(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 979 287 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.04.2022 Bulletin 2022/14

(21) Application number: **20199459.7**

(22) Date of filing: **30.09.2020**

(51) International Patent Classification (IPC):
***H01H 33/90** (2006.01)*

(52) Cooperative Patent Classification (CPC):
H01H 33/901; H01H 2033/906; H01H 2033/908

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

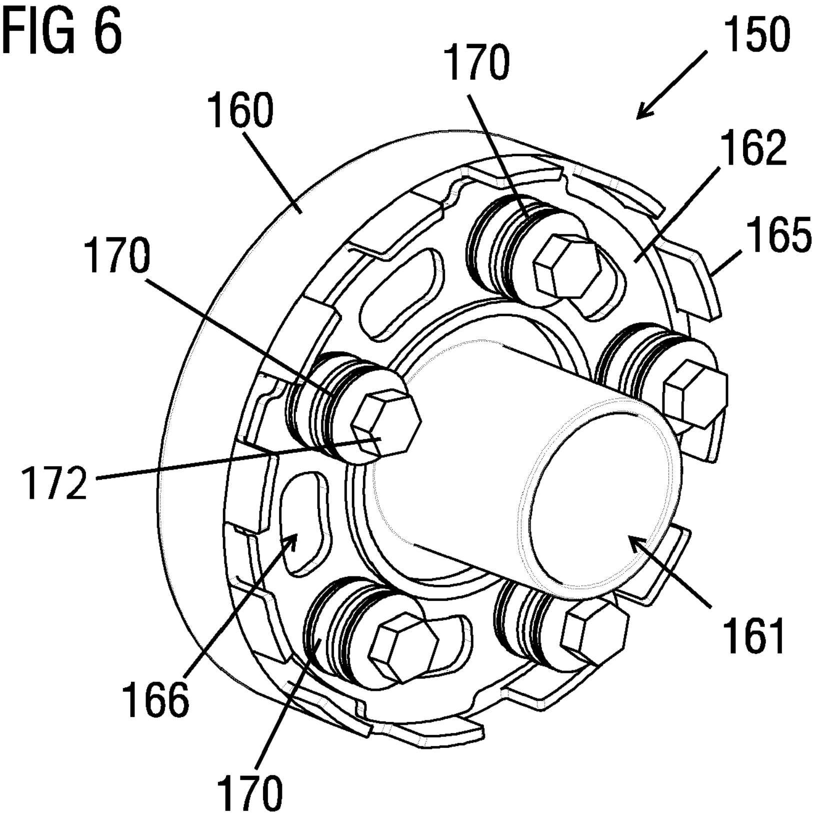
(71) Applicant: **Siemens Energy Global GmbH & Co. KG**
81739 München (DE)

(72) Inventors:
- **BAGALE, Tammaraya**
431005 Aurangabad (IN)
- **MARATHE, Nakul**
422009 Nashik (IN)

(54) CIRCUIT BREAKER, VALVE ASSEMBLY AND OPERATING METHOD THEREOF

(57) A circuit breaker, a valve assembly and an operating method thereof are provided. The circuit breaker comprises a compression volume surrounding at least a portion of a space between first and second electric contacts, and a low-pressure volume, filled with insulating gas, disposed adjacent to the compression volume. The circuit breaker further comprises a valve assembly interconnecting the compression volume and the low-pressure volume, and configured to allow threshold-based flow of the insulating gas. The valve assembly comprises a valve body. The valve assembly also comprises a first valve plate movably mounted in the valve body and a second valve plate movably seated on the first valve plate. The valve assembly further comprises a plurality of Belleville springs radially arranged in the valve body, and configured to constrain the movement of the first valve plate up to the third position of the second valve plate in the valve body.

FIG 6



EP 3 979 287 A1

Description

[0001] The present invention relates generally to arc chambers for extinguishing arcs, such as in circuit breakers, and more particularly relates to a valve assembly for regulating flow of insulating gas in a circuit breaker.

[0002] In general, a circuit breaker operates to engage and disengage a selected electrical circuit from an electrical power supply. The circuit breaker ensures current interruption thereby, providing protection to the electrical circuit from continuous over current conditions and high current transients due to, for example, electrical short circuits. Such circuit breakers operate by separating a pair of internal electrical contacts contained within a housing e.g., molded case of the circuit breaker. Typically, one electrical contact is stationary while the other is movable e.g., typically mounted on a pivotable contact arm.

[0003] The contact separation may occur manually, such as when a person throws an operating handle of the circuit breaker. This may engage an operating mechanism, which may be coupled to the contact arm and moveable electrical contact. Alternatively, the electrical contacts may be separated automatically when an over current, short circuit, or fault condition is encountered. Automatic tripping may be accomplished by an operating mechanism actuated via a thermal overload element e.g., a bimetal element or by a magnetic element, or even by an actuator e.g., a solenoid.

[0004] Upon separation of the electrical contacts by tripping, an intense electrical arc may be formed in an arc chamber containing the electrical contacts. This separation may occur due to heat and/or high current through the circuit breaker or due to sensing a ground or other arc fault. It is desirable to extinguish the arc as quickly as possible to avoid damaging internal components of the circuit breaker.

[0005] In power distribution networks, a circuit breaker of type, called a gas-insulated circuit breaker is commonly used. Such gas-insulated circuit breaker is designed in such a way that in the event of separating of the contacts, or in case of a short circuit, the arc is blasted with gas and consequently quenched as quickly as possible. In such circuit breaker, a pressure chamber, in which the arc is created, is connected in a valve-controlled manner to a compression chamber. The compression chamber is connected to a low-pressure chamber via a valve arrangement. The valve arrangement, on the low-pressure chamber side, is pressed by a spring against a valve holder in the direction of the compression volume. Gas can therefore flow from the compression volume into the low-pressure chamber only when its pressure is higher than the spring force.

[0006] In a high voltage circuit breaker, a valve is typically implemented to regulate the flow of gas towards arcing contact. Such a valve allows the free flow of gas in one direction while gas flow in other direction is dependent on the pressure built in compression volume. It is required that the valve should allow gas flow towards arcing contacts during gas filling. Further, during opening of the circuit breaker, the valve has to be closed such that pressure in the compression volume increases up to specified limit. Also, it is required that once the pressure in compression volume increases beyond specified limit, valve should open.

[0007] European Patent Application Number 3419039A1 ('039 application) relates to an electric high-voltage circuit breaker comprising a primary chamber and a compression chamber, wherein said circuit breaker further comprises a valve configured to control a fluid flow between said primary chamber and said compression chamber. The electric high-voltage circuit breaker of the '039 application discloses that said valve comprises a valve body, a first valve plate that is arranged axially movable with respect to said valve body, and a second valve plate that is arranged between and movable, preferably at least axially movable, with respect to said valve body and said first valve plate, wherein said first valve plate comprises at least one opening enabling a fluid flow through said first valve plate, wherein a first surface of said valve body forms a valve seat for said first valve plate, and wherein a first surface of said first valve plate forms a valve seat for said second valve plate.

[0008] In the circuit breaker of the '039 application, one or more guide pins may be provided for guiding an axial movement of both said first valve plate and said second valve plate. Further, a first spring force mechanism is provided to press said first valve plate to said valve seat of the valve body, and a second spring force mechanism is provided to press said second valve plate to said valve seat of the first valve plate. Each of the spring force mechanisms may comprise one or more springs (for example, helical springs) arranged at said guide pins.

[0009] The type of construction implemented for the valve in the circuit breaker, as disclosed in the '039 application, is relatively complicated and requires a large number of components, and that may result in hindrance to the path of flow of gas which is undesirable. It may be appreciated that pressure opening from compression volume is only possible from one side in such configuration. Further, in such configuration of the valve arrangement, typically, a pneumatic press is required to mount the spring on the valve which is an added expense. Also, the load value needs to be set for each of the springs to get desired pressure release output, which may be time-consuming and cumbersome.

[0010] In light of the above, it is an object of the present disclosure to provide a circuit breaker with a valve assembly to regulate the flow of gas towards arcing contact, which is simple in construction, is economical to manufacture and is efficient to operate.

[0011] The object of the present disclosure is achieved by a circuit breaker comprising first and second electrical contacts, the electrical contacts configured to generate an electrical arc upon being separated during operation of the circuit breaker. The circuit breaker comprises a first chamber at least partially surrounding the first and second electric contacts, and a second chamber filled with insulating gas. The circuit breaker further comprises a valve assembly interconnecting the first chamber and the second chamber. The valve assembly is configured to allow threshold-based flow of the insulating gas into and out of the first chamber. The valve assembly comprises a valve body. The valve assembly also comprises a first valve plate movably mounted in the valve body, and a second valve plate arranged in the valve body so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate is seated on the first valve plate, in the second position, the second valve plate is lifted from the first valve plate to above the first position thereof, and in the third position, the second valve plate is seated on the first valve plate and moves the first valve plate therewith below the first position thereof. The valve assembly further comprises a plurality of Belleville springs radially arranged in the valve body below the first valve plate, the plurality of Belleville springs configured to constrain the movement of the first valve plate up to the third position of the second valve plate in the valve body.

[0012] In an embodiment, the second valve plate assumes the second position during filling of the insulating gas into the second chamber thereby, allowing passage to the insulated gas into the first chamber which is at a lower pressure than the second chamber, and wherein the second valve plate assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber is higher than in the second chamber.

[0013] In an embodiment, the second valve plate assumes the third position upon generation of the electrical arc, moving the first valve plate therewith, by overcoming the constrain on the movement of the first valve plate by the plurality of Belleville springs due to additional pressure built in the first chamber, allowing passage to the insulated gas into the second chamber.

[0014] In an embodiment, the plurality of Belleville springs are tensioned to define the constrain on the movement of the first valve plate in the valve body based on desired threshold pressure of the insulating gas in the first chamber.

[0015] In an embodiment, each of the plurality of Belleville springs comprises two or more Belleville spring units arranged in a stacked configuration to provide the tension, to define the constrain on the movement of the first valve plate in the valve body based on the desired threshold pressure of the insulating gas in the first chamber.

[0016] In an embodiment, the valve assembly further comprises a plurality of fasteners, corresponding to the plurality of Belleville springs, fixed to the valve body. Each of the plurality of fasteners supports one of the plurality of Belleville springs below the first valve plate.

[0017] In an embodiment, the valve body comprises a stopper formed therein, such that the stopper limits the lifting of the second valve plate up to the second position thereof in the valve body.

[0018] In an embodiment, the valve body has a substantially cylindrical shape.

[0019] In an embodiment, the first valve plate has one or more openings formed therein. The second valve plate is seated on the first valve plate in a manner so as to seal the one or more openings thereof.

[0020] The object of the present disclosure is also achieved by a valve assembly for a circuit breaker having a first chamber and a second chamber filled with insulating gas, the valve assembly being of the configuration as discussed in preceding paragraph.

[0021] The object of the present disclosure is further achieved by an arc pressure control arrangement, which may be implemented, for example, in a circuit breaker. Herein, the arc pressure control arrangement comprises a first chamber containing first and second electrical contacts, the electrical contacts configured to generate an electrical arc upon being separated during operation of the circuit breaker. The arc pressure control arrangement further comprises a second chamber filled with insulating gas. The arc pressure control arrangement further comprises a valve assembly interconnecting the first chamber and the second chamber, the valve assembly being of the configuration as discussed in preceding paragraphs.

[0022] The object of the present disclosure is further achieved by a method of operating a circuit breaker. The method comprises providing a valve assembly comprising a valve body interconnecting a first chamber and a second chamber in the circuit breaker, a first valve plate movably mounted in the valve body, and a second valve plate arranged in the valve body so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate is seated on the first valve plate, in the second position, the second valve plate is lifted from the first valve plate to above the first position thereof, and in the third position, the second valve plate is seated on the first valve plate and moves the first valve plate therewith below the first position thereof. The method further comprises providing a plurality of Belleville springs radially arranged in the valve body below the first valve plate to constrain the movement of the first valve plate up to the third position of the second valve plate in the valve body. The method further comprises filling the second chamber with insulating gas such that the second valve plate assumes the second position during filling of the insulating gas into the second chamber thereby, allowing passage to the insulated gas into the first chamber which is at a lower pressure than the second chamber, and the second valve plate assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber is higher than in the second chamber. The method further comprises separating a first electrical contact from a second electrical contact in a first chamber of the circuit breaker to generate an electrical arc, such that the second valve plate assumes the third position upon generation of the electrical arc, moving the first valve plate therewith, by overcoming the constrain on the movement of the first valve plate by the plurality of Belleville springs due to additional pressure built in the first chamber, allowing passage to the insulated gas into the second chamber.

[0023] Still other aspects, features, and advantages of the invention are readily apparent from the following detailed description, simply by illustrating a number of particular embodiments and implementations, including the best mode contemplated for carrying out the invention. The invention is also capable of other and different embodiments, and its several details can be modified in various obvious respects, all without departing from the scope of the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

[0024] A more complete appreciation of the present disclosure and many of the attendant aspects thereof will be readily obtained as the same becomes better understood by reference to the following description when considered in connection with the accompanying drawings:

- FIG 1 is a diagrammatic perspective representation of an exemplary circuit breaker, in accordance with an embodiment of the present invention;
- FIG 2 is a diagrammatic cross-sectional representation of a pole column of the circuit breaker as shown in FIG 1, in accordance with an embodiment of the present invention;
- FIG 3 is a diagrammatic cross-sectional representation of an interrupter unit of the circuit breaker, in accordance with an embodiment of the present invention;
- FIGS 4A-4B are partial sectional representations of an arc pressure control arrangement depicting arc quenching operation therein, in accordance with an embodiment of the present invention;
- FIG 5 is a diagrammatic front-side perspective representation of a valve assembly, in accordance with an embodiment of the present invention;
- FIG 6 is a diagrammatic back-side perspective representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 7 is a diagrammatic front planar representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 8 is a diagrammatic back planar representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 9 is a diagrammatic side planar representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 10 is a diagrammatic sectional representation of the valve assembly along section CC' of FIG 8, in accordance with an embodiment of the present invention;
- FIG 11 is a diagrammatic front-side exploded representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 12 is a diagrammatic back-side exploded representation of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 13 is a diagrammatic perspective representation of a first plate of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 14 is a diagrammatic perspective representation of a second plate of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 15 is a diagrammatic perspective representation of a Belleville spring unit of the valve assembly, in accordance with an embodiment of the present invention;
- FIG 16 is a schematic representation of the circuit breaker with the valve assembly in normal state thereof, in accordance with an embodiment of the present invention;
- FIG 17 is a diagrammatic cross-sectional representation of the valve assembly in normal state thereof, in accordance with an embodiment of the present invention;
- FIG 18 is a schematic representation of the circuit breaker with the valve assembly in gas upward state thereof, in accordance with an embodiment of the present invention;
- FIG 19 is a diagrammatic cross-sectional representation of the valve assembly in gas upward state thereof, in accordance with an embodiment of the present invention;
- FIG 20 is a schematic representation of the circuit breaker with the valve assembly in gas downward state thereof, in accordance with an embodiment of the present invention;
- FIG 21 is a diagrammatic cross-sectional representation of the valve assembly in gas downward state thereof, in accordance with an embodiment of the present invention;
- FIG 22 is a flowchart listing steps involved in a method of operating a circuit breaker, in accordance with an embodiment of the present invention.

[0025] Various embodiments are described with reference to the drawings, wherein like reference numerals are used to refer the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for the purpose of explanation, numerous specific details are set forth in order to provide thorough understanding of one or more embodiments. It may be evident that such embodiments may be practiced without these specific details.

[0026] In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the embodiments of the invention. It is apparent, however, to one skilled in the art that the embodiments of the invention may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the embodiments of the invention.

[0027] Example embodiments of an arc pressure control arrangement described herein may be included in a circuit breaker to prevent a re-ignition failure of the circuit breaker. In certain example embodiments, upon contact separation, an arc is formed in a compression volume of the circuit breaker. The arc, extending between the first and second electrical contacts (e.g., stationary and moveable electrical contacts), produces arcing gases and also heats up and pressurizes the insulating gas within the compression volume. This causes a flow of the heated insulating gas and arc gasses, due to the pressure change, into a low-pressure volume disposed adjacent to the compression volume, but only at certain times during the arcing event.

[0028] A valve assembly is provided between the compression volume and the low-pressure volume to allow flow into and out of the compression volume only at the certain times during the arcing event. For example, the valve assembly may allow gas flow only when an inlet threshold pressure in the compression volume is exceeded. Further, the valve assembly may allow gas flow only when a pressure in the compression volume falls below an outlet threshold pressure. Thus, gas flows into the low-pressure volume after the gas pressure in the compression volume reaches the inlet threshold pressure, is held in the low-pressure volume for part of the arc cycle, and then flows out of the low-pressure volume and back into the compression volume when the pressure in the compression volume falls below the outlet threshold pressure.

[0029] Examples of a circuit breaker, a valve assembly for a circuit breaker, an arc pressure control arrangement, and a method of operating a circuit breaker are disclosed and fully described with reference to FIGS 1 through 22 herein.

[0030] FIG 1 is a diagrammatic perspective representation of an exemplary circuit breaker 100, in accordance with one or more embodiments of the present disclosure. In the present illustration, the depicted circuit breaker 100 is a three-pole pillar mounted circuit breaker; however, for the purposes of the present disclosure, the circuit breaker 100 may be any type of high-voltage circuit breaker as known in the art. The circuit breaker 100 includes a common breaker base 102 onto which the various components are mounted. In the present three-pole circuit breaker 100, there pole columns 104, 106 and 108 are provided which are mounted on the common breaker base 102. The pole columns 104, 106 and 108 are connected by tubes to a gas compartment (not shown) and are filled with insulating gas, such as, but not limited to, SF_6 (Sulphur Hexafluoride) for arc-quenching and insulating purposes. The gas density is monitored by a density monitor (not shown), and the pressure can be displayed by a pressure gauge or a pressure display on the density monitor.

[0031] The circuit breaker 100 also includes an operating mechanism unit 110 fastened to the breaker base 102. A mounting plate (not shown) is integrated in the operating mechanism unit 110, which contains all equipment for control and monitoring of the circuit breaker 100 and also terminal blocks required for electrical connections. The circuit breaker 100 further includes a spring drive mechanism (not shown) located in the operating mechanism unit 110. Typically, the spring drive mechanism includes closing and opening springs, and the energy required for switching is stored in one closing spring common to all three poles and one opening spring. In the circuit breaker 100, the pole column 106 is actuated by the spring drive mechanism via a corner gear 112 (as shown in FIG 2) and is connected with corner gears of the pole columns 104 and 108 by means of coupling rods. The circuit breaker 100 further includes a switching position indicator 114 which indicates the position and status of all switch equipment thereof.

[0032] FIG 2 is a diagrammatic cross-sectional representation of the pole column 104 of the circuit breaker 100. It may be appreciated that all of the three pole columns 104, 106 and 108 are similar in design and the present illustration can be construed to be representative of any of the three pole columns 104, 106 and 108 for the purposes of the present disclosure. As illustrated, the pole column 104 includes a post insulator 116 which provides insulation against earth. Further, the pole column 104 includes an insulated drive rod 118. The pole column 104 includes an interrupter unit 120 mounted on the post insulator 116.

[0033] FIG 3 is a diagrammatic cross-sectional representation of the interrupter unit 120. Referring to FIGS 2 and 3 in combination, the interrupter unit 120 contains the filter material 122, generally in the form of filter bag. The filter material 122 is used for the absorption of decomposition products of the insulating gas (like SF_6) and for keeping the gas dry. The interrupter unit 120 further includes a gas-tight jacket 124 which accommodates the breaker contacts. In the pole column 104, the switching motion is transferred from the spring drive mechanism (at earth potential) via a coupling rod 126, a shaft 128, and thereby from the insulated drive rod 118 to the interrupter unit 120 (at high voltage potential).

[0034] As illustrated, the main circuit for the interrupter unit 120 includes an upper high-voltage terminal 130, a lower high-voltage terminal 132, a diffuser socket 134, ring-placed contact laminations 136 arranged with the diffuser socket 134, a heat cylinder 138 and an operating socket 140. Herein, the contact laminations 136 are self-sprung and centrically pressed inwards, which ensures the necessary contact pressure on the heat cylinder 138 and the diffuser socket 134.Also, the upper high-voltage terminal 130 and the lower high-voltage terminal 132 are mounted using O-rings 141. Further, an arcing circuit is arranged parallel to the main circuit, which is made up of a pin 142 (also referred to as first electrical contact 142) situated in the diffuser socket 134 and a moving tube contact 144 (also referred to as second electrical contact 144) placed in the heat cylinder 138. Herein, the pin 142 and the tube contact 144 are made of materials, which produce only minimal contact erosion. Further, as illustrated, a piston 146 and a pull rod 148 are arranged in the interrupter unit 120. Herein, the tube contacts 144, the piston 146 and the heat cylinder 138 are mechanically interconnected and coupled with the pull rod 148, and form the moving parts of the interrupter unit 120. In the circuit breaker 100, a valve assembly 150 is arranged in cylindrical casting 152, which together with an arc quenching nozzle 154 makes up the compression unit for arc quenching purposes.

[0035] FIGS 4A and 4B are partial schematic representations of an arc pressure control arrangement 155, implemented in the circuit breaker 100, or specifically the interrupter unit 120 of the circuit breaker 100, depicting stages of arc quenching operation therein. As illustrated, the arc pressure control arrangement 155 includes the first electrical contact 142 and the second electrical contact 144. Herein, the first electrical contact 142 and the second electrical contact 144 are configured to generate an electrical arc upon being separated during operation of the circuit breaker 100. As illustrated, the arc pressure control arrangement 155 includes a first chamber (generally represented by numeral 156) at least partially surrounding the first electric contact 142 and the second electric contact 144. Further, the arc pressure control arrangement 155 includes a second chamber (generally represented by numeral 158) disposed adjacent to the first chamber 156. Herein, the second chamber 158 is filled with insulating gas, such as, for example, SF6. It may be understood that the first chamber 156 is a compression volume and the second chamber 158 is a low-pressure volume in the circuit breaker 100, and the said terms have been interchangeably used in the description without any limitations. In the arc pressure control arrangement 155, as illustrated, the valve assembly 150 interconnects the first chamber 156 and the second chamber 158. The valve assembly 150 regulates the flow of the insulating gas from the second chamber 158 into the first chamber 156, and vice-versa. In particular, the valve assembly 150 allows the flow of the insulating gas based on desired threshold pressure of the insulating gas in the first chamber 156. Thereby, the valve assembly 150 is configured to allow threshold-based flow of the insulating gas into and out of the first chamber 156.

[0036] In one or more embodiments, the first chamber 156 includes an internal storage volume that is greater than about 500 mm^3. For example, an internal storage volume of the first chamber 156may be greater than about 1,000 mm^3 for a 600V/250A circuit breaker, or even greater than about 1,500 mm^3 for a 600V/250A circuit breaker. In some embodiments, the internal storage volume of the second chamber 158 may be about 2,000 mm^3 or more. In some example embodiments, the second chamber 158 may be a rectangular shape and may include an internal height of about 38 mm, an internal width of about 6 mm, and an internal thickness of 6 mm. Other sizes, shapes, and storage volumes for the second chamber 158 may be used.

[0037] In an opening operation, the main contact that exists between the contact laminations 136 and the heat cylinder 138 is opened (as shown in FIG 4A). The arcing contact, consisting of the first electrical contact 142 and the second electrical contact 144 remains closed, with the result that the current commutates onto the arcing contact. During the continued course of the opening operation, the arcing contact opens creating an arc. At the same time, the heat cylinder 138 moves downward and compresses the quenching gas between the heat cylinder 138 and plate supporting the valve assembly 150. This causes the quenching gas to be forced in the direction opposite to the movement of the moving contact components, into the heat cylinder 138 and through the gap between the second electrical contact 144 and the arc-quenching nozzle, thus quenching the arc. With large short-circuit currents, the quenching gas surrounding the first electrical contact 142 in the arcing chamber is heated by the arc's energy and driven into the heat cylinder 138 at high pressure. When the current passes through zero, the gas flows back from the heat cylinder 138 into the nozzle and quenches the arc.

[0038] FIGS 5-12 are different diagrammatic representations of the valve assembly 150. As illustrated, the valve assembly 150 includes a valve body 160. Herein, the valve body 160 has a substantially cylindrical or annular shape. As shown, the valve body 160 has a radially inner, central opening 161. The valve body 160 is guided through the wall of the first chamber 156, with a gas passage which connects the first chamber 156 and the second chamber 158. Generally, a radially outer surface of the valve body 160 may contact a surrounding surface (not shown) of the circuit breaker 100 in a sealing (substantially gas-tight) manner. Similarly, a radially inner surface of the valve body 160 may contact a radially outer surface of the drive rod 118 (as may be seen from FIG 2) or an extension of the drive rod 118 protruding through the central opening 161 of the valve body 160 in a sealing manner. As an example, at both radially outer surface and radially inner surface, suitable sealing may be provided such as sealing rings and the like.

[0039] The valve assembly 150 further includes a first valve plate 162 (as better illustrated in FIG 13) movably mounted in the valve body 160. The valve assembly 150 also includes a second valve plate 164 (as better illustrated in FIG 14) movably seated on the first valve plate 162. In the present examples, the valve body 160, along with the first valve plate 162 and the second valve plate 164, may be formed of any suitable metallic material, such as, but not limited to, stainless steel or the like. Herein, the valve body 160 has generally larger diameter than the first valve plate 162 and the second valve plate 164, while the first valve plate 162 and the second valve plate 164 have substantially similar diameter. Generally, the first valve plate 162 and the second valve plate 164 may be pressed to the valve body 160 in a sealing manner.

[0040] In the present embodiments, the second valve plate 164 is arranged in the valve body 160 so as to move between a first position, a second position and a third position therein. Herein, in the first position, the second valve plate 164 is seated on the first valve plate 162. In the second position, the second valve plate 164 is lifted from the first valve plate 162 to above the first position thereof. In the third position, the second valve plate 164 is seated on the first valve plate 162 and move the first valve plate 162 therewith below the first position thereof.

[0041] In one or more examples, the first valve plate 162 may include seats defined therein onto which the second valve plate 164 is seated. As can best be seen from FIGS 11-14, the first valve plate 162 has one or more openings 166 formed therein, presently five openings 166. The openings 166 are radially segregated on planar exposed surface of the first valve plate 162. Further, the second valve plate 164 is a substantially solid annular member seated on the first valve plate 162 in a manner so as to seal the one or more openings 166 thereof. Further, as may be seen, the valve body 160 has one or more openings 168, presently five openings 168. Similar to the openings 166, the openings 168 are radially segregated on planar exposed surface of the valve body 160. Herein, the openings 168 are generally disposed inline with the openings 166 in the first valve plate 162, enabling a fluid flow through the first valve plate 162, for example in a basically axial direction of the circuit breaker 100.

[0042] The valve assembly 150 further includes a plurality of Belleville springs 170. Belleville spring is a type of spring shaped like a washer. Belleville spring, also known as a coned-disc spring, conical spring washer, disc spring, Belleville washer or cupped spring washer, is a conical shell which can be loaded along its axis either statically or dynamically. Belleville spring has the frustoconical shape that gives the washer its characteristic spring properties. As illustrated, the Belleville springs 170 are radially arranged in the valve body 160 below the first valve plate 162. In the present configuration, the Belleville springs 170 are coupled to the first valve plate 162.

[0043] As can best be seen from FIGS 9-12, the valve assembly 150 further comprises a plurality of fasteners 172, corresponding to the plurality of Belleville springs 170, fixed to the valve body 160. Each of the plurality of fasteners 172 supports one of the plurality of Belleville springs 170 below the first valve plate 162. In particular, each of the fasteners 172 include a shaft 174 onto which the corresponding Belleville spring 170 is mounted and a nut 176 which supports the corresponding Belleville spring 170 on the shaft 174. Such assembly may be contemplated by a person skilled in the art in light of the included drawings and thus has not been explained herein for the brevity of the present disclosure.

[0044] Herein, the plurality of Belleville springs 170 are configured to constrain the movement of the first valve plate 162 up to the third position of the second valve plate 164 in the valve body 160. For this purpose, the plurality of Belleville springs 170 are tensioned to define the constrain on the movement of the first valve plate 162 in the valve body 160 based on desired threshold pressure of the insulating gas in the first chamber 156. It may be appreciated by a person skilled in the art that the constrain may be defined based on the voltage rating of the circuit breaker 100, in order to be able to quench the generated arc in required time to avoid any damage, as will be discussed in more detail in the proceeding paragraphs.

[0045] In one or more embodiments, each of the plurality of Belleville springs 170 comprises two or more Belleville spring units 178 (as better illustrated in FIG 15). The two or more Belleville spring units 178 in each of the plurality of Belleville springs 170 are arranged in a stacked configuration to provide the tension to the corresponding Belleville spring 170, to define the constrain on the movement of the first valve plate 162 in the valve body 160 based on the desired threshold pressure of the insulating gas in the first chamber 156. As may be contemplated, by stacking multiple Belleville spring units 178 in a single Belleville spring 170, desired tension for the corresponding Belleville spring 170 can be achieved. In the present configuration, as illustrated in FIG 12, each of the Belleville springs 170 comprises six Belleville spring units 178. Alternatively, each of the plurality of Belleville springs 170 may include single Belleville spring unit 178 which may have suitable stiffness to achieve the required tension for the corresponding Belleville spring 170 to define the constrain on the movement of the first valve plate 162 in the valve body 160 based on the desired threshold pressure of the insulating gas in the first chamber 156. It may be appreciated by a person skilled in the art that with the use of Belleville springs 170, load value can be set for different pressure release value by stacking different number of Belleville spring units 178.

[0046] In one or more embodiments, as better illustrated in FIG 10, the valve body 160 comprises a stopper 180 formed therein. The stopper 180 is in the form of a tab protruding out from an inner wall of the valve body

160. The stopper 180 limits the lifting of the second valve plate 164 up to the second position thereof in the valve body 160. That is, the stopper 180 may be integrated into the valve body 160 and limits the movement of the first valve plate 162 when the circuit breaker 100 closes.

[0047] FIGS 16-21 are representations depicting various positions of the valve assembly 150 during arc quenching operation in the circuit breaker 100. As illustrated in FIGS 16-17, during normal state of the valve assembly 150, the second valve plate 164 in the first position, i.e. the second valve plate 164 is seated on the first valve plate 162. In particular, the first valve plate 162 is arranged in the valve body 160 with the second valve plate 164 seated on the first valve plate 162.

[0048] Further, as illustrated in FIGS 18-19, during filling operation, the valve assembly 150 is moved to gas upward state. Herein, the second valve plate 164 assumes the second position, i.e. the second valve plate 164 is lifted from the first valve plate 162 to above the first position thereof, during filling of the insulating gas into the second chamber 158 thereby, allowing passage to the insulated gas into the first chamber 156 which is at a lower pressure than the second chamber 158. In other words, the second valve plate 164 gets lifted from the first valve plate 162 due to pressure of the insulating gas in the second chamber 158 to provide a flow path for the insulating gas to flow from the second chamber 158 into the first chamber 156. Subsequently, the second valve plate 164 assumes the first position (akin to the normal state of FIGS 16-17) upon completion of the filling of the insulating gas when the pressure in the first chamber 156 is higher than in the second chamber 158.

[0049] As discussed, upon contact separation, an arc is formed in the first chamber 156 of the circuit breaker 100. The arc, extending between the first electrical contact 142 and the second electrical contact 144 (e.g., stationary and moveable electrical contacts), produces arcing gases and also heats up and pressurizes the insulating gas within the first chamber 156. This causes a flow of the heated insulating gas and arc gasses, due to the pressure change, into the second chamber 158 disposed adjacent to the first chamber 156, but only at certain times during the arcing event.

[0050] As illustrated in FIGS 20-21, upon generation of the electrical arc, the valve assembly 150 is moved to gas downward state. Herein, the second valve plate 164 assumes the third position, i.e. the second valve plate 164 is seated on the first valve plate 162 and have moved the first valve plate 162 therewith to below the first position thereof, by overcoming the constrain on the movement of the first valve plate 162 by the plurality of Belleville springs 170 due to additional pressure built in the first chamber 156, allowing passage to the insulated gas into the second chamber 158. In other words, the first valve plate 162 is separated from the second valve plate 164 due to further pressure build-up of the insulating gas in the first chamber 156 overcoming the constrain of the Belleville springs 170 coupled thereto to provide a flow path for the insulating gas to flow out of the first chamber 156 to the second chamber 158.

[0051] Thus, the insulating gas flows into the second chamber 158 after the gas pressure in the first chamber 156 reaches the inlet threshold pressure, is held in the second chamber 158 for part of the arc cycle, and then flows out of the second chamber 158 and back into the first chamber 156 when the pressure in the first chamber 156 falls below the outlet threshold pressure. This gas flow may cool down the first chamber 156 and may also increase dielectric strength thereof. In one or more embodiments, the gas flow around the arc increases the arc voltage, thereby providing better current limiting performance.

[0052] FIG 22 is a flowchart 2200 listing steps involved in a method of operating a circuit breaker, such as the circuit breaker 100. At step 2202, the method includes providing a valve assembly 150 comprising a valve body 160 interconnecting a first chamber 156 and a second chamber 158 in the circuit breaker 100, a first valve plate 162 movably mounted in the valve body 160, and a second valve plate 164 arranged in the valve body 160 so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate 164 is seated on the first valve plate 162, in the second position, the second valve plate 164 is lifted from the first valve plate 162 to above the first position thereof, and in the third position, the second valve plate 164 is seated on the first valve plate 162 and moves the first valve plate 162 therewith below the first position thereof. At step 2204, the method includes providing a plurality of Belleville springs 170 radially arranged in the valve body 160 below the first valve plate 162 to constrain the movement of the first valve plate 162 up to the third position of the second valve plate 164 in the valve body 160. At step 2206, the method includes filling the second chamber 158 with insulating gas such that the second valve plate 164 assumes the second position during filling of the insulating gas into the second chamber 158 thereby, allowing passage to the insulated gas into the first chamber 156 which is at a lower pressure than the second chamber 158, and the second valve plate 164 assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber 156 is higher than in the second chamber 158. At step 2208, the method includes separating a first electrical contact 142 from a second electrical contact 154 in a first chamber 156 of the circuit breaker 100 to generate an electrical arc, such that the second valve plate 164 assumes the third position upon generation of the electrical arc, moving the first valve plate 162 therewith, by overcoming the constrain on the movement of the first valve plate 162 by the plurality of Belleville springs 170 due to additional pressure built in the first chamber 156, allowing passage to the insulated gas into the second chamber 158.

[0053] In the embodiments of the present disclosure, the function of multiple linear helical springs as used with valve arrangements of prior-art is carried out by utilizing a Belleville springs 170 below the first valve plate 162 (i.e. the pressure plate). This makes the design of the valve assembly 150 simple and easy to assemble. Use of the Belleville springs 170 results in compactness of the valve assembly 150, as the Belleville spring 170 can provide same stiffness (sufficient for executing the operation of the valve assembly 150) as helical spring with lesser diameter, i.e. large pressure can be supported with small Belleville spring and small installation space. Herein, the pressure can be adjusted by the stacking multiple Belleville spring units 178. Further, Belleville springs 170 has high service life under the dynamic load which leads to reduced maintenance cost. Use of the Belleville springs 170 also results in simple design and assembly. Furthermore, unlike valve arrangements of prior-art with linear helical springs, no guides are required to operate the Belleville springs 170. Further, the valve body 160 itself act as guide for the first valve plate 162 and the second valve plate 164. All of these factors result in that the present valve assembly 150 incorporates a lesser number of components, and thus provides an economical and cost-effective proposition to manufacture. This further results in more opening or space for the flow of the insulating gas, for flow into and out of the first chamber 156, thus increasing in efficiency and response time for the circuit breaker 100.

[0054] While the present disclosure has been described in detail with reference to certain embodiments, it should be appreciated that the present disclosure is not limited to those embodiments. In view of the present disclosure, many modifications and variations would be present themselves, to those skilled in the art without departing from the scope of the various embodiments of the present disclosure, as described herein. The scope of the present disclosure is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

Claims

1. A circuit breaker (100), comprising:

    first and second electrical contacts (142, 144), the electrical contacts (142, 144) configured to generate an electrical arc upon being separated during operation of the circuit breaker (100);
    a first chamber (156) at least partially surrounding the first and second electric contacts (142, 144);
    a second chamber (158) filled with insulating gas; and
    a valve assembly (150) configured to allow threshold-based flow of the insulating gas into and out of the first chamber (156), the valve assembly (150) comprising:

        a valve body (160) interconnecting the first chamber (156) and the second chamber (158);
        a first valve plate (162) movably mounted in the valve body (160); and
        a second valve plate (164) arranged in the valve body (160) so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate (164) is seated on the first valve plate (162), in the second position, the second valve plate (164) is lifted from the first valve plate (162) to above the first position thereof, and in the third position, the second valve plate (164) is seated on the first valve plate (162) and moves the first valve plate (162) therewith below the first position thereof, wherein the valve assembly (150) comprises a plurality of Belleville springs (170) radially arranged in the valve body (160) below the first valve plate (162), the plurality of Belleville springs (170) configured to constrain the movement of the first valve plate (162) up to the third position of the second valve plate (164) in the valve body (160) .

2. The circuit breaker (100) as claimed in claim 1, wherein the second valve plate (164) assumes the second position during filling of the insulating gas into the second chamber (158) thereby, allowing passage to the insulated gas into the first chamber (156) which is at a lower pressure than the second chamber (158), and wherein the second valve plate (164) assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber (156) is higher than in the second chamber (158).

3. The circuit breaker (100) as claimed in claim 1, wherein the second valve plate (164) assumes the third position upon generation of the electrical arc, moving the first valve plate (162) therewith, by overcoming the constrain on the movement of the first valve plate (162) by the plurality of Belleville springs (170) due to additional pressure built in the first chamber (156), allowing passage to the insulated gas into the second chamber (158).

4. The circuit breaker (100) as claimed in claim 1, wherein the plurality of Belleville springs (170) are tensioned to define the constrain on the movement of the first valve plate (162) in the valve body (160) based on desired threshold pressure of the insulating gas in the first chamber (156).

5. The circuit breaker (100) as claimed in claim 4, wherein each of the plurality of Belleville springs (170) comprises two or more Belleville spring units (178) arranged in a stacked configuration to provide the tension, to define the constrain on the movement of the first valve plate (162) in the valve body (160) based on the desired threshold pressure of the insulating gas in the first chamber (156).

6. The circuit breaker (100) as claimed in claim 1, wherein the valve assembly (150) further comprises a plurality of fasteners (172), corresponding to the plurality of Belleville springs (170), fixed to the valve body (160), and wherein each of the plurality of fasteners (172) supports one of the plurality of Belleville springs (170) below the first valve plate (162).

7. The circuit breaker (100) as claimed in claim 1, wherein the valve body (160) comprises a stopper (180) formed therein, such that the stopper (180) limits the lifting of the second valve plate (164) up to the second position thereof in the valve body (160) .

8. The circuit breaker (100) as claimed in claim 1, wherein the valve body (160) has a substantially cylindrical shape.

9. The circuit breaker (100) as claimed in claim 1, wherein the first valve plate (162) has one or more openings (168) formed therein, and wherein the second valve plate (164) is seated on the first valve plate (162) in a manner so as to seal the one or more openings (168) thereof.

10. A valve assembly (150) for a circuit breaker (100) having a first chamber (156) and a second chamber (158) filled with insulating gas, the valve assembly (150) comprising:

a valve body (160) interconnecting the first chamber (156) and the second chamber (158);
a first valve plate movably mounted in the valve body;
a second valve plate movably seated on the first valve plate; and
a first valve plate (162) movably mounted in the valve body (160) ;
a second valve plate (164) arranged in the valve body (160) so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate (164) is seated on the first valve plate (162), in the second position, the second valve plate (164) is lifted from the first valve plate (162) to above the first position thereof, and in the third position, the second valve plate (164) is seated on the first valve plate (162) and moves the first valve plate (162) therewith below the first position thereof; and
a plurality of Belleville springs (170) radially arranged in the valve body (160) below the first valve plate (162), the plurality of Belleville springs (170) configured to constrain the movement of the first valve plate (162) up to the third position of the second valve plate (164) in the valve body (160) .

11. The valve assembly (150) as claimed in claim 10, wherein the second valve plate (164) assumes the second position during filling of the insulating gas into the second chamber (158) thereby, allowing passage to the insulated gas into the first chamber (156) which is at a lower pressure than the second chamber (158), and wherein the second valve plate (164) assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber (156) is higher than in the second chamber (158).

12. The valve assembly (150) as claimed in claim 10, wherein the second valve plate (164) assumes the third position upon generation of the electrical arc, moving the first valve plate (162) therewith, by overcoming the constrain on the movement of the first valve plate (162) by the plurality of Belleville springs (170) due to additional pressure built in the first chamber (156).

13. The valve assembly as claimed in claim 11, wherein the plurality of Belleville springs (170) are tensioned to define the constrain on the movement of the first valve plate (162) in the valve body (160) based on desired threshold pressure of the insulating gas in the first chamber (156).

14. The valve assembly as claimed in claim 11, wherein each of the plurality of Belleville springs (170) comprises two or more Belleville spring units (178) arranged in a stacked configuration to provide the tension, to define the constrain on the movement of the first valve plate (162) in the valve body (160) based on the desired threshold pressure of the insulating gas in the first chamber (156).

15. A method of operating a circuit breaker (100), comprising:

providing a valve assembly (150) comprising a valve body (160) interconnecting a first chamber (156) and a second chamber (158) in the circuit breaker (100), a first valve plate (162) movably mounted in the valve body (160), and a second valve plate (164) arranged in the valve body (160) so as to move between a first position, a second position and a third position therein, wherein in the first position, the second valve plate (164) is seated on the first valve plate (162), in the second position, the second valve plate (164) is lifted from the first valve plate (162) to above the first position thereof, and in the third position, the second valve plate (164) is seated on the first valve plate (162) and moves the first valve plate (162) therewith below the first position thereof;

providing a plurality of Belleville springs (170) radially arranged in the valve body (160) below the first valve plate (162) to constrain the movement of the first valve plate (162) up to the third position of the second valve plate (164) in the valve body (160);

filling the second chamber (158) with insulating gas such that the second valve plate (164) assumes the second position during filling of the insulating gas into the second chamber (158) thereby, allowing passage to the insulated gas into the first chamber (156) which is at a lower pressure than the second chamber (158), and the second valve plate (164) assumes the first position upon completion of the filling of the insulating gas when the pressure in the first chamber (156) is higher than in the second chamber (158); and

separating a first electrical contact (142) from a second electrical contact (154) in a first chamber (156) of the circuit breaker (100) to generate an electrical arc, such that the second valve plate (164) assumes the third position upon generation of the electrical arc, moving the first valve plate (162) therewith, by overcoming the constrain on the movement of the first valve plate (162) by the plurality of Belleville springs (170) due to additional pressure built in the first chamber (156), allowing passage to the insulated gas into the second chamber (158).

FIG 1

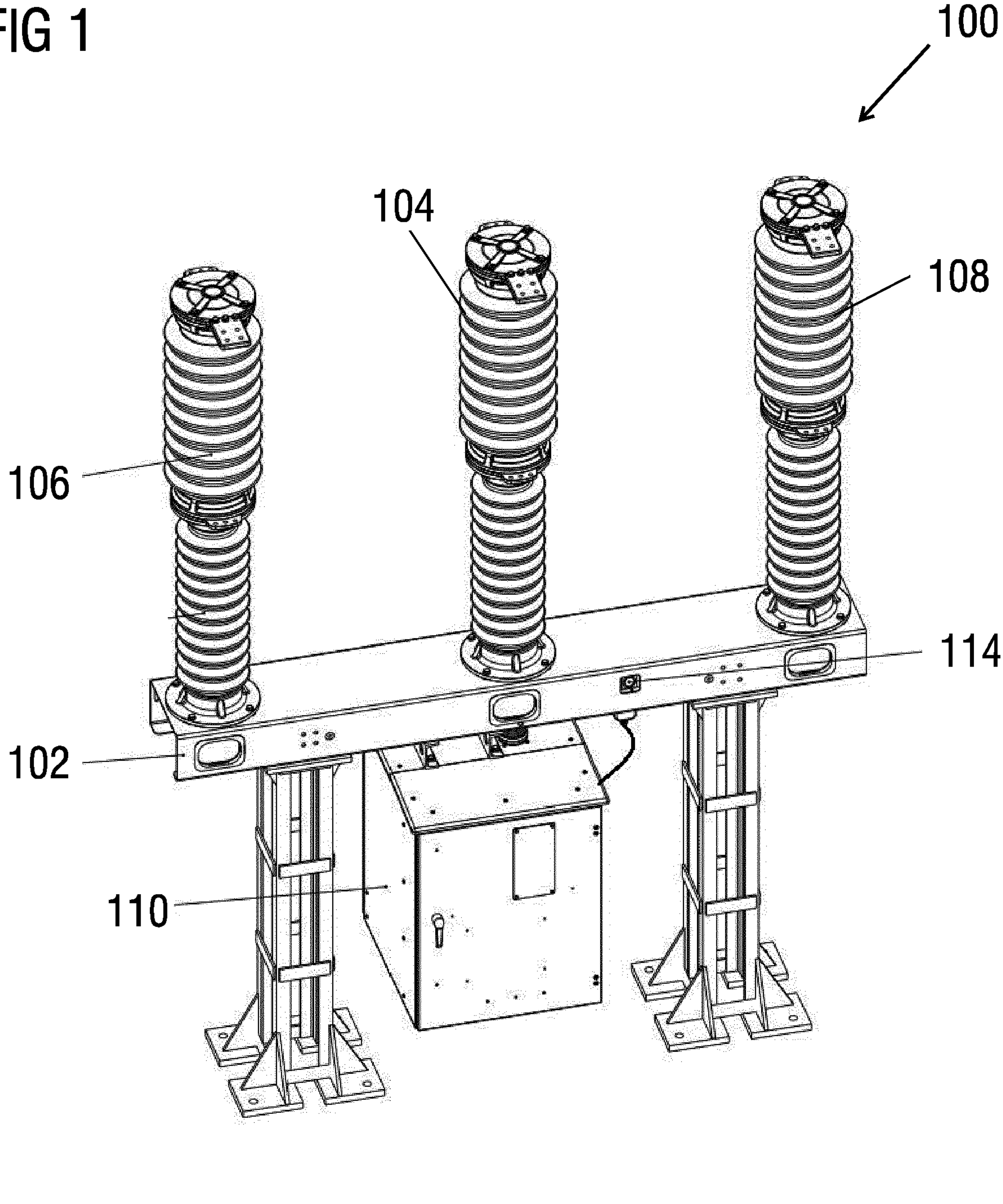


FIG 2

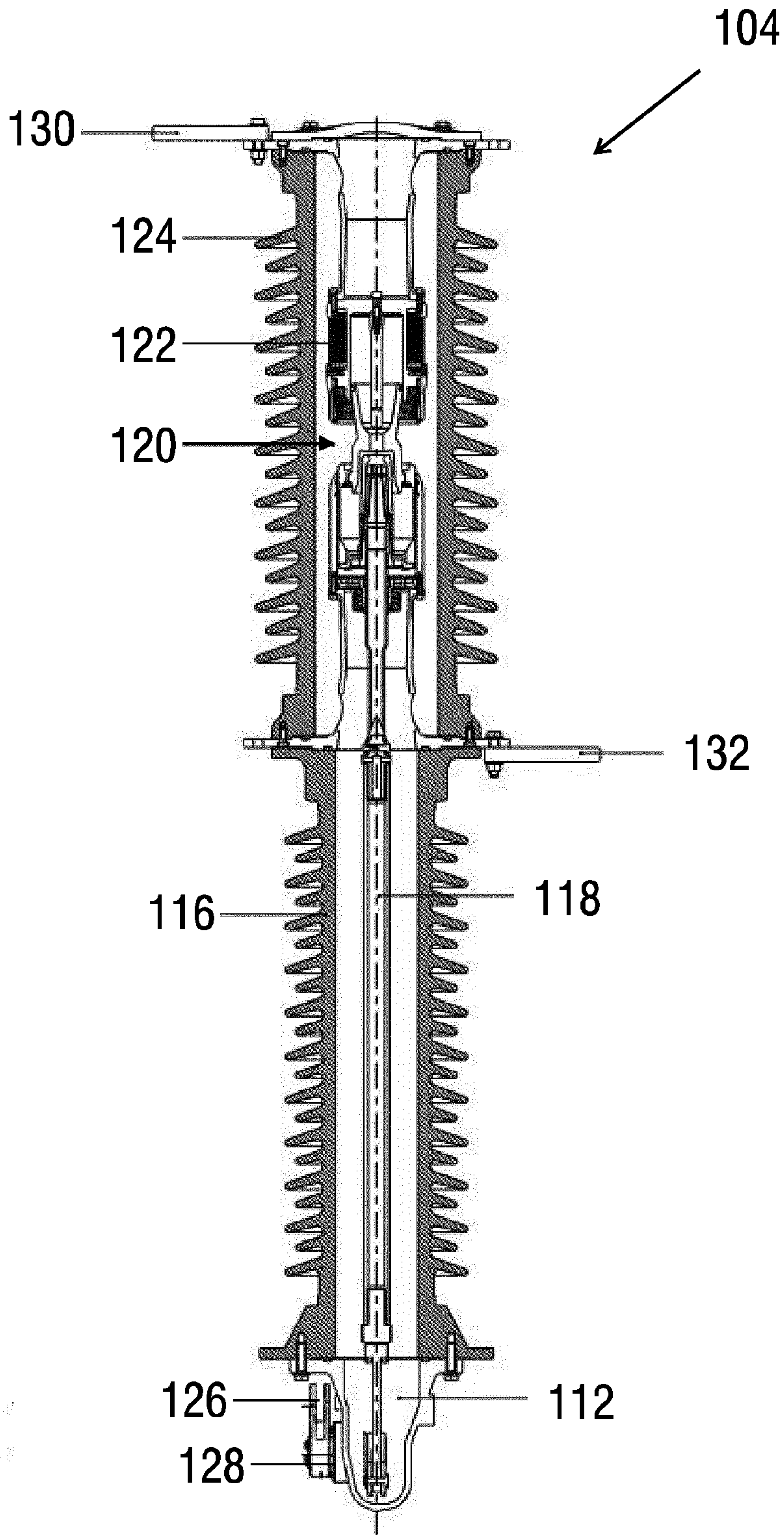
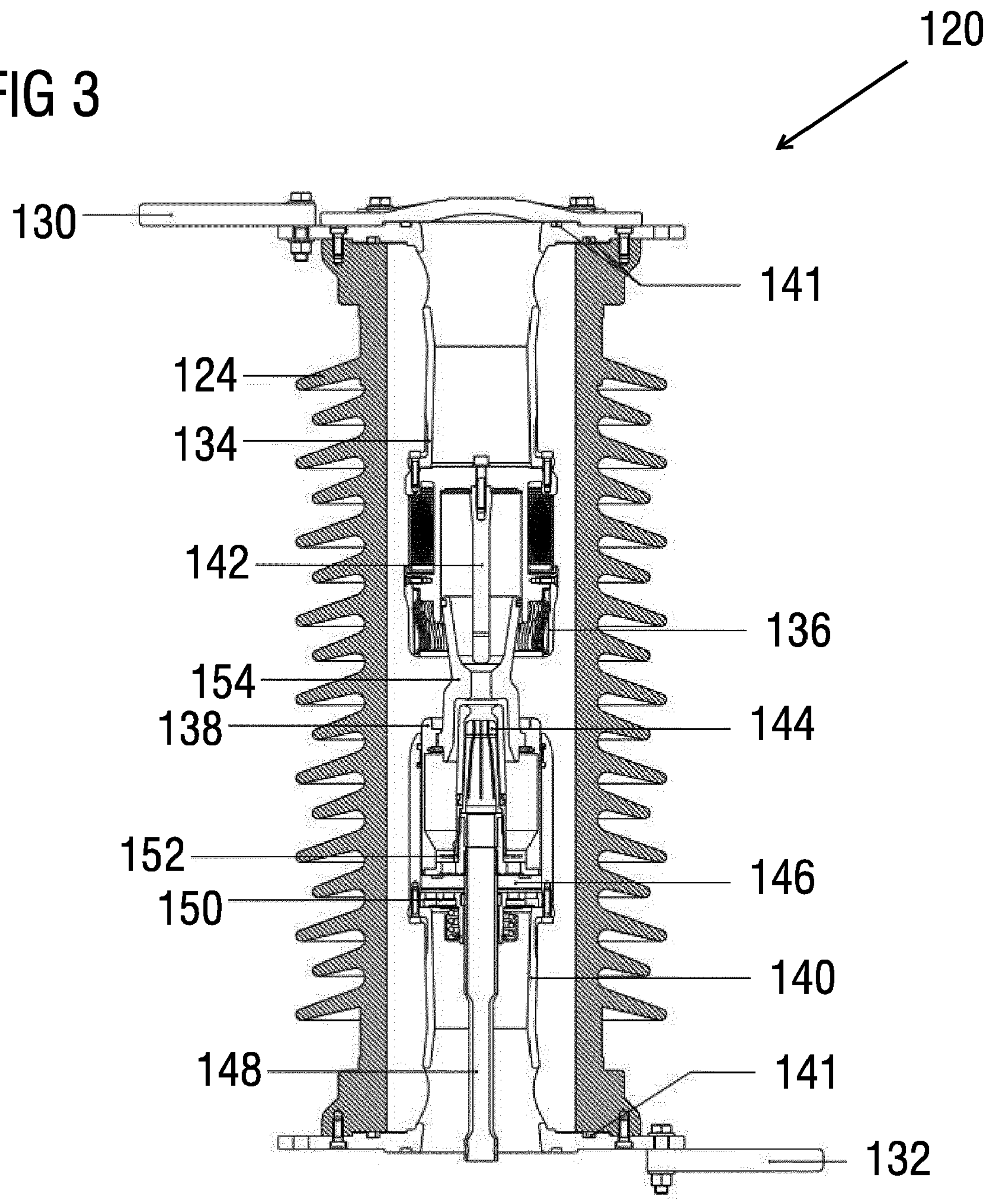


FIG 3


120
130
141
124
134
142
136
154
138
144
152
146
150
140
148
141
132

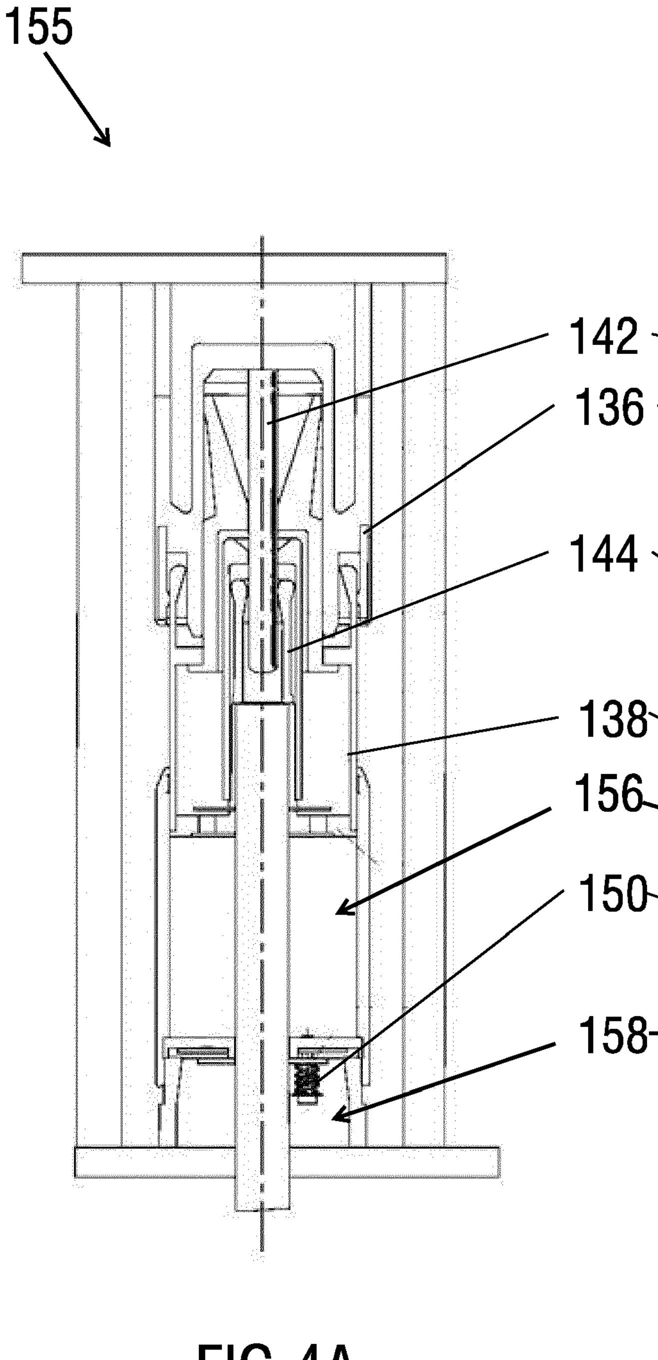


FIG 4A

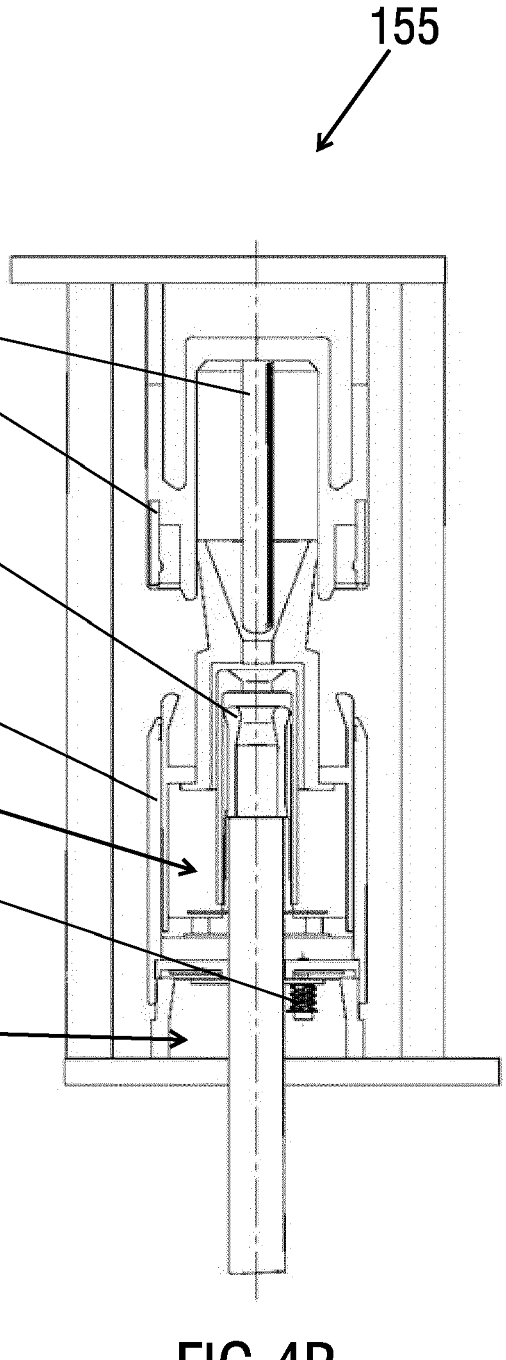


FIG 4B

FIG 5

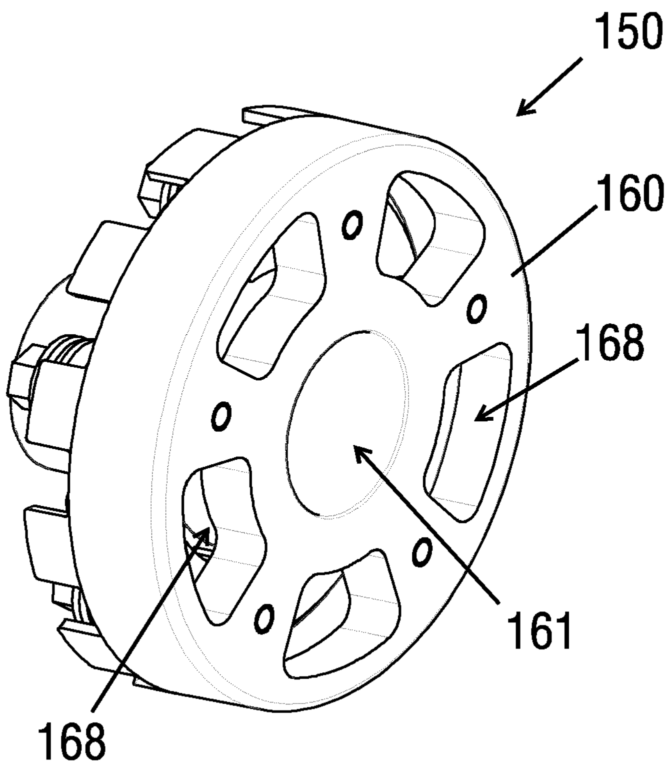


FIG 6

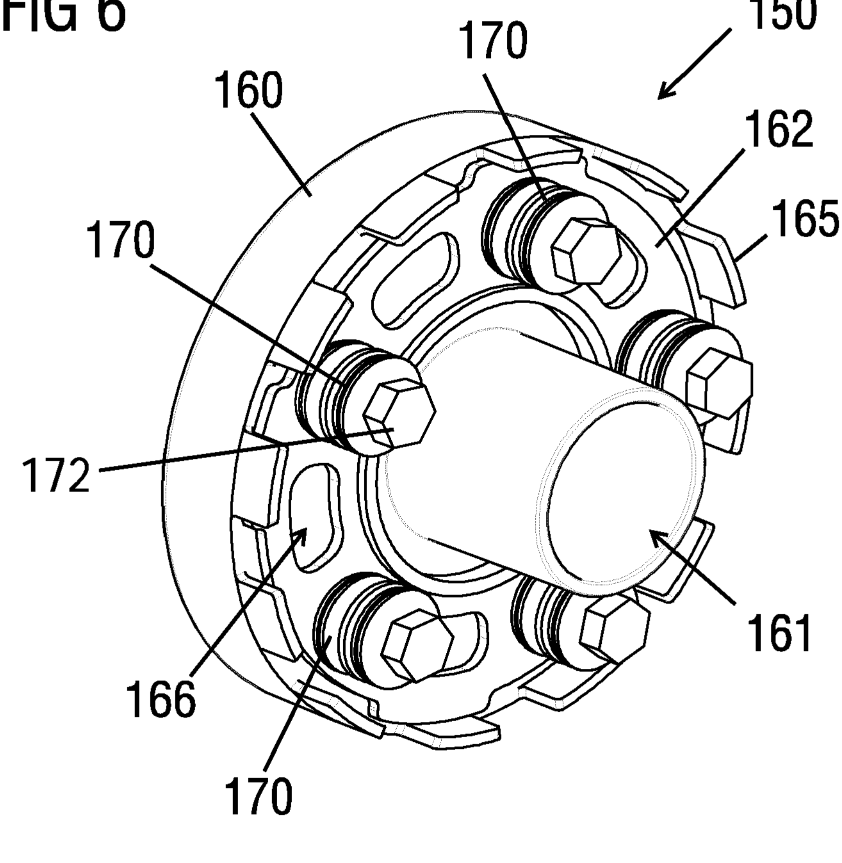


FIG 7

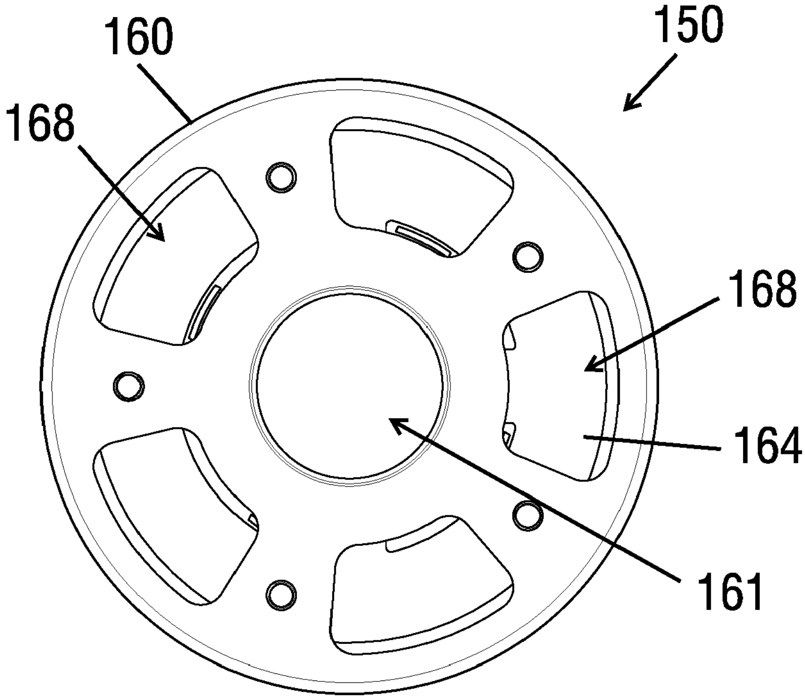


FIG 8

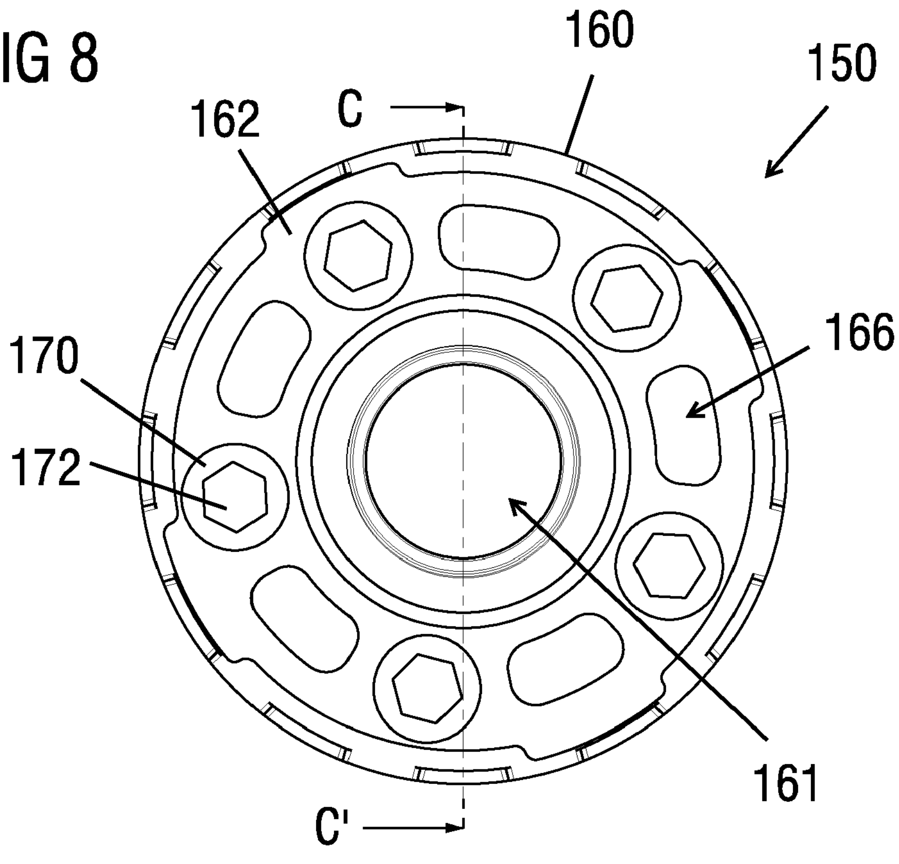


FIG 9

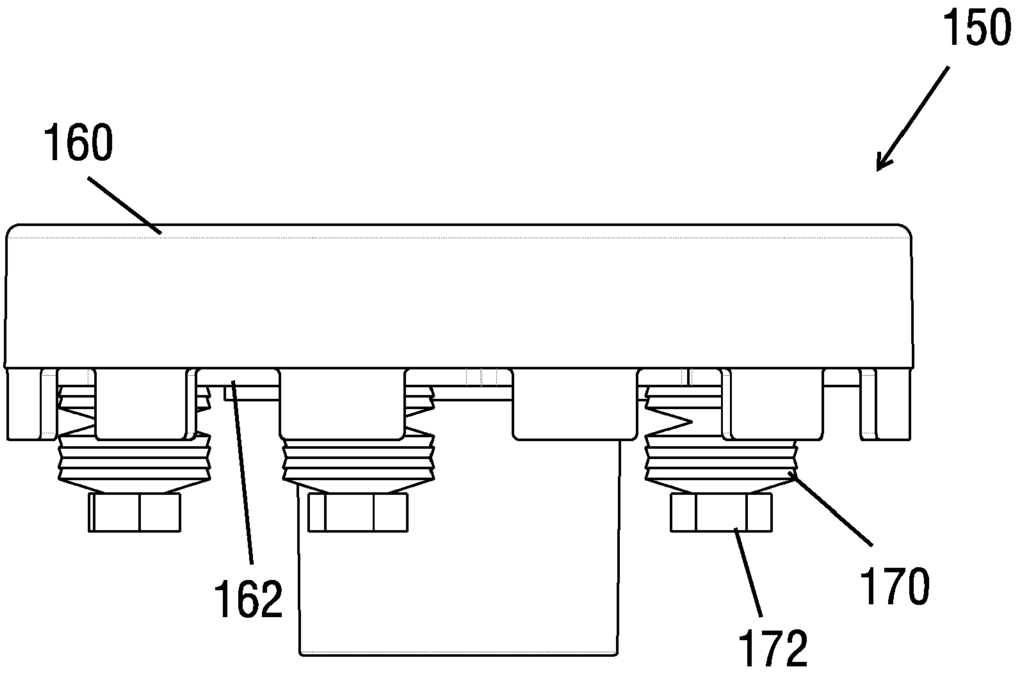
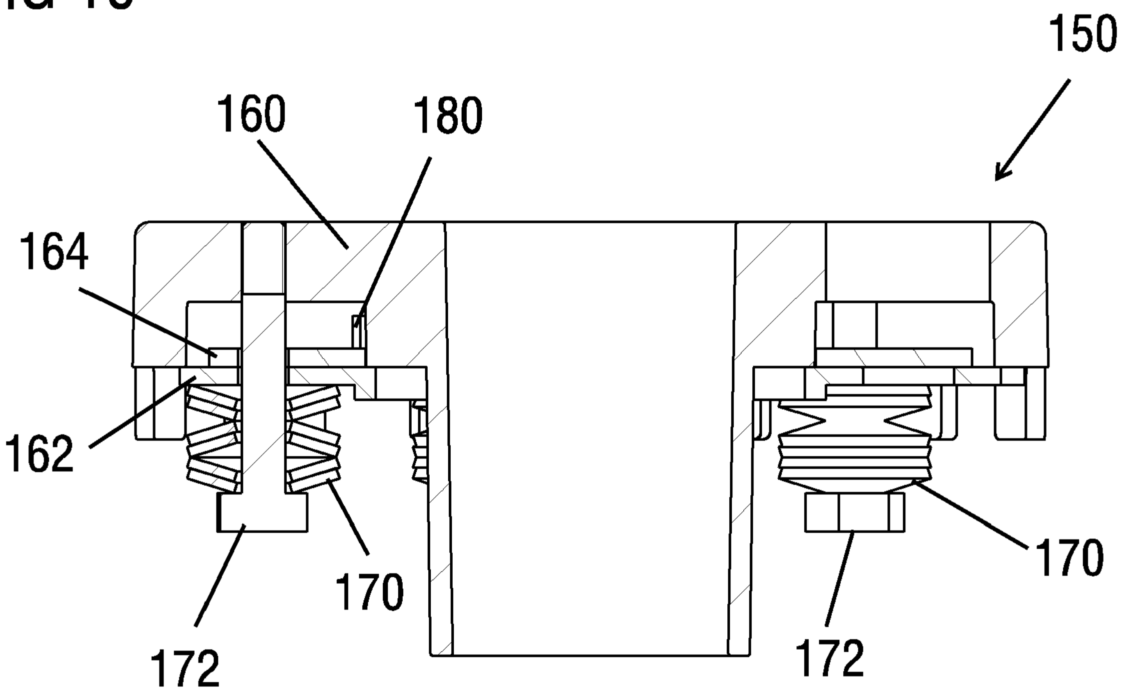


FIG 10



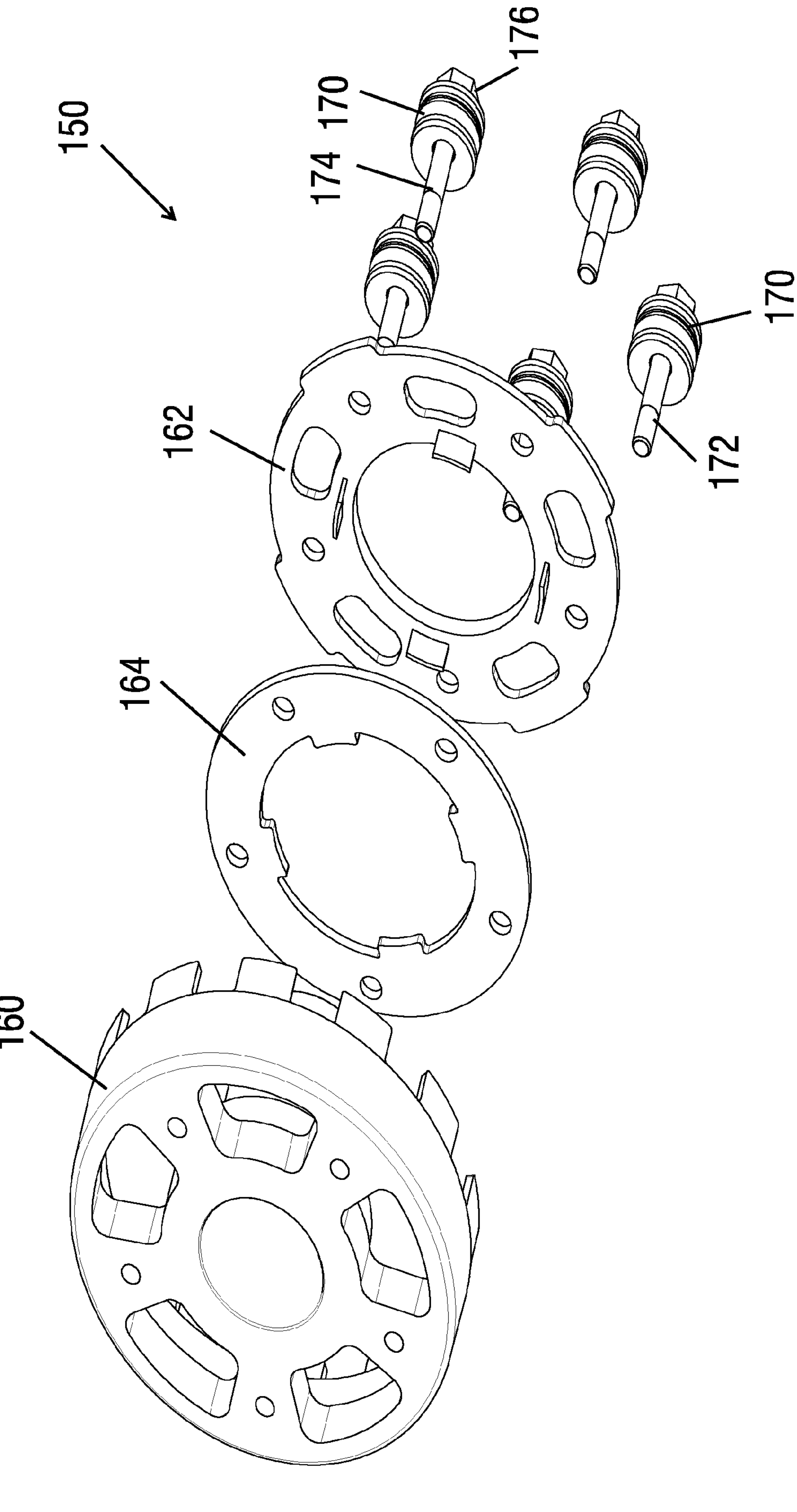


FIG 11

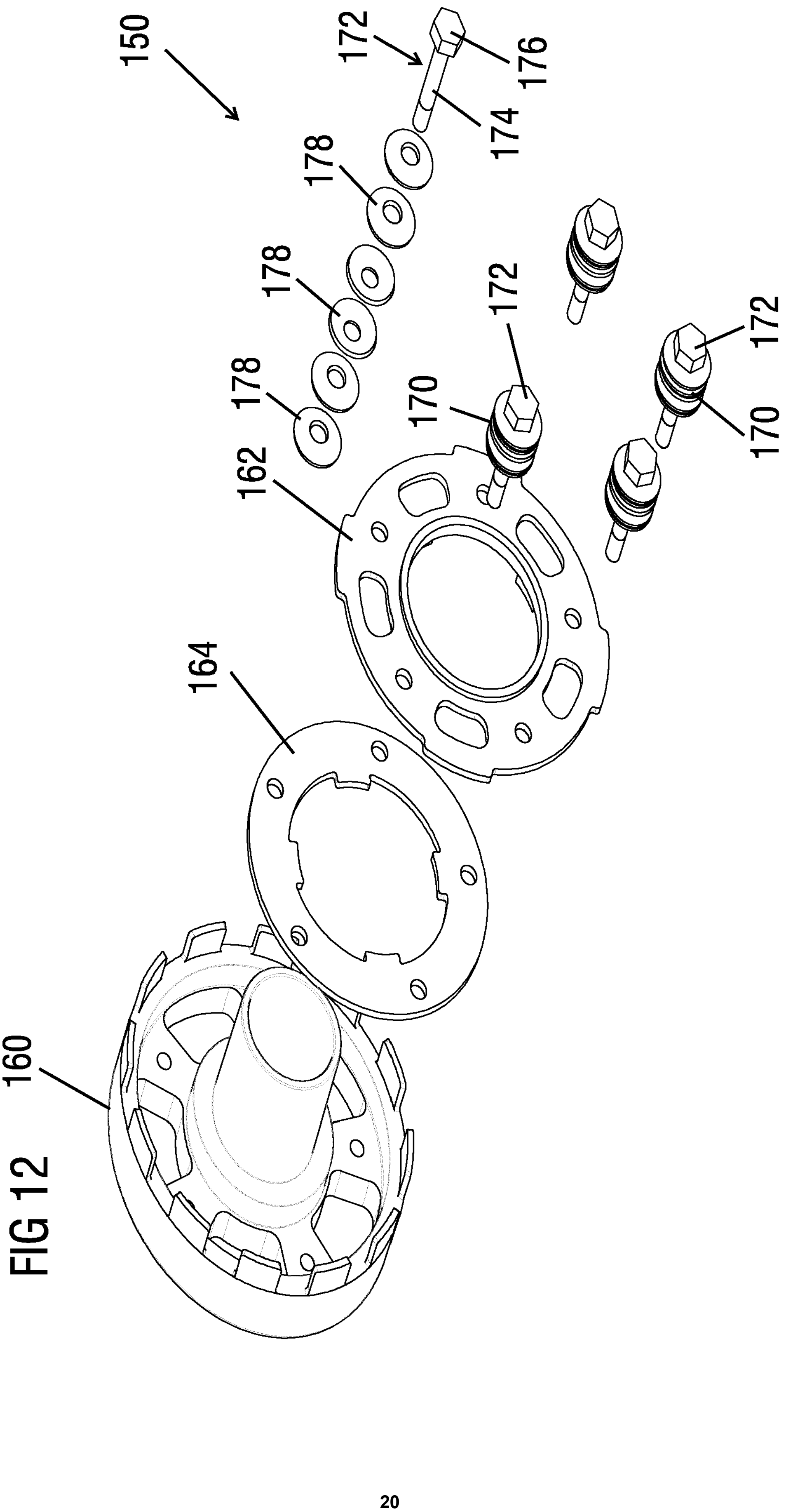


FIG 12

FIG 13

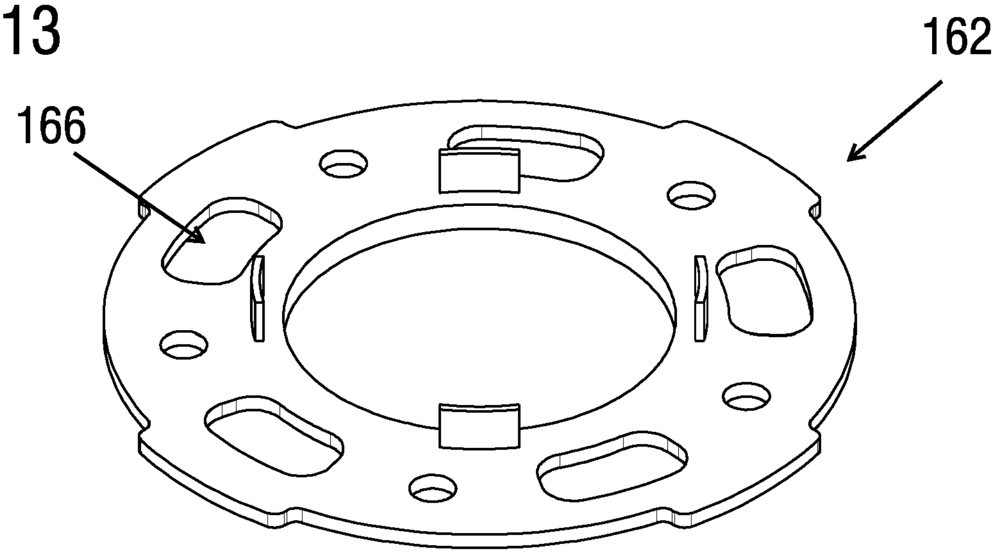


FIG 14

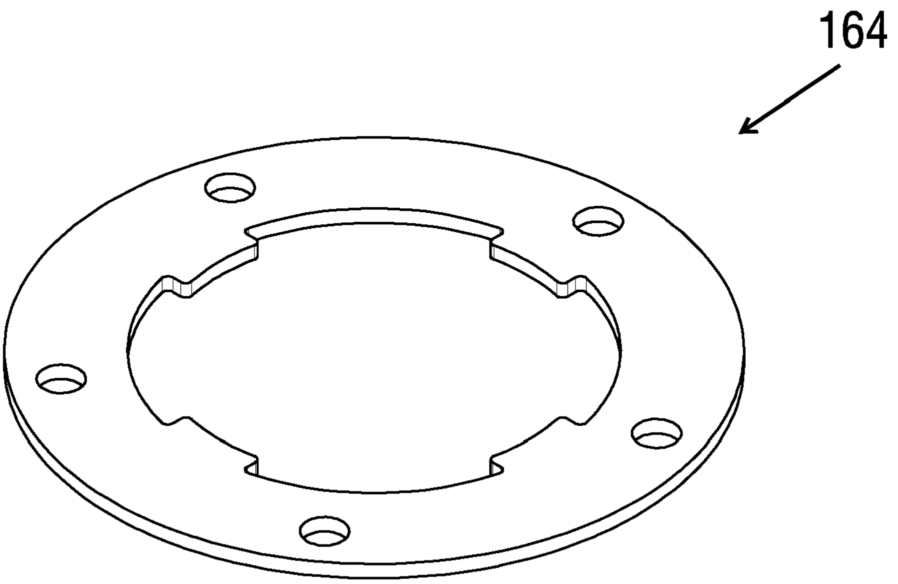


FIG 15

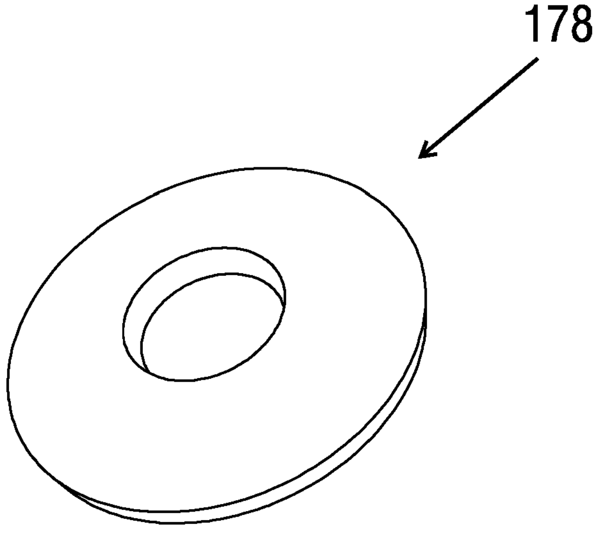


FIG 16

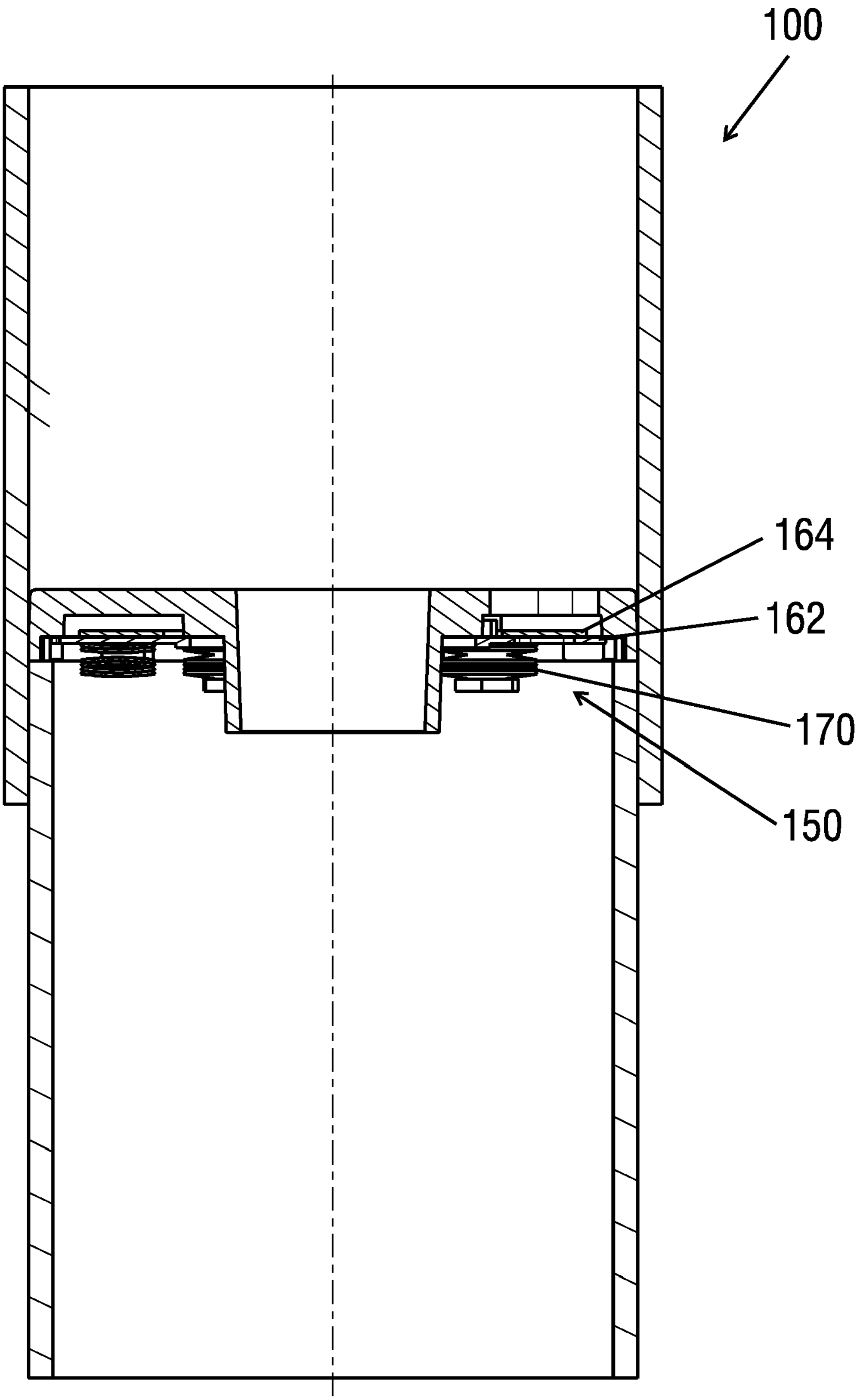


FIG 17

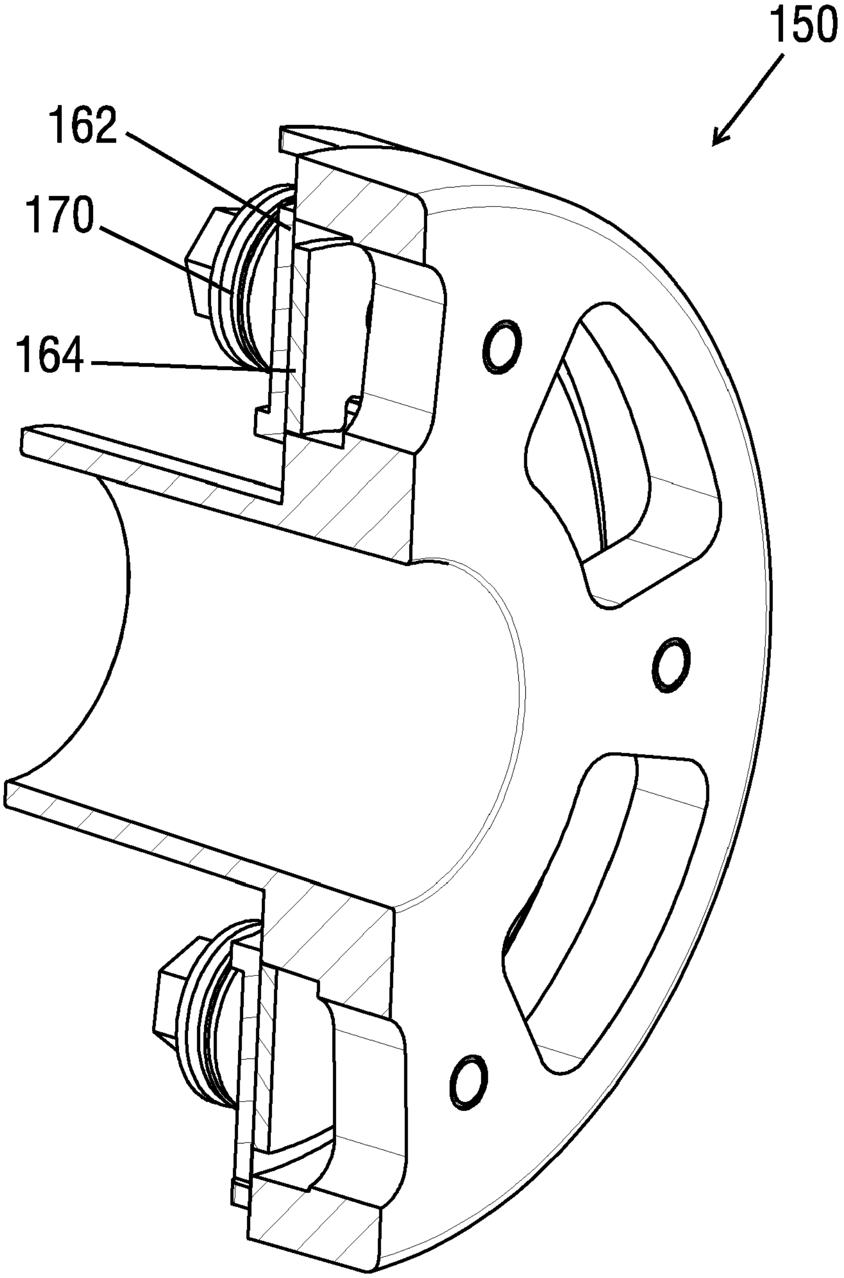


FIG 18

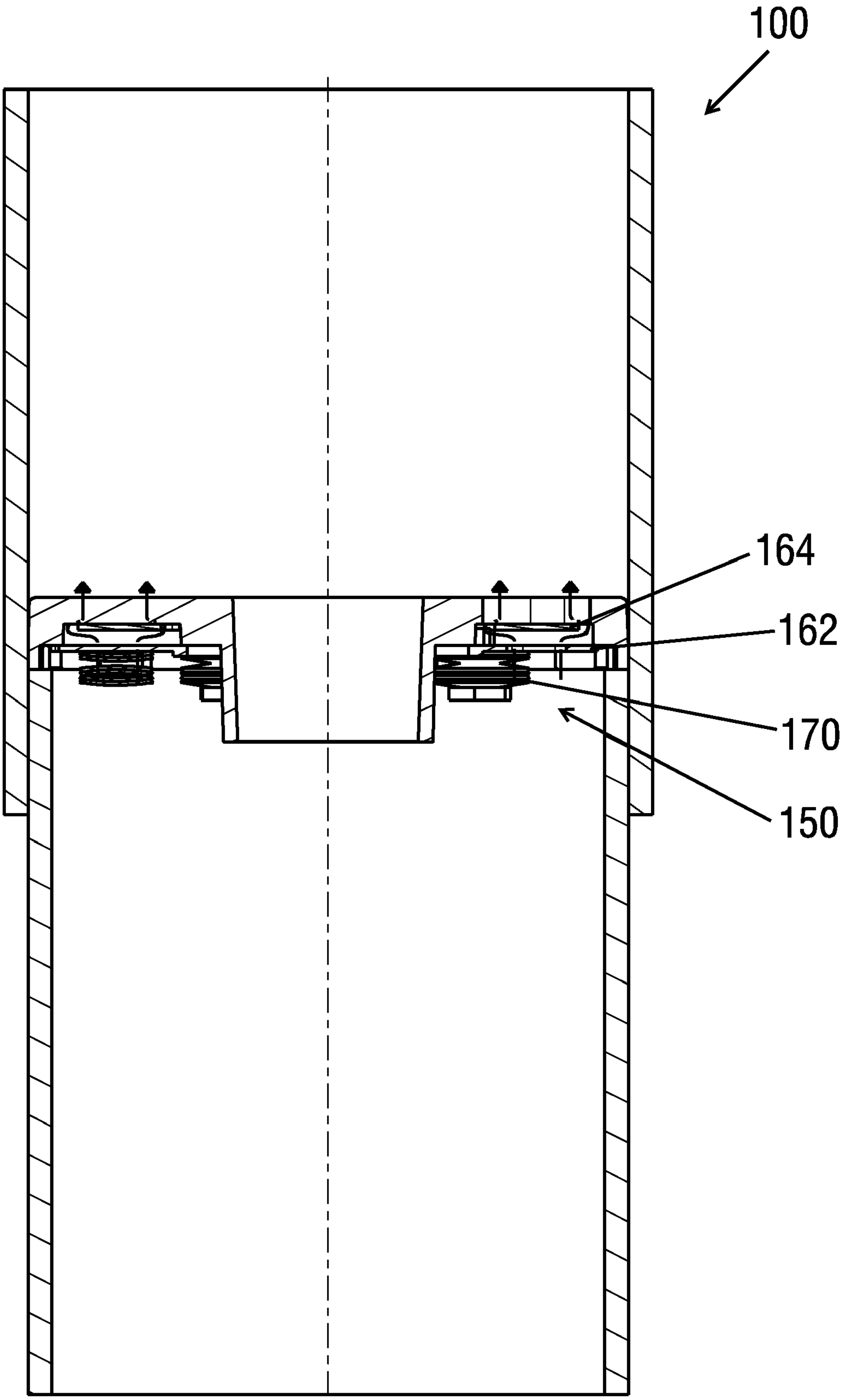


FIG 19

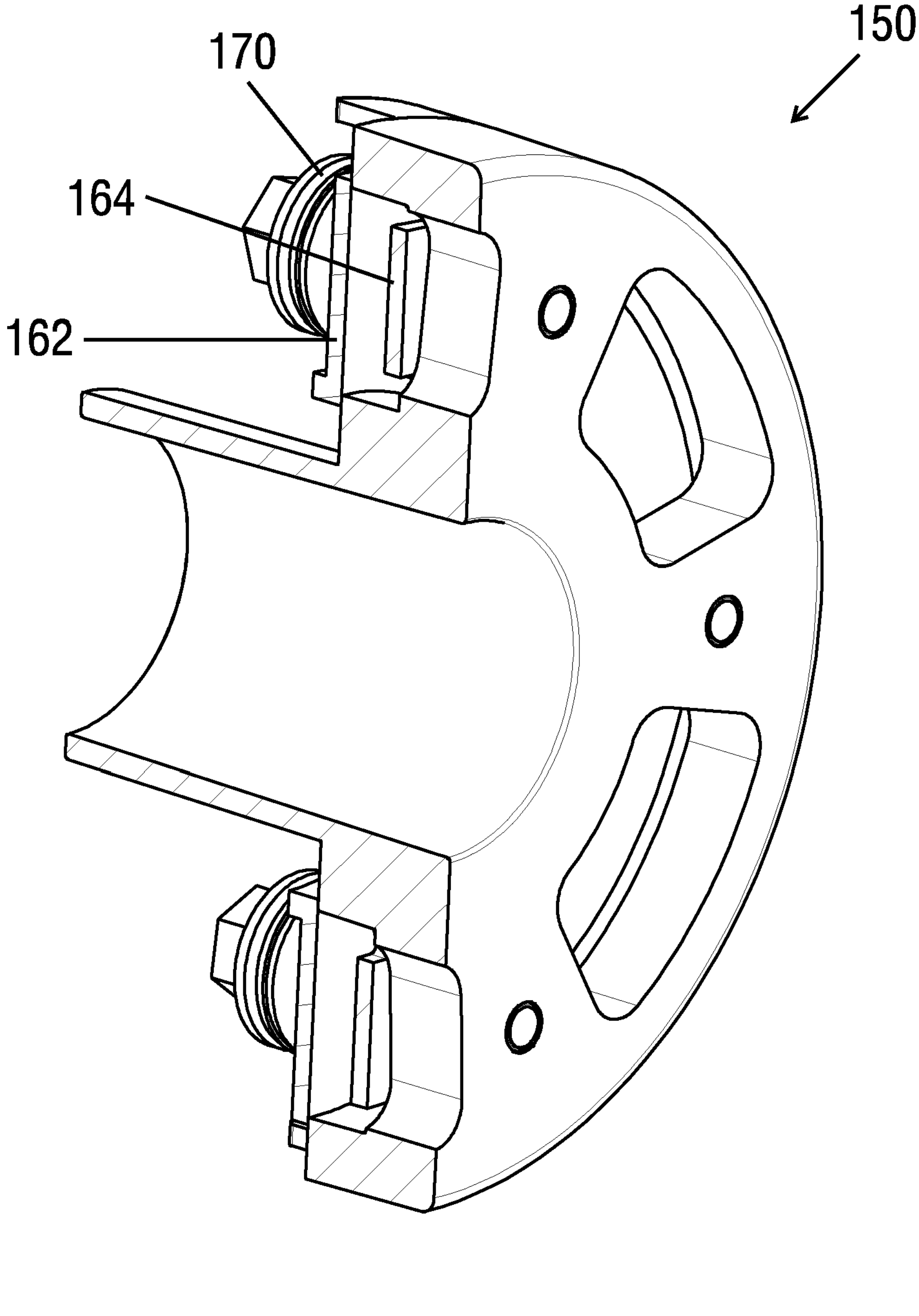


FIG 20

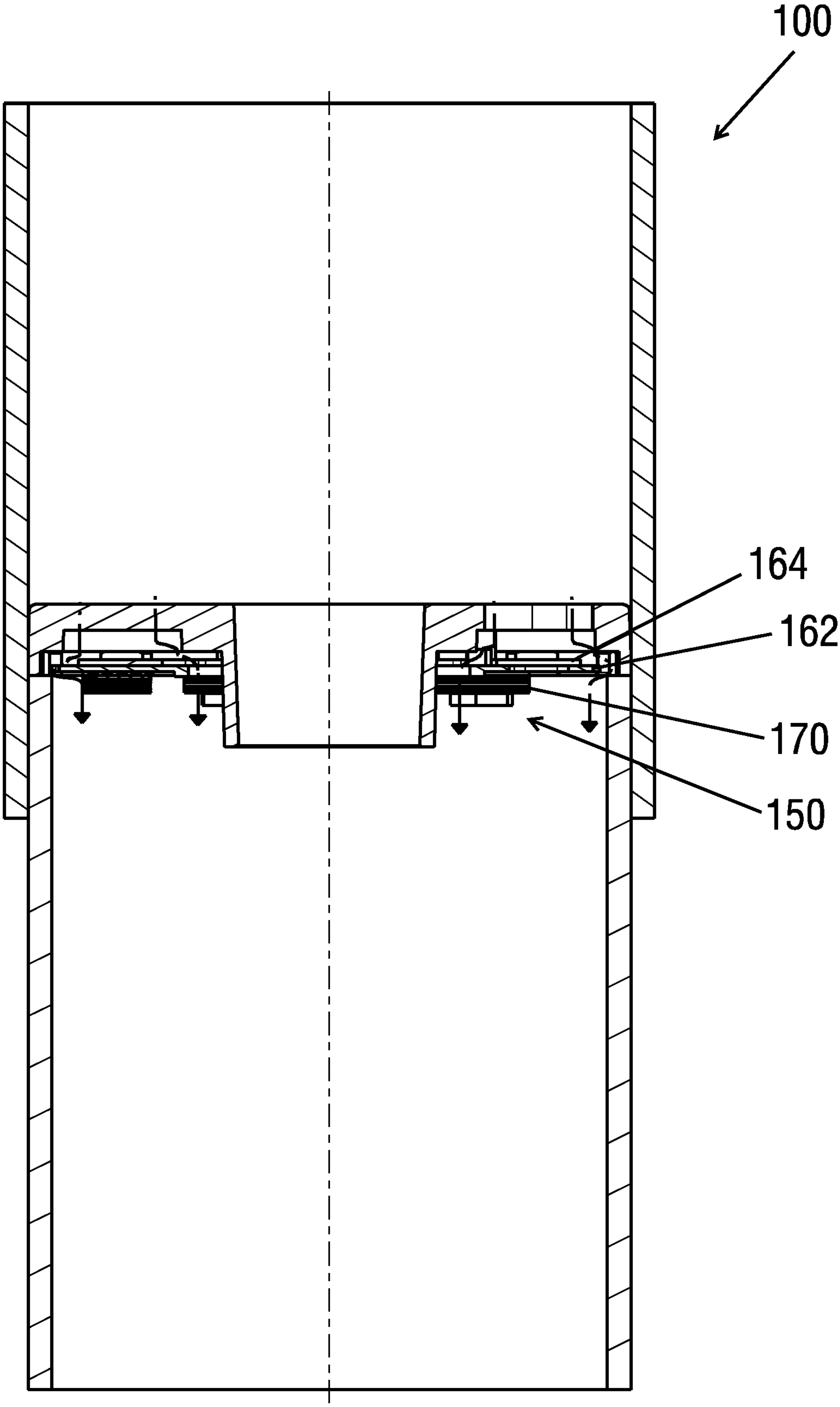


FIG 21

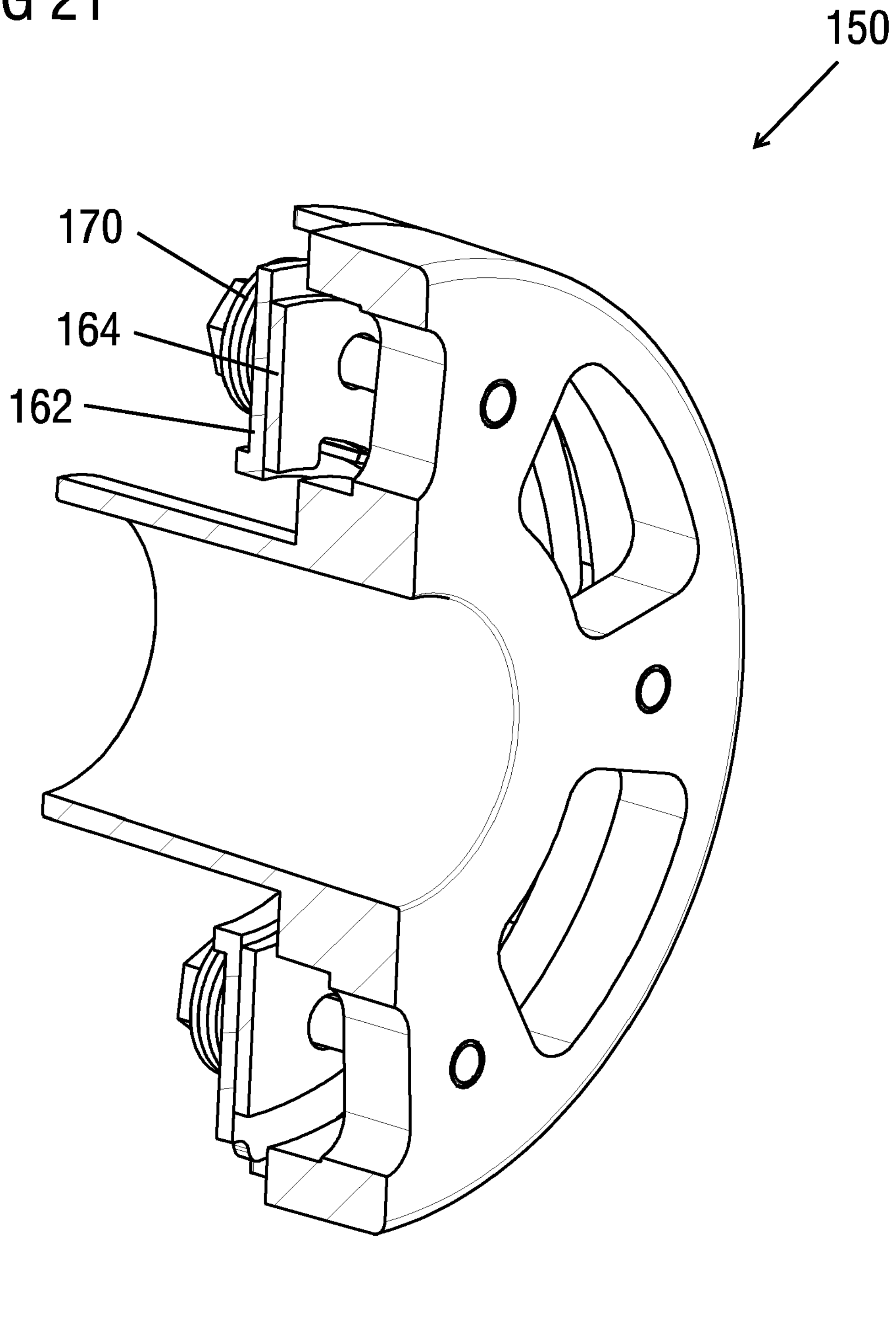
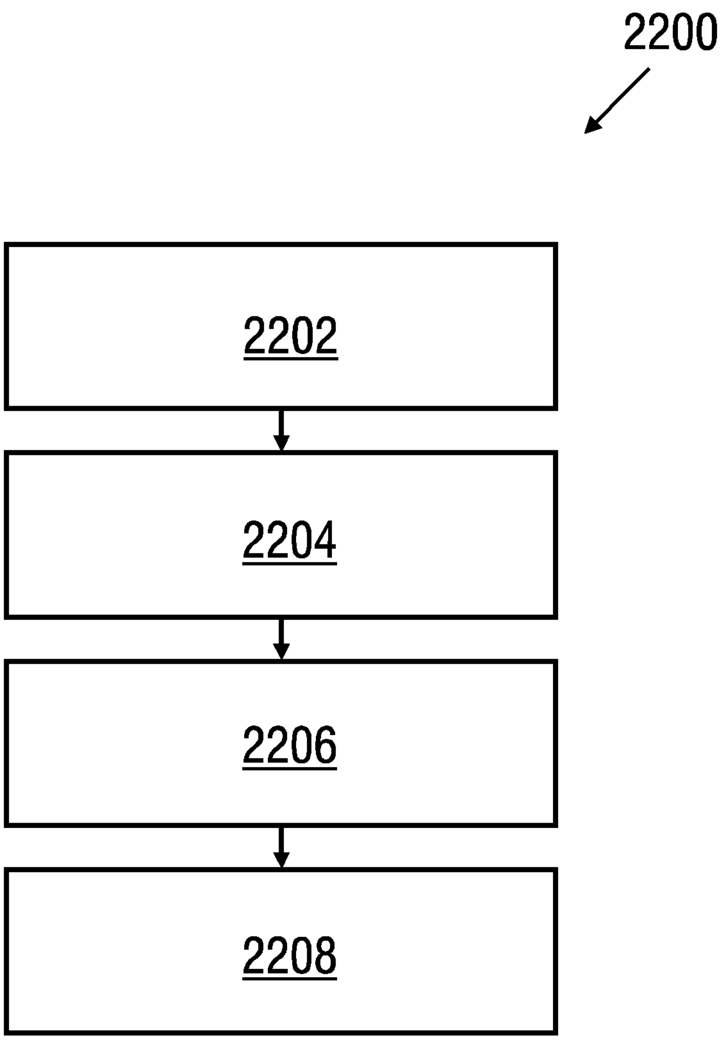


FIG 22



Europäisches Patentamt
European Patent Office
Office européen des brevets

PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 20 19 9459

