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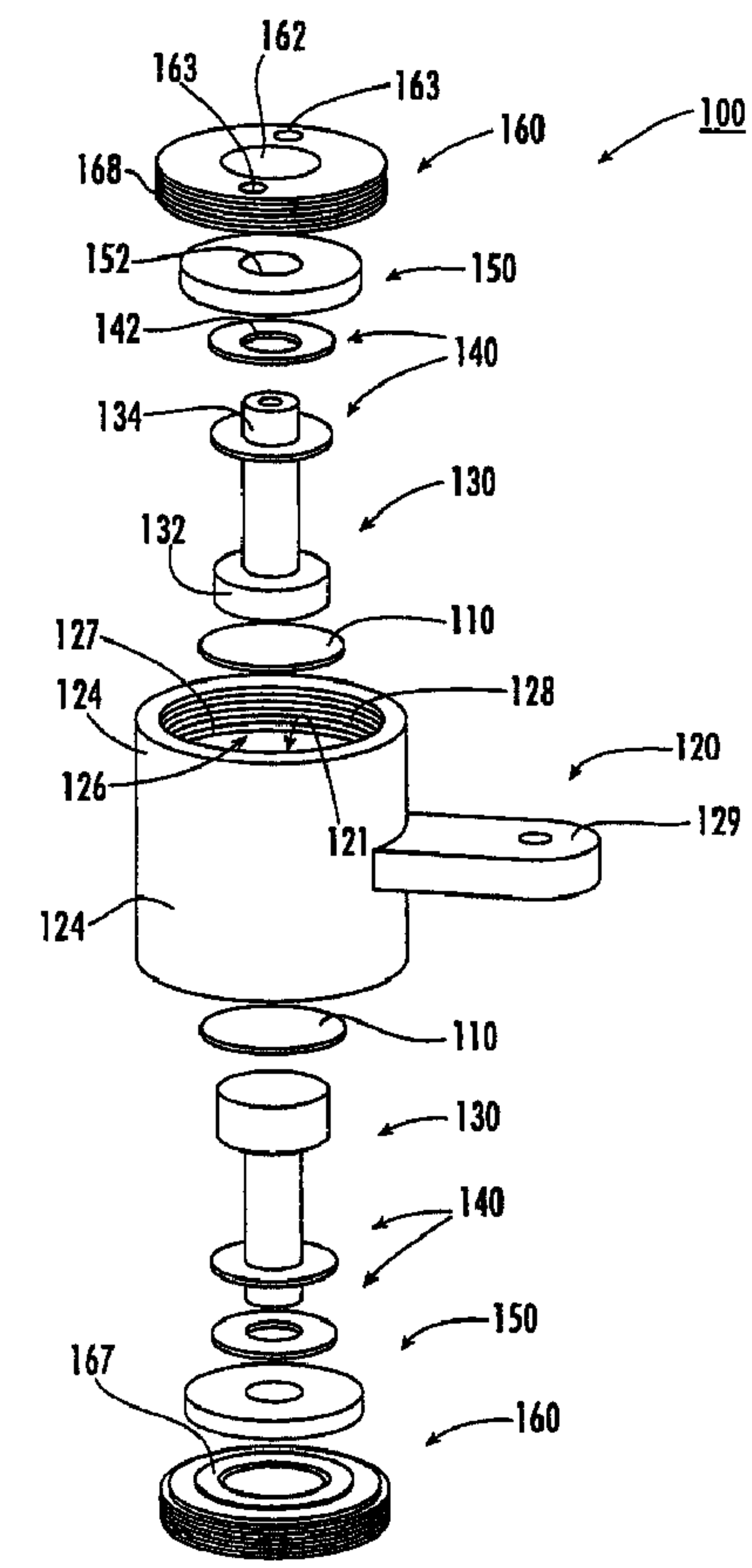

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material and having first and second opposed, substantially planar wafer surfaces is positioned between the first and second contact surfaces with the first and second wafer surfaces engaging the first and second contact surfaces, respectively. The contact surfaces may apply a load to the wafer surfaces. Preferably, the electrode members have a combined thermal mass which is substantially greater than a thermal mass of the wafer. The wafer may be formed by slicing a rod of varistor material. The device may include a housing including the first substantially planar contact surface and a sidewall, the housing defining a cavity within which the second electrode is disposed.

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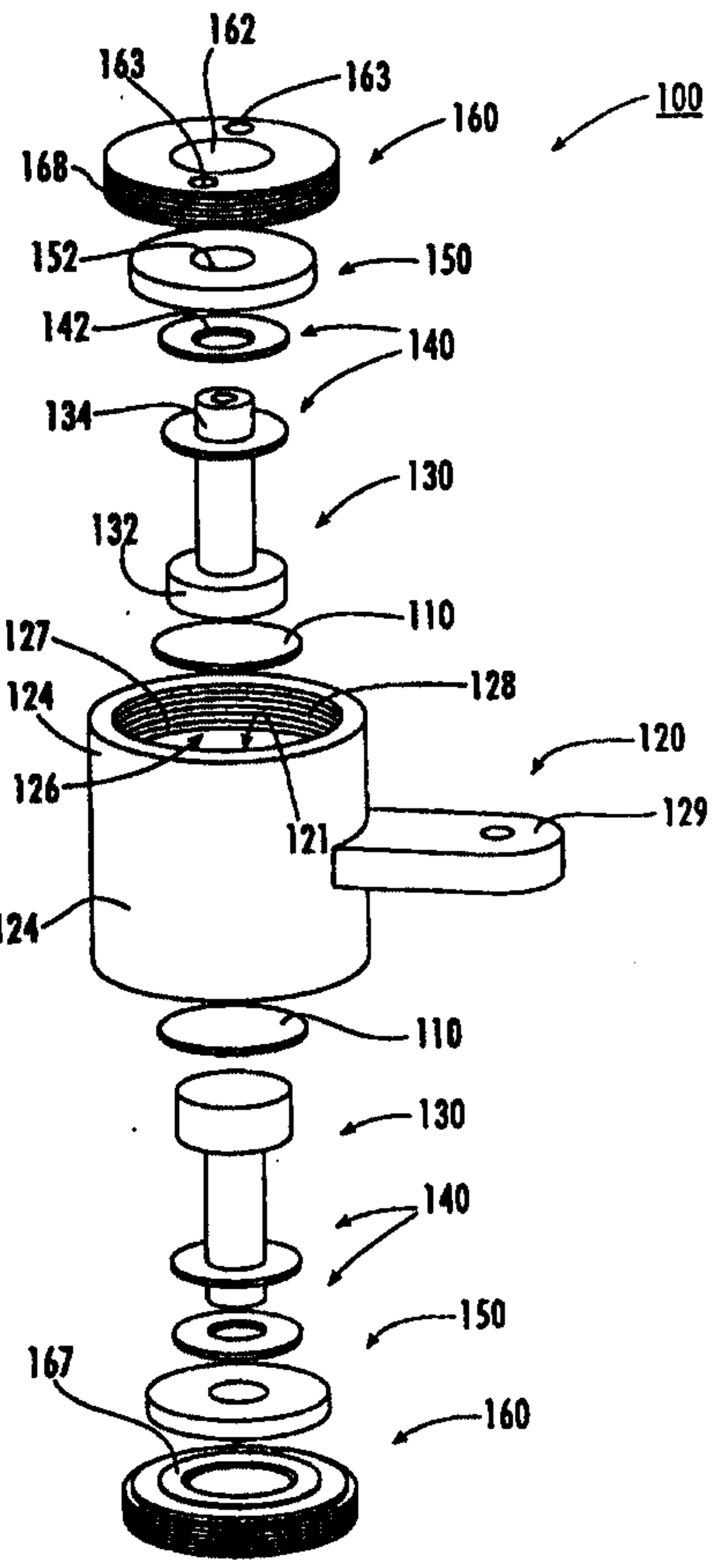
(54) Title: OVERVOLTAGE PROTECTION DEVICE INCLUDING WAFER OF VARISTOR MATERIAL

(57) Abstract

An overvoltage protection device includes a first electrode member having a first substantially planar contