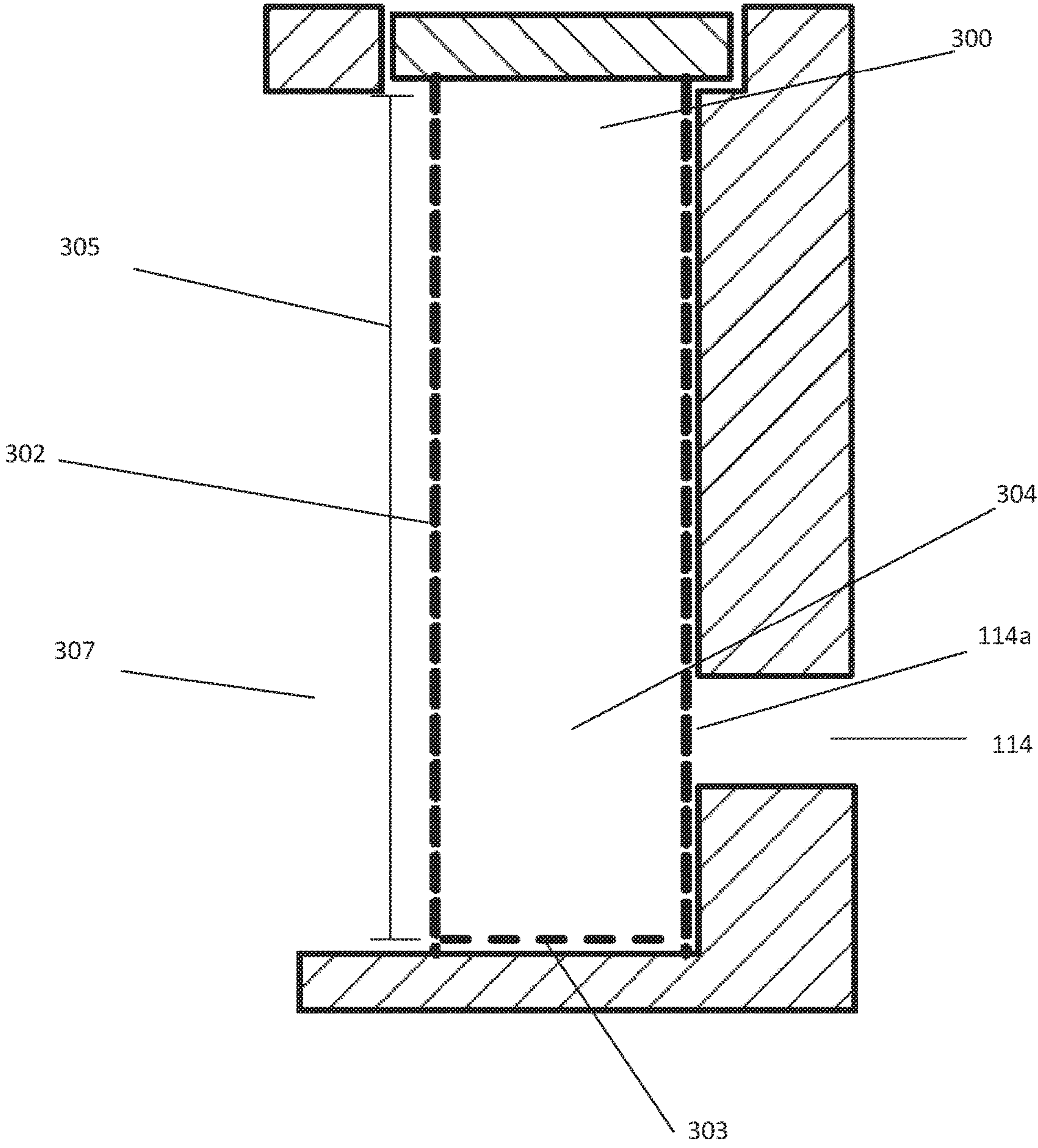


FIG. 3A

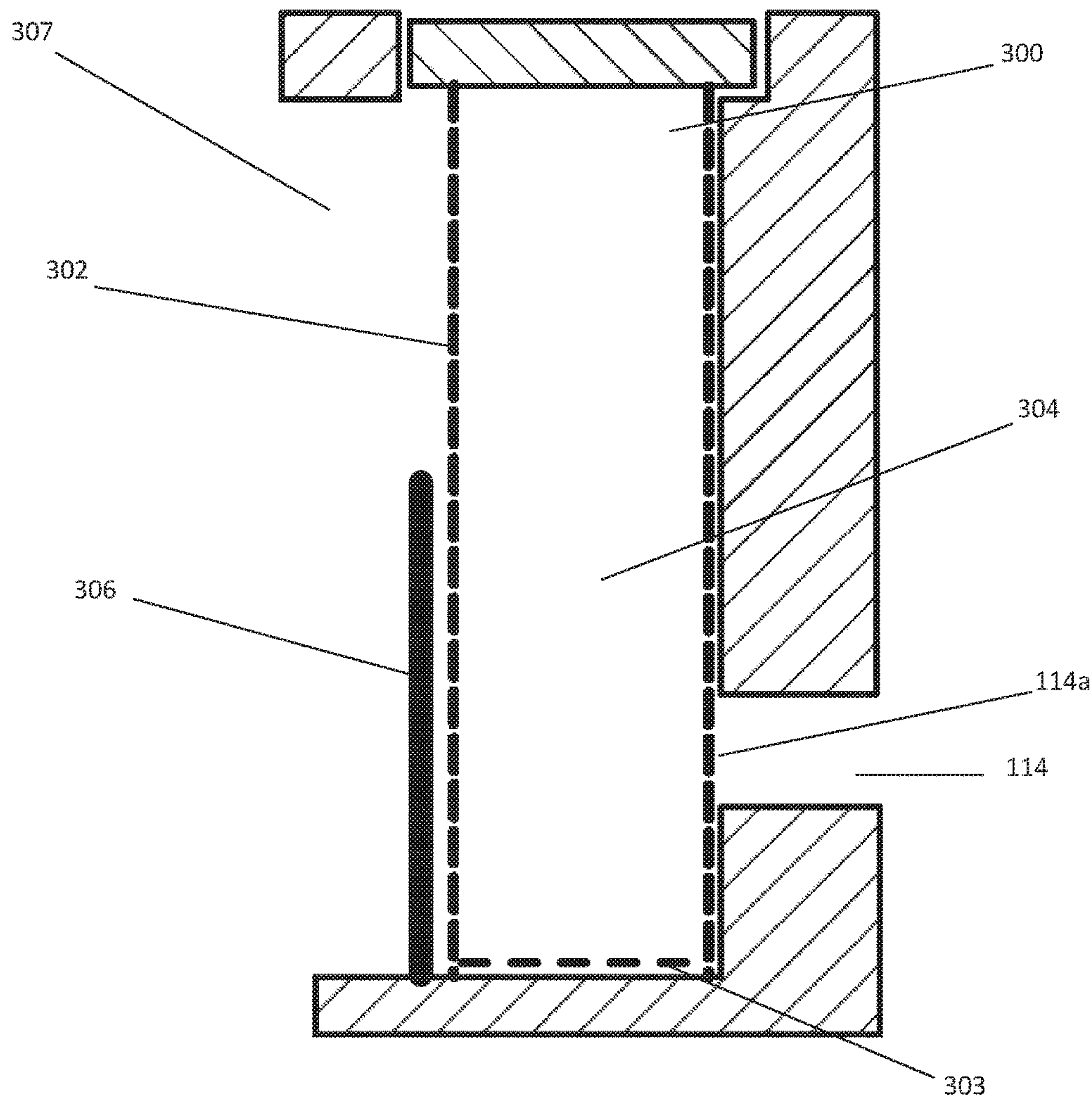


FIG. 3B



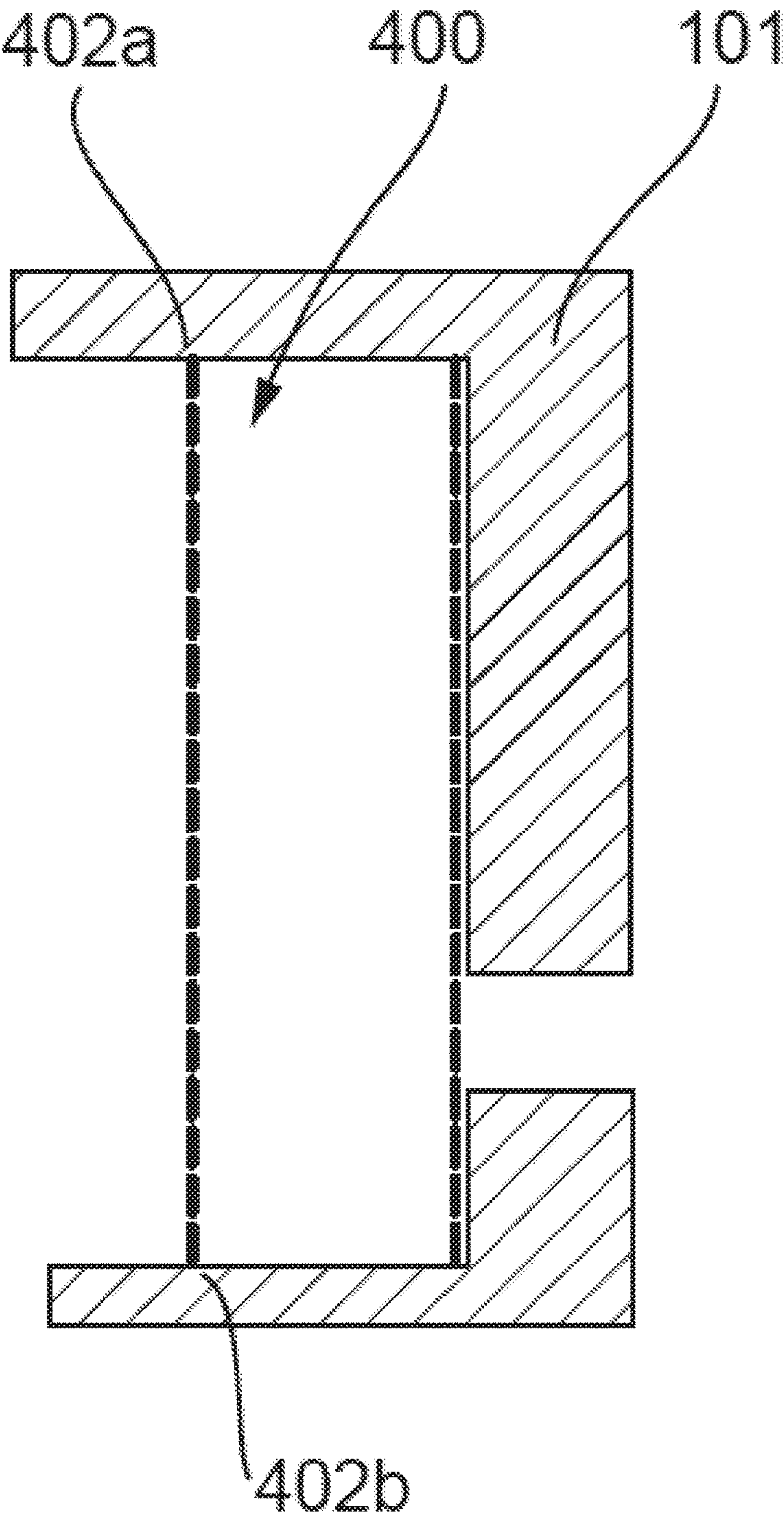


FIG. 4



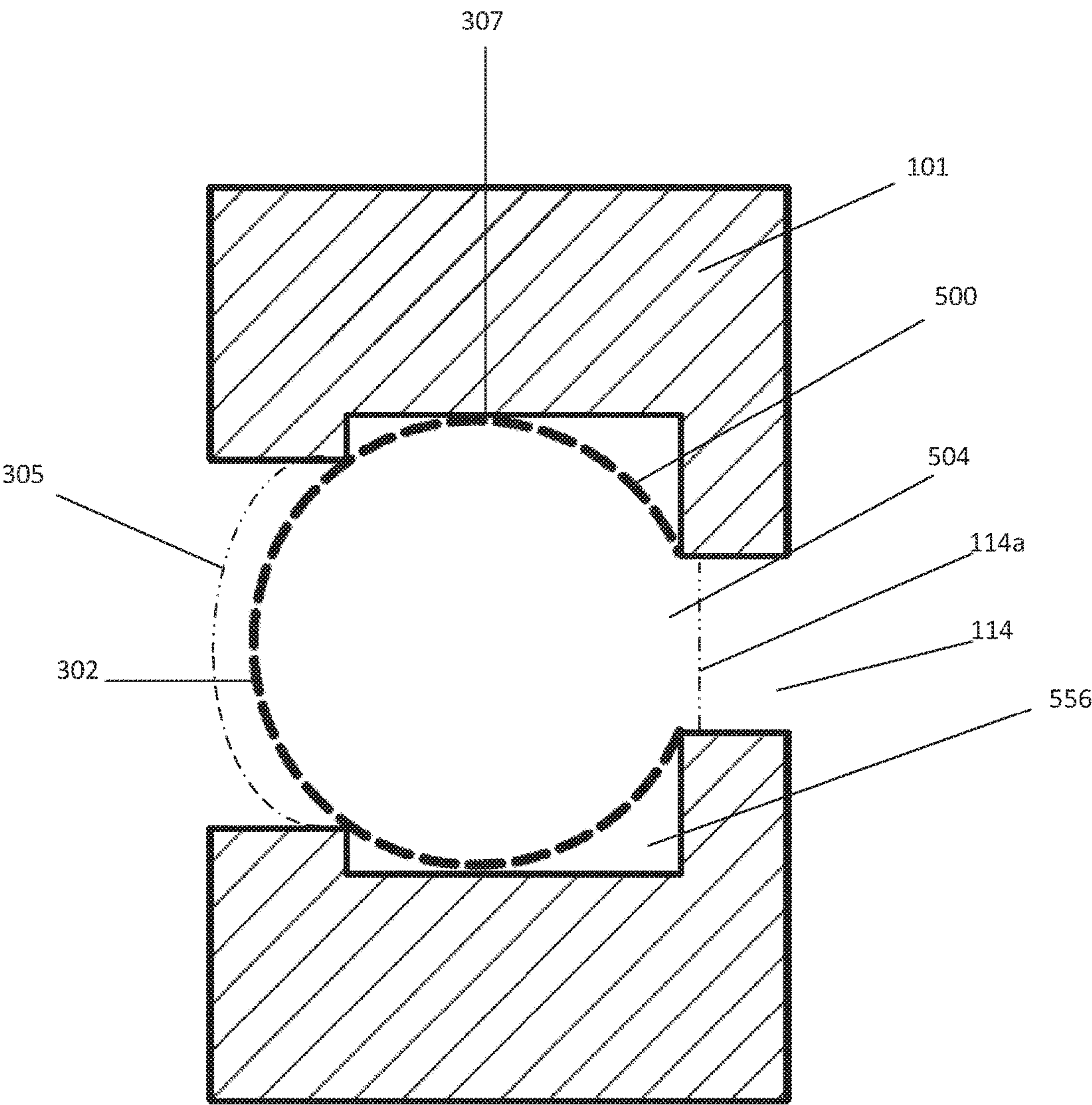


FIG. 5

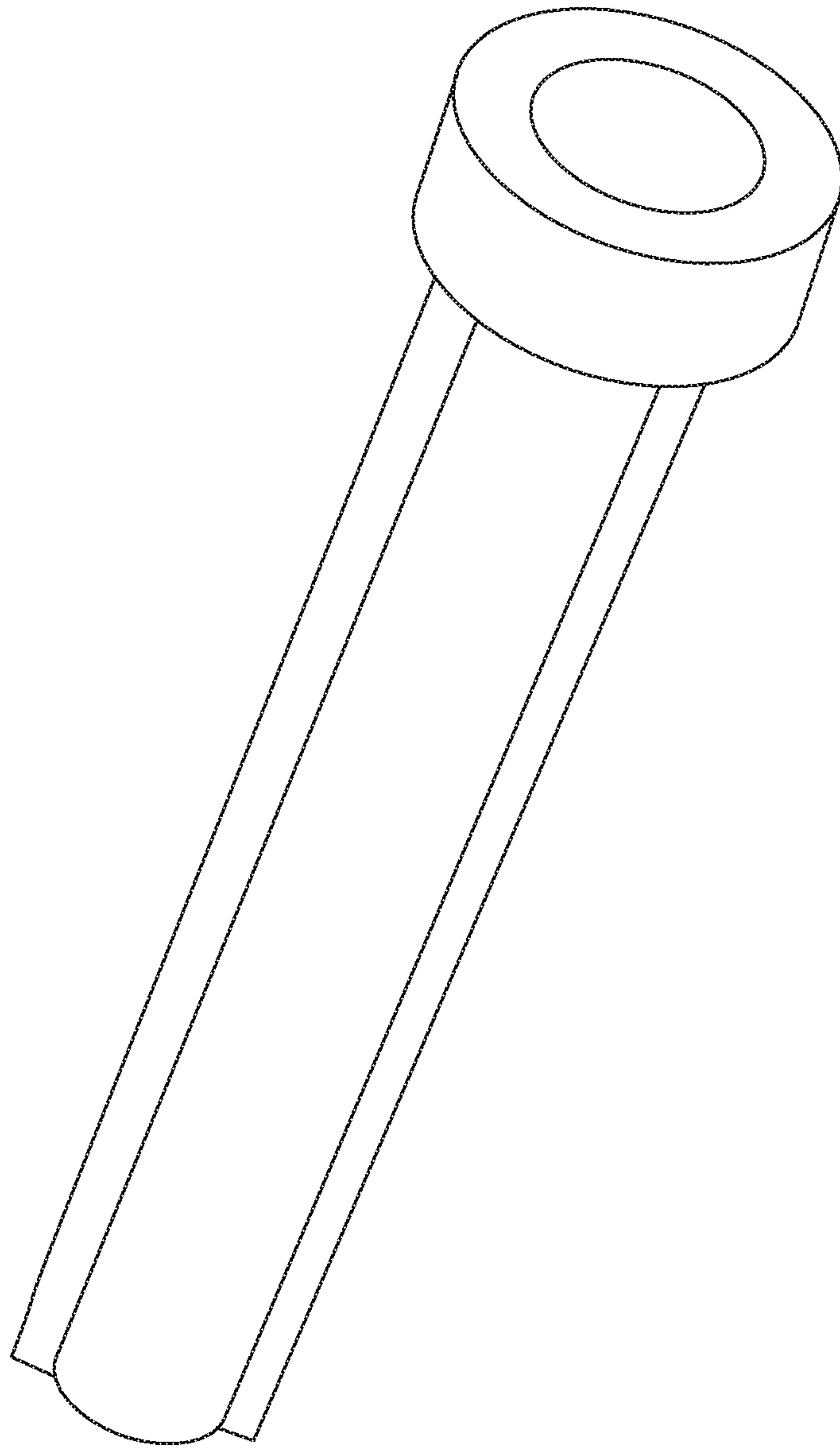


FIG. 6

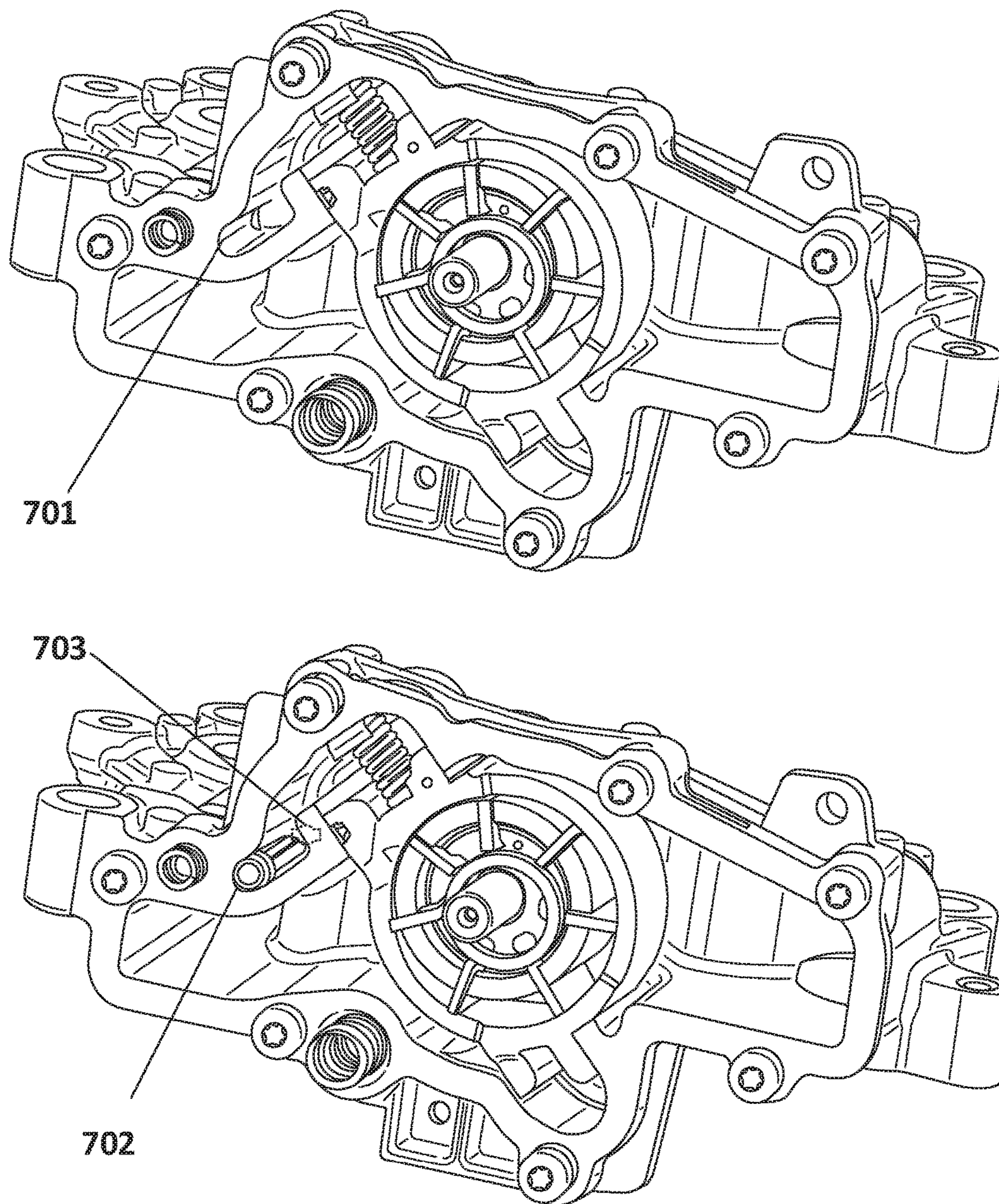


FIG. 7



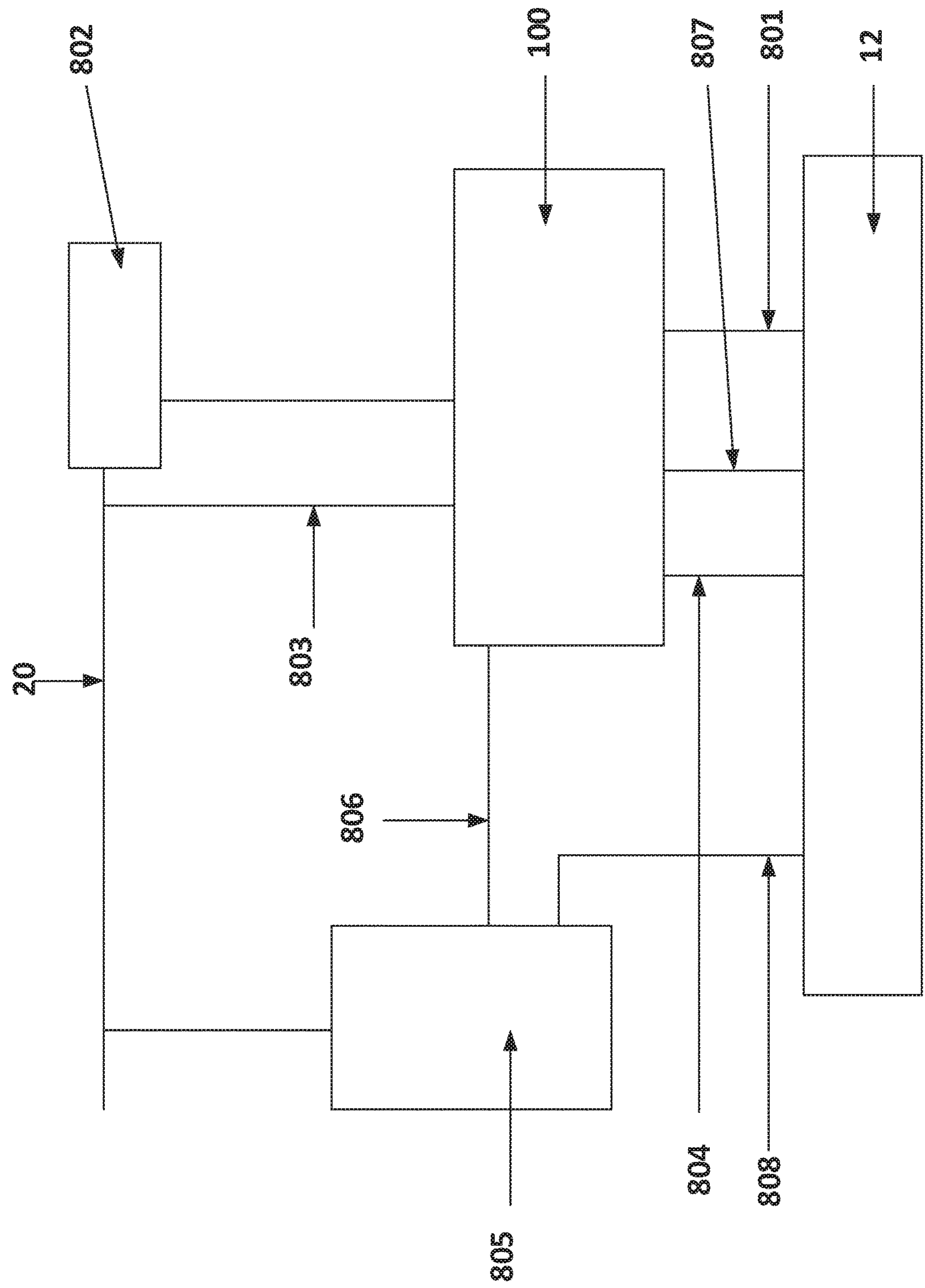


FIG. 8

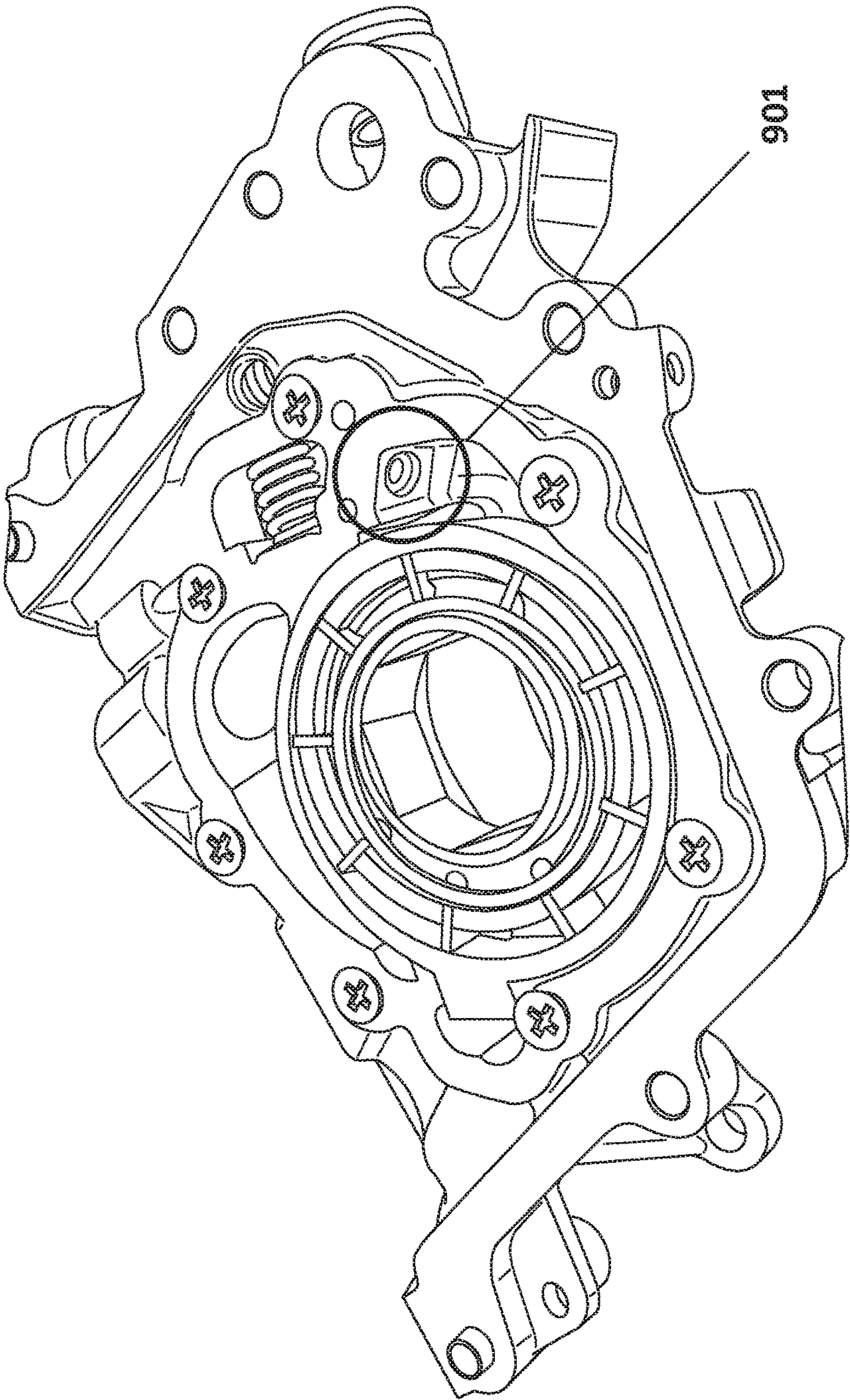


FIG. 9

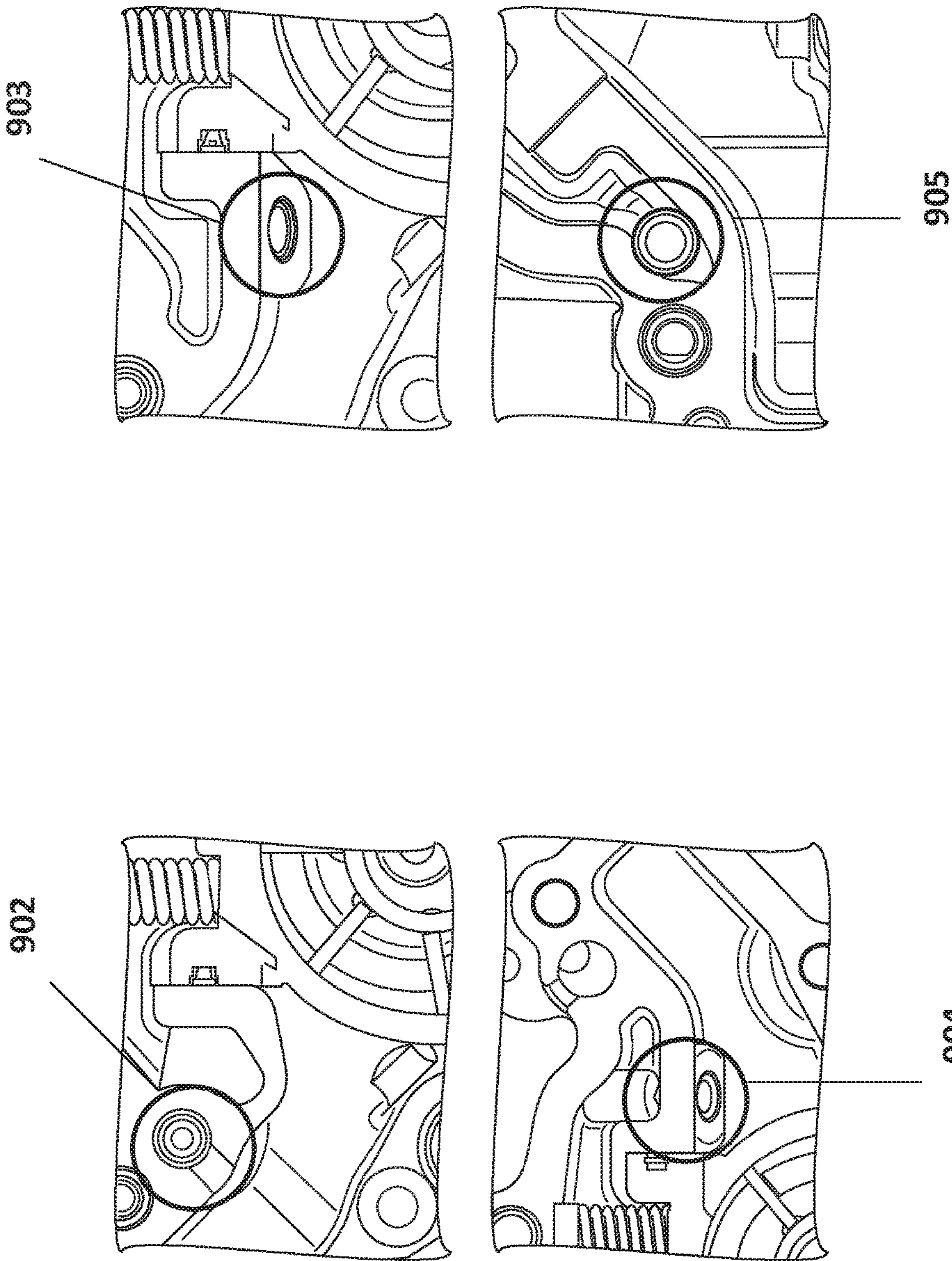


FIG. 10



## 1

**OIL SYSTEM WITH CLOG RESISTANT OIL FILTER****CROSS REFERENCE TO RELATED APPLICATION**

This application claims priority to Great Britain Patent Application No. 1700951.5, filed Jan. 19, 2017. The entire contents of the above-referenced application are hereby incorporated by reference in its entirety for all purposes.

**FIELD**

The present description relates generally to methods and systems for oil filters, oil pumps and variable displacement oil pumps.

**BACKGROUND/SUMMARY**

Oil systems for motor vehicles typically comprise an oil pump configured to circulate oil from an oil sump of the engine to pressure lubricated components of the engine. The components require a pressurized oil feed in order to cool and lubricate the engine components. The oil pump may be a fixed displacement oil pump configured such that the pressure of oil output by the pump varies according to a running speed of an engine of the motor vehicle. Alternatively, the oil pump may be a variable displacement oil pump configured such that the pressure of oil output by the pump is substantially maintained within preset limits independent of the engine running speed.

The variable displacement oil pump may comprise a pressure regulation mechanism configured to vary the displacement of the oil pump in order to regulate the pressure of oil output by the pump. It is desirable to ensure that the pressure regulation mechanism of the pump continues operating effectively throughout the life of the oil pump to ensure that the oil pump continues to supply oil to the components.

The inventors herein have recognized potential issues with conventional oil filters. Oil filters remove harmful contaminants from oil to protect components of the oil system from wear or degradation. Oil filters may become clogged by these contaminants and not allow oil to pass. Oil may not be able to flow through a filter if an alternative path around clogging particulates is not available. One example of a conventional filter is a circular filter within a circular oil passage. Particulates may build up on the filter blocking the entire passage and preventing flow of oil.

In one example, the issues described above may be addressed by a system for a variable displacement oil pump for a motor vehicle, the oil pump comprising: a mechanism for adjusting the displacement of the pump, the mechanism including an oil port formed in an internal wall of the pump, the oil port having a filter wherein a filter surface area of the filter is spaced apart from an inlet of the oil port, wherein the filter surface area is larger than an area of the inlet, wherein the filter is substantially prism shaped and wherein the filter surface area forms an outer surface of the prism. In this way, the larger surface area of the filter surface area and the prism shape of the filter allow for oil to pass around possible particulates and into the inlet.

As one example, a rectangular prism shaped oil filter is positioned over an oil port. The filter has a greater surface area than the inlet port. The prism shape also allows oil to flow through the interior of the prism shape. Thus, if particulates clog part of the filter surface area, oil can flow through a different surface area, into the space between the

## 2

filter surface area and inlet, and into the inlet. Therefore, the filter may still allow oil to flow in the presence of clogging particulates.

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**

FIG. 1 is a schematic view of a lubricating oil system for a motor vehicle.

FIG. 2A is a schematic sectional views of an oil pump.

FIG. 2B is a schematic sectional views of an oil pump.

FIG. 3A shows an embodiment of a prism shaped oil filter.

FIG. 3B show operation of a prism shaped oil filter with accumulation of contaminants on the oil filter.

FIG. 4 is a schematic sectional view of an oil filter with a filter surface area greater than a port inlet area.

FIG. 5 is a schematic sectional view of an oil filter with longitudinal slot.

FIG. 6 is a view of a cylindrical embodiment of an oil filter.

FIG. 7 is a view of an embodiment of a mounting location of an oil filter in variable displacement pump.

FIG. 8 is an oil circuit diagram of a potential embodiment.

FIG. 9 is a view of a conventional oil filter and mounting location.

FIG. 10 is a view of various mounting locations within oil pumps.

FIGS. 2-7, 9 and 10 are shown approximately to scale.

**DETAILED DESCRIPTION**

The following description relates to various embodiments of systems including oil filters that allow oil flow around clogging particulates. Features of these oil filters will also be described such as the oil filter shape, filter surface area, distance between filter surface area and inlet, and orientation of the filter. The figures will also demonstrate embodiments of the filter and features of the embodiments.

FIGS. 1-10 show example configurations with relative positioning of the various components. If shown directly contacting each other, or directly coupled, then such elements may be referred to as directly contacting or directly coupled, respectively, at least in one example. Similarly, elements shown contiguous or adjacent to one another may be contiguous or adjacent to each other, respectively, at least in one example. As an example, components laying in face-sharing contact with each other may be referred to as in face-sharing contact. As another example, elements positioned apart from each other with a space there-between and no other components may be referred to as such, in at least one example. As yet another example, elements shown above/below one another, at opposite sides to one another, or to the left/right of one another may be referred to as such, relative to one another. Further, as shown in the figures, a topmost element or point of element may be referred to as a "top" of the component and a bottommost element or point of the element may be referred to as a "bottom" of the component, in at least one example. As used herein, top/bottom, upper/lower, above/below, may be relative to a



vertical axis of the figures and used to describe positioning of elements of the figures relative to one another. As such, elements shown above other elements are positioned vertically above the other elements, in one example. As yet another example, shapes of the elements depicted within the figures may be referred to as having those shapes (e.g., such as being circular, straight, planar, curved, rounded, chamfered, angled, or the like). Further, elements shown intersecting one another may be referred to as intersecting elements or intersecting one another, in at least one example. Further still, an element shown within another element or shown outside of another element may be referred as such, in one example.

With reference to FIG. 1, an embodiment of an engine 2 comprises a lubricating oil system 10 and one or more pressure lubricated components 50 requiring a feed of lubricating oil. The oil system 10 comprises an oil sump 12 configured to store oil when the oil is not being circulated around the engine. The oil system 10 also includes an oil pump 100 configured to pump the oil from the oil sump 12 to the pressure lubricated components 50. The oil pump 100 may be driven by the engine using a gear, belt or other form of mechanical drive.

An oil pick-up 18 is arranged within the oil sump 12 and configured to allow the oil to be drawn into an inlet of the oil pump. In some arrangements, the oil pick-up 18 may comprise a mesh, generally a relatively coarse mesh, configured to prevent debris within the oil sump being drawn into the pump 100.

The oil pump 100 may be a variable displacement pump. The oil pump 100 may comprise a displacement control mechanism configured to adjust the displacement of the pump according to an outlet pressure of the pump in order to regulate the outlet pressure.

A bulk flow of oil pumped by the pump 100 leaves the pump via an outlet. The oil leaving the pump may be delivered to an oil gallery 20 of the engine 2. The oil gallery 20 supplies oil to each of the pressure lubricated components 50 of the engine.

In an embodiment featuring a variable displacement pump, a third inlet 176, described further in reference to FIG. 2B, may be in fluid communication with the oil gallery 20. Hence the third inlet 176 may receive oil at a pressure substantially equal to the outlet pressure of the oil pump 100. A second inlet 174 may be in fluid communication with a pressure control valve 24. The pressure control valve 24 may provide pressurized oil to the second inlet 176 when it is desirable to reduce the pressure of oil being supplied by the oil pump, as described below.

The mesh provided at the oil pick-up 18 may have a large mesh size to prevent large pieces of debris from being drawn into the pump. Before the oil is circulated around the engine, it is desirable for the oil to be filtered to remove smaller solid contaminants. These contaminants might otherwise build up within and damage the pressure lubricated components 50 of the engine 2.

The oil system 10 may comprise a pressure control valve. The pressure control valve receives a supply of oil from the oil gallery 20. The pressure control valve 24 is operable to provide pressurized oil to the second inlet 174. Oil provided to the second inlet 174 may enter a second regulation pressure chamber 156. Providing pressurized oil to the second inlet therefore may have the effect of increasing the outlet pressure of the pump. Providing pressurized oil to the inlet therefore leads to a reduction in the outlet pressure to which the pump is regulated.

When the engine is operating at a high speed or under a high load, it is desirable for the oil pump 100 to provide oil at a high pressure. Conversely, when the engine is operating at a low speed or load, it is desirable to reduce the pressure of oil supplied by the pump 100. A reduction in pressure may improve the fuel economy of the engine.

The oil system 10 may further comprise an oil filter 22. The oil leaving the outlet of the pump may be passed through the oil filter 22 before reaching the oil gallery 20. Oil filter 22 removes potentially damaging or wear inducing solid contaminants present within the oil leaving the oil pump 100.

As described above, the oil pick-up 18 is provided with a coarse mesh configured to prevent large pieces of debris from entering the oil pump 100. The oil filter 22 is provided to remove smaller pieces of debris and solid contaminants from the oil that passed through the pick-up mesh.

In some oil systems, oil passing through a port such as oil port 114 into the first pressure regulation chamber may not have been passed through the oil filter 22 since leaving the oil sump 12. Any solid contaminants present within the oil passing through the port 114 may settle into pumping or valve components which may be degraded or rendered inoperable by a buildup of contaminants. Therefore, filtering oil before it enters these components is desirable.

With reference to FIGS. 2A and 2B, an oil pump 100 according to arrangements of the present disclosure comprises a housing 101 defining an inlet chamber 102 and an outlet chamber 104, and a pump portion 120. Oil entering the pump via the inlet 100a is received within the inlet chamber 102. The oil within the inlet chamber 102 is drawn into the pump portion 120 and the pressure of the oil is increased before the oil is delivered into the outlet chamber. The outlet 100b of the oil pump 100 is provided in the outlet chamber 104.

FIG. 2A depicts an embodiment of a variable displacement oil pump with a rotor. The pump portion 120 may comprise a rotor rotatable within a compression volume. The pump 100 may also comprise a plurality of stators (not shown) arranged within the compression volume. The rotor and stators are configured such that rotation of the rotor within the compression volume increases the pressure of the oil within the compression volume and pumps the oil into the outlet chamber 104 of the pump 100. Rotation of the rotor is driven by the engine of the motor vehicle or via a mechanical drive system, such as a gear drive or belt drive.

The pump portion 120 may also comprise a setting ring 126. The setting ring 126 is movable in order to adjust a compression volume and thereby adjust the capacity of the pump. When the pump is operating at a constant power, adjusting the capacity of the pump adjusts the outlet pressure of oil supplied by the pump. Similarly, when the power supplied to drive the pump varies, the capacity of the pump may be adjusted in order to maintain the outlet pressure of oil supplied by the pump.

FIG. 2A depicts an embodiment wherein the pump 100 may also comprise a first pressure chamber 106 and a second pressure chamber 108. The first and second pressure chambers 106 and 108 are defined by the pump housing 101. The setting ring 126 comprises a first pressure face 126a and a second pressure face 126b. As depicted in FIG. 2A, the pump 100 is configured such that the first pressure face 126a is exposed to oil within the first pressure chamber 106 and the second pressure face 106b is exposed to oil within the second pressure chamber 108. The position of the setting ring and the operation of the pump 100 is therefore determined by a difference in pressure between the first



## 5

pressure chamber **106** and second pressure chamber **108**. The pump **100** may further comprise a biasing element configured to bias the position of the setting ring. In the arrangement depicted, the position of the setting ring is biased towards the first pressure chamber **106**.

The first pressure chamber **106** and second pressure chamber **108** may be in fluid communication with the outlet chamber **104**. Hence the pressure chambers **106** and **108** may be supplied with oil at a pressure substantially equal to the outlet pressure of the pump.

FIG. 2A depicts an embodiment wherein the first pressure chamber **106** does not comprise an outlet, therefore the pressure of oil within the first pressure chamber **106** may be substantially equal to the outlet pressure of the oil pump **100**.

In contrast to first pressure chamber **106**, the second pressure chamber **108** comprises an oil port **114**. The oil port **114** allows oil to flow from the second pressure chamber **108** to the displacement control mechanism **150**. As described below, the displacement control mechanism controls the rate at which oil flows through the oil port **114**. As the rate of flow of oil through the oil port **114** increases, the pressure of oil within the second pressure chamber **108** is reduced. The operation of the displacement control mechanism **150** can thereby control the pressure of the second pressure chamber **108**.

If the pressure of oil within the second pressure chamber is reduced, the pressure force acting on the setting ring **126** at the second pressure face **126b** may also reduce. In particular, the force acting on the setting ring **126** at the second pressure face **126b** is reduced compared to the force acting on setting ring **126** at the first pressure face **126a**. A net force is therefore placed on the setting ring **126**, which moves the setting ring **126** within the pump portion **120**, adjusting the operation of the pump **100**.

With reference to FIG. 2B, an embodiment of the oil system may comprise a spool valve, having a spool cavity **152** and a spool **160** movable within the spool cavity **152**.

The spool cavity **152** may comprise a substantially cylindrical cavity formed within the spool valve **150**. The diameter of the spool cavity **152** may be constant. Alternatively, as depicted in FIG. 2B, the diameter of the spool cavity may vary. For example, a first length **152a** of the spool cavity may be a first diameter and a second length **152b** of the spool cavity may be a second diameter that is different to the first diameter.

One embodiment of spool **160** comprises a rod **162** and a plurality of pistons **164**, **166**, **168**. The pistons **164** are spaced along the length of the rod **162**. The pistons **164**, **166**, **168** may be substantially cylindrical. The shape of the pistons is configured such that a seal is formed between outer surfaces **164a**, **166a**, **168a** of the pistons and an inner surface **152c** of the spool cavity. In particular, the pistons are configured to limit the leakage of oil past the pistons **164**, **166**, **168** of the spool **160**. For example, the diameter of the pistons may substantially correspond to the diameter of the spool cavity **152** at the location of the piston. In some arrangements, the pistons may comprise one or more seals provided at the outer surfaces **164a** of the pistons in order to improve the seal between the pistons and the spool cavity **152**.

In such an embodiment, each pair of adjacent pistons defines a pressure regulation chamber, such as the first pressure regulation chamber **154**, second pressure regulation chamber **156** and third pressure regulation chamber **158**, which may be respective portions of the spool cavity provided between the pistons. Additionally, pressure regulation chambers, such as the third pressure regulation chamber **158**

## 6

may be defined between one of the pistons and an end **152d** of the spool cavity. As the pistons are configured to limit the leakage of oil past the pistons, each regulation chamber is substantially isolated from the other pressure regulation chambers.

The pistons **164**, **166**, **168** of an embodiment, each define pressure faces **164b**, **166b**, **168b** against which pressurized oil within the pressure regulation chambers **154**, **156**, **158** may act. The diameter of one or more of the pistons may differ from the diameter of one or more of the other pistons. For example, as depicted in FIG. 2B, first and second pistons **164**, **166** have a first diameter, and third piston **168** has a second diameter that is different than the first and second pistons.

For pressure regulation chambers that are defined by a pair of adjacent pistons that are the same diameter, such as the first pressure regulation chamber **154**, the forces acting on the spool **160** due to the pressure of oil within the pressure regulation chamber acting on the pressure faces of the pistons is balanced, e.g. there is no net force acting on the spool **160**. However, for pressure regulation chambers, such as the second pressure regulation chamber **156**, that are defined by pistons having different diameters, the force acting on the piston with a larger diameter is greater than the force acting on the piston with a smaller diameter. Similarly, for pressure regulation chambers that are defined by a single piston and an end of the spool cavity, such as the third pressure regulation chamber **158**, the force acting on the spool **160** due to the pressurized oil within the chamber equals the pressure force acting on the single piston defining the pressure regulation chamber.

By providing pressurized oil within the pressure regulation chambers such as the second and third pressure regulation chambers **156** and **158**, a net pressure force may be applied to the spool **160**. The spool valve **150** further comprises a biasing element **170**, such as a resilient member configured to oppose the pressure balance force applied to the spool such as during steady state operation of the pump **100**.

A biasing element **170** may be configured such that an opposing force provided by the biasing element is proportional to a displacement of the spool **160**. For example, a neutral position of the spool in which the biasing element does not provide any balancing force. Hence, the position of the spool **160** within the spool cavity **152**, will be dependent on the net pressure force applied to the spool. In other words, the position of the spool **160** may depend on the pressure of oil provided within the second and third pressure regulating chambers **156** and **158**.

The spool valve may comprise first, second and third inlets **172**, **174**, **176**, in fluid communication with the first, second and third pressure regulation chambers **154**, **156**, **158** respectively. In the arrangement shown in FIG. 2B, the first inlet **172** receives pressurized oil from the second pressure chamber **108** of the pump **100** via the oil port **114**.

With reference to the embodiment depicted in FIG. 2B, the spool valve **150** further comprises a pressure regulation port **153**. The pressure regulation port may be configured to permit oil to leak out of the spool cavity **152** and return to the oil sump **12** of the engine. As depicted in FIG. 2B, when the pump is operating in a particular operating condition, the pressure regulation port **153** is blocked by a spool piston. However, if the position of the spool varies, the pressure regulation port is no longer blocked by the piston. A pressure regulation outlet **153a** is defined by the portion of the pressure regulation outlet **153** that is not blocked by the piston.



The size of the pressure regulation outlet **153** may affect the rate at which oil is able to flow through the spool valve through the first inlet **172**. As described above with reference to FIG. 2A, the rate at which oil is able to flow out of the second pressure chamber **108** affects the pressure of oil within the second pressure chamber, thereby affecting the operation of the pump **100**. In this way, the spool valve **150** is configured to control the pressure of oil supplied by the pump **100**.

The engine speed may be correlated to the oil pump operation. In one example, increasing engine speed increases the pressure of oil within the outlet chamber **104**, the first pressure chamber **106** and the second pressure chamber **108**. The outlet pressure of oil from the pump **100** is thereby increased, and hence, the pressure of oil in the oil gallery **20** is increased accordingly.

As described above, an embodiment of the third inlet **176** of the spool valve receives oil from the oil gallery **20**, and hence, if the pressure of oil within the third pressure regulation chamber **158** increases, then the pressure force applied to the third piston **168** increases. If the pressure of oil within the first pressure regulation chamber has increased, it may not affect the net pressure force applied to the spool **160** because the diameters of the first piston **164** and second pistons **166** may be the same,

An increased pressure of the third pressure regulation chamber **158** may cause the spool **160** to be displaced such that the size of the pressure regulation outlet **153a** is increased. This leads to an increased rate of flow of oil from the second pressure chamber **108** into the oil port **114**. The oil flows from port **114** into the first pressure regulation chamber **154** and further through the pressure regulation port **153**. The increased flow of oil reduces the pressure within the second pressure chamber **108**.

With reference to the embodiment shown in FIG. 2A, reducing the pressure within the second pressure chamber **108** changes the balance of pressure forces acting on the setting ring **120** of the pump **100**. The setting ring **120** is moved within the pump due to the change in pressure balance. The capacity of the pump is thereby affected by the change in position of the setting ring **120**, which affects the outlet pressure of the pump. In this way, the outlet pressure of the pump **100** is regulated.

Reliably regulating the outlet pressure of oil supplied by the pump **100** helps to ensure that the pressure lubricated components **50** of the engine continue to operate effectively.

As shown in the embodiment depicted in FIG. 1, the oil system **10** may comprise a pressure control valve **24**. The pressure control valve receives a supply of oil from the oil gallery **20**. The pressure control valve **24** is operable to provide pressurized oil to the second inlet **174** of the spool valve **150**. Oil provided to the second inlet **174** enters the second regulation pressure chamber **156** of the spool valve. As shown in FIG. 2B, the diameters of the pistons defining the second regulation chamber may differ. In particular, the diameter of the second piston **166** may be greater than the diameter third piston **168**. Hence, pressurized oil provided to the second inlet may induce a net force applied to the spool **160**. In an embodiment, the net force applied to the spool is in the same direction as the force applied to the spool by the oil within the third pressure regulation chamber **158**. Providing pressurized oil to the second inlet therefore has the same effect as an increase in the outlet pressure of the pump. Providing pressurized oil to the inlet therefore leads to a change in the outlet pressure by which the pump is regulated.

As depicted in FIGS. 2A and 2B, the oil pump **100** also comprises an internal filter **300**. The filter is configured such that oil passing through the oil port **114** passes through a filter element **302**, shown in FIGS. 3A and 3B, which may comprise a mesh. The mesh **302** is sufficiently fine that potentially harmful solid contaminants are separated from the oil passing through the filter. The filter element **302** may be spaced apart from an opening **114a** of the oil port **114**. Additionally, an area of the filter element **302** through which the oil passes before passing through the oil port **114** may be greater than an area of the oil port opening **114a**.

In the arrangements shown in FIGS. 2A and 2B, the filter **300** is provided within a second pressure chamber and configured to filter oil within the chamber. However, it is equally envisaged that the filter **300** may be provided outside the second pressure chamber and configured to filter oil passing into the second pressure chamber. The oil filter may also be provided to filter oil prior to reaching the pump.

The oil pump may be a variable displacement oil pump. The mechanism for adjusting the displacement of the pump may comprise a pressure regulation outlet downstream of the oil port. A flow area defined by the pressure regulation outlet may be varied by the mechanism for adjusting displacement of the pump according to an operating condition such as an outlet pressure of the oil pump. Adjusting the displacement of the pump may be used to regulate the pressure of oil supplied by the oil pump.

The oil pump may include a spool valve configured to vary the rate at which oil passes through the oil port according to an outlet pressure of the oil pump. In other words, the mechanism for adjusting the displacement of the pump may comprise the spool valve.

The spool valve may comprise a pressure regulation chamber and a spool, movable within the pressure regulation chamber. Oil passing through the oil port may flow into the pressure regulation chamber. The spool valve may further comprise a pressure regulation outlet configured to allow oil to flow out of the pressure regulation chamber. The position of the spool within the pressure chamber may be varied according to an outlet pressure of the oil pump, in order to vary a flow area of the pressure regulation outlet.

The spool valve may be configured such that the outlet pressure of the oil pump affects the position of the spool valve within the pressure regulation chamber. For example, the outlet of the oil pump may be in fluid communication with a pressure face of the spool. The spool may be biased by a resilient element

The flow area of the pressure regulation outlet may affect the pressure of the oil within the pressure chamber of the oil pump and thereby affect the outlet pressure of the oil pump. In other words, the spool valve and the pressure chamber of the oil pump may regulate the outlet pressure of the oil pump.

The spool valve may further comprise a low pressure set input. The spool valve may be configured to receive oil via the low pressure set input in order to adjust the position of the spool within the pressure regulation chamber and thereby to adjust the outlet pressure of the oil pump. Providing oil to the low pressure set input may adjust a balance of forces acting on the spool, which may affect the regulated outlet pressure of the oil pump.

With reference to FIGS. 3A and 3B, oil with contaminants will initially flow through the filter element **302**. The flow of oil may be greatest through an area of the filter element **302** adjacent to the oil port **114**. The portion of the filter element that contacts the oil containing contaminants is the filter surface area **305**. Contaminants from the oil may begin to



build up on the filter element **302** after a period of operation. Contaminates may build up quickest in an area adjacent to the oil port **114**. By providing the filter element **302** having a greater filter surface area **305** compared to the oil port opening **114a**, the likelihood of the filter element **302** oil flow becoming blocked is significantly reduced.

As depicted in FIG. 3B, if a portion of the filter element adjacent to the port **114** includes a particulate blockage **306**, oil can continue to flow through a portion of the filter element further from the oil port. By spacing the filter surface area apart from the oil port **114**, an oil flow channel **304** is maintained on the filtered side of the filter element **302**. Oil that has passed through the filter element **302** can therefore flow through the clean oil channel **304** to reach the oil port.

As shown in FIGS. 2A, 2B, 3A, 3B, the oil filter **300** may be prismatic in shape. For example, the oil filter may be substantially cylindrical. Alternatively, the oil filter may be shaped as a triangular, square prism, or any other regular or irregular prism. An area of the cross-section of the filter may be constant along the length of the prism. An example would be a cylindrical filter. Alternatively, the cross-sectional area of the prism may vary along the central axis of the prism. In other words, the shape of the filter **300** may be conical. The filter element **302** may form an outer surface of the prism. In some arrangements, the filter **300** may primarily consist of the filter element **302**. For example, the filter element forms an outer surface of the prism.

The oil filter **300** may be arranged within the oil pump **100** such that the central axis of the oil filter **300** is disposed at an angle relative to a flow path defined by the oil port **114**. For example, the oil filter **300** may be arranged such that the central axis of the filter is approximately perpendicular relative to the flow path of the oil port **114**. This orientation may provide the space between the filter surface area **305** and oil port **114**. This flow space **304** allows oil to flow after passing through the filter surface area prior to entering the port **114**. The filter surface area **305** may be supported by the pump housing away from the opening of the oil port. The filter may fit into a cavity **307** within the housing. In some arrangements, the filter may be supported by an internal wall. In other arrangements, a sidewall portion of the filter may provide the distance between the filter surface area and the port. This distance may be defined by the length of the side wall portion. This side wall portion is depicted in FIGS. 3A and 3B as **303**.

The filter element may comprise a mesh and may be metallic. The filter element may also comprise felt, paper or any other material capable of filtering oil. The material may provide resiliency. This resiliency may provide the side wall stiffness to support the filter surface area a distance away from the port. In a filter composed entirely of metallic mesh, this resiliency may be a property of the filter material. If the filter is composed of a less resilient material, the side wall may be composed of a different material than the filter portion.

With reference to FIGS. 4 and 5, oil filters **400**, **500** according to arrangements of the present disclosure will now be described. The oil filter **400** or **500** may be supported by the housing **101** of the oil pump. The oil filter **400** or **500** may be supported by the housing at a location on the housing away from the oil port opening **114a**. As shown in FIG. 4, the filter may comprise a substantially planar filter element. The filter element may be supported by the housing at ends **402a**, **402b** of the filter element.

With reference to FIG. 5, the oil filter **500** may be substantially prismatic in shape and may include a longitudinal slot **504**. For example, the slot may extend along a

length dimension of a cylinder shaped filter as depicted in FIG. 5. The slot **504** may be defined in the outer surface of the prism. When the filter is installed into the pump **100** the longitudinal slot may be aligned with the oil port **114**. Alternatively, the filter may be arranged such that edges of the longitudinal slot contact the wall of the housing **101**. In some embodiments oil does not flow through the slot prior to passing through the filter element **502**. For example, oil may pass through the filter element of the filter prior to passing through the longitudinal slot. The filter may be arranged within the oil pump such that the longitudinal slot of the filter is substantially aligned with the oil port. For example, the filter may be arranged, such that the edges of the longitudinal slot contact a wall of the housing.

The filter **500** may be compressible by reducing the width of the slot. Compression of the slot will reduce the cross-sectional area of the filter in a plane perpendicular to the central/longitudinal axis of the filter. For example, the filter **500** may be compressed during assembly, in order to fit the filter into the oil pump.

The filter **500** may be resilient. Once the filter has been installed within the pump **100**, the filter **500** may expand by virtue of its own resilience. This expansion may be due to an increasing of the width of the slot **504**. The filter **500** may expand such that a part of the outer surface of the filter engages walls of the housing **101**, such that the filter **500** is supported by the housing. The filter may be compressed prior to installation into the pump and may expand during installation in order to engage the walls of the pump.

As depicted in FIG. 5, the housing **101** may define a filter chamber portion **550** configured to receive the filter. The filter chamber portion may be formed within the second chamber **104** of the oil pump **100** depicted in FIGS. 2A and 2B. The filter **500** may engage two or more walls of a filter chamber, such that the filter is supported by the housing **101** within the filter chamber.

The filter chamber may define a shoulder configured to abut the filter **500** in order to retain the filter within the filter chamber. The shoulder may be a square, chamfered or rounded shoulder. The shape of the shoulder may correspond to the shape of the filter at the position at which the shoulder abuts the filter. The shoulder may at least partially define a neck portion of the filter chamber portion. The neck portion may have a reduced width or area compared to a cavity **556** portion of the filter chamber in which the filter is supported.

The filter **500** may be arranged such that a central/longitudinal axis of the prismatic shape of the filter is at an angle relative to a flow path defined by the oil port. For example, the oil filter may be arranged such that the central axis of the oil filter is at substantially perpendicular to the flow path defined by the oil port.

The oil port may be configured to deliver oil to the mechanism for adjusting the displacement of the pump of the oil pump, in order to regulate the pressure of oil supplied by the pump.

The oil pump may comprise a pressure chamber. Displacement of the pump may vary according to a pressure of oil within the pressure chamber. The oil pump may comprise a further filter chamber. The displacement of the pump may vary according to a difference in pressure between the pressure chamber and the further pressure chamber.

The filter may be configured to filter oil within the pressure chamber. The filter may be configured to filter the oil passing into the pressure chamber. The filter may be provided within the pressure chamber. An oil port may be defined within the pressure chamber. The oil port may be configured to allow oil to flow out of the pressure chamber



## 11

in order to affect the pressure of oil within the pressure chamber. The filter may be configured to filter the oil leaving the pressure chamber. The filter chamber portion may be defined within the pressure chamber.

The filter **300**, **400**, **500** may be a press fit glued, threaded, clipped or otherwise fixed in position relative to the oil port.

FIG. **6** depicts an embodiment of an oil filter. The oil filter has a cylindrical shape. The outer surface of the cylinder may be composed of a metal mesh. If this embodiment is positioned such that the longitudinal axis of the filter is oriented perpendicular to a port, then the filter surface area will likely be greater than the port area. Furthermore, the oil will be able to pass through the filter surface area into the interior of the cylinder before entering the port. Therefore, even if part of the filter surface area is clogged, the oil has a path to flow to the port.

FIG. **7** depicts an embodiment of the use of a cylindrical filter in a variable displacement pump. Spool valve chamber **701** is shown without a cylindrical filter installed. Spool valve chamber **702** is shown with a cylindrical filter covering the spool valve chamber inlet hole **703**. The area of the spool valve chamber inlet hole **703** is less than the surface area of the filter installed in spool valve chamber **702**. The oil may flow through the shown outer surface of the cylindrical filter before passing into the inlet hole **703**. This embodiment provides minimal changes to the manufacturing of the pump internal casting. Furthermore, cross drilling through the housing walls is not required.

FIG. **8** depicts an example oil circuit diagram of an oil system **10**. The oil pump **100** receives oil from the sump **12** via the oil pick up **801**. The oil pump **100** sends oil to the oil filter cooler assembly **802**. The oil then flows to the oil gallery **20**. The pump **100** receives a constant feedback signal **803** from the oil gallery **20**. This feedback signal **803** may enter a spool valve chamber of oil pump **100**. Regulated oil is discharged into the oil sump out of the regulation output port **804**. A switch **805** receives oil from the oil gallery **20** and operates to switch between a high pressure set point and a low pressure set point. This switch may be a solenoid. The switch **805** operates by switching on the low set point signal **806** to the pump which may enter the spool valve. A pump may be equipped with an over-pressure discharge port **807** in case there is a blockage in the oil filter or engine. Similarly, the switch **805** may have a pressure relief port **808**.

FIG. **9** depicts an example of a conventional button filter **901** mounted in an oil pump. The button filter **901** is positioned inside of an oil port. Clogging particulates may build up on the button filter and block the flow of the entire oil port. Clogging of an entire oil passage may lead to catastrophic failure of engine components.

FIG. **10** depicts other examples of mounting conventional filters in oil pumps. Filter **902** is fitted into a vertical drilling which is fed via a horizontal hole. Filter **902** is prone to filter clogging over time because oil flows through the filter and not past it. Therefore, contamination will build up on the filter media until the filter is completely clogged. Filter **903** is located in a housing wall, however the filter **903** may be angled. Filters are commonly be angled if the housing wall is too thin to house the filter or if there isn't space for drill access. This design may allow oil to flow both past and through but may be expensive due to the angled drilling. Filter **904** is similar to filter **903** but the filter **904** is located in the pump cover rather than the housing. Filter **904** may also be expensive to manufacture as it may require casting and machining. Filter **905** fitted close to the spool valve

## 12

chamber inlet hole, but this is easily clogged as oil flows through it similarly to filter **902**.

In embodiments, the oil filter may maintain oil flow in the presence of clogging particulates. The large filter surface area will allow oil to flow in alternative path around clogging particulates. This may allow the filters to operate with a high level of clogging particulates than conventional filters. The alternative flow path is operable due to a large filter surface area and the filter surface area being located a distance from an oil port. This configuration allows the oil to flow through unclogged portions of the filter surface area and into the interior of the filter before passing into the port.

It will be appreciated that the configurations and routines disclosed herein are exemplary in nature, and that these specific embodiments are not to be considered in a limiting sense, because numerous variations are possible. For example, the above technology can be applied to V-6, I-4, I-6, V-12, opposed 4, and other engine types. The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various systems and configurations, and other features, functions, and/or properties disclosed herein.

The following claims particularly point out certain combinations and sub-combinations regarded as novel and non-obvious. These claims may refer to "an" element or "a first" element or the equivalent thereof. Such claims should be understood to include incorporation of one or more such elements, neither requiring nor excluding two or more such elements. Other combinations and sub-combinations of the disclosed features, functions, elements, and/or properties may be claimed through amendment of the present claims or through presentation of new claims in this or a related application. Such claims, whether broader, narrower, equal, or different in scope to the original claims, also are regarded as included within the subject matter of the present disclosure.

The invention claimed is:

**1.** A variable displacement oil pump for a motor vehicle, the oil pump comprising:

a mechanism for adjusting displacement of the pump, the mechanism including an oil port formed in an internal wall of the pump;

a filter supported by a wall such that a filter surface area is a distance from an inlet of the oil port and wherein the filter is substantially prism shaped and includes a longitudinal slot provided within an outer surface of the prism shaped filter; and

the filter is compressible by reducing a width of a longitudinal slot; and

wherein the filter surface area is larger than an area of the inlet of the oil port, and wherein the filter surface area forms the outer surface of the prism shaped filter.

**2.** The oil pump of claim **1**, wherein the filter is arranged such that oil passes through the filter surface area prior to the longitudinal slot.

**3.** The oil pump of claim **2**, wherein the filter is configured to expand due to a material resilience in order to engage one or more walls of the pump such that the filter is supported within the pump.

**4.** The oil pump of claim **3**, wherein a housing of the pump defines a filter chamber portion configured to receive the filter.

**5.** The oil pump of claim **4**, wherein the filter chamber portion defines a shoulder configured to abut the filter in order to retain the filter within the filter chamber portion.



## 13

6. The oil pump of claim 5, wherein the filter is configured to filter oil passing into a pressure chamber and displacement of the pump varies according to a pressure of oil within the pressure chamber.

7. The oil pump of claim 6, wherein the filter is located within the pressure chamber.

8. The oil pump of claim 5, wherein the filter is arranged such that the longitudinal slot of the filter is substantially aligned with the oil port.

9. The oil pump of claim 8, wherein the filter is arranged such that a central axis of the filter is approximately perpendicular to a flow path defined by the oil port.

10. An engine with an oil pumping system including a cavity:

an oil filter being insertable into the cavity and being arranged such that oil passes through a filter surface area prior to a port;

the filter surface area being greater than an inlet area of the port;

the oil filter including a rear surface; and

the oil filter having a side wall portion extending between the filter surface area and the rear surface creating a hollow space without filter media between the filter surface area and the rear surface.

11. The engine of claim 10, wherein the filter surface area is at least twice the inlet area.

12. The engine of claim 11, where the oil filter has a cylindrical or rectangular prism shape surrounding the hollow space.

## 14

13. The engine of claim 12, wherein oil flows through the hollow space defined by a length of the side wall portion after flowing through the filter surface area and before entering the port.

14. An engine with an oil pumping system including a cavity:

an oil filter within the cavity arranged such that oil passes through a filter surface area prior to a port and a second surface contacts a wall forming the port;

the filter surface area being greater than an inlet area of the port; and

the filter surface area being supported such that a hollow space without filter media is maintained between the filter surface area and the second surface.

15. The engine of claim 14, wherein the hollow space is created by an outward pressure of a material comprising the filter against one or more walls of the cavity.

16. The engine of claim 14, wherein the hollow space is created by a side wall portion and the side wall portion has a length which is greater than the inlet area.

17. The engine of claim 16, wherein a volume defined by the length of the side wall portion and the filter surface area is greater than a volume of the port.

18. The engine of claim 15, wherein the oil filter has an oil filter cavity in an outer surface that is positioned over the port.

19. The engine of claim 15, wherein a cylindrical or prismatic shape of the oil filter forms the hollow space with the cylindrical or prismatic shape.

20. The engine of claim 15, wherein the second surface includes a longitudinal slot.

\* \* \* \* \*