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	EP 3 419 039 A1 (GENERAL ELECTRIC TECHNOLOGY GMBH [CH]) 26 December 2018 (2018-12-26) * the whole document * -----	1-9,15	INV. H01H33/90
Y	EP 0 951 039 A1 (ABB RESEARCH LTD [CH]) 20 October 1999 (1999-10-20) * paragraph [0023] * * paragraph [0028] * -----	1-9,15	
A	WO 93/20573 A1 (SIEMENS AG [DE]; LEHMANN VOLKER [DE] ET AL.) 14 October 1993 (1993-10-14) * claim 1 * -----	1-9,15	

TECHNICAL FIELDS SEARCHED (IPC)

H01H

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	19 April 2021	Socher, Günther

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04E07)

Europäisches Patentamt
European Patent Office
Office européen des brevets

INCOMPLETE SEARCH SHEET C

Application Number
EP 20 19 9459

Claim(s) completely searchable:
1-9, 15

Claim(s) not searched:
10-14

Reason for the limitation of the search:

The search is carried out in accordance to the applicant's letter dated 15.04.2021.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 19 9459

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

19-04-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 3419039 A1	26-12-2018	CA 3066186 A1	27-12-2018
		EP 3419039 A1	26-12-2018
		HU E050927 T2	28-01-2021
		US 2020219689 A1	09-07-2020
		WO 2018234076 A1	27-12-2018
EP 0951039 A1	20-10-1999	CN 1232280 A	20-10-1999
		DE 19816505 A1	21-10-1999
		EP 0951039 A1	20-10-1999
		JP 4786773 B2	05-10-2011
		JP H11329191 A	30-11-1999
		US 6163001 A	19-12-2000
WO 9320573 A1	14-10-1993	CA 2133330 A1	01-10-1993
		DE 4211159 A1	07-10-1993
		EP 0634049 A1	18-01-1995
		US 5589673 A	31-12-1996
		WO 9320573 A1	14-10-1993

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 3419039 A1 **[0007]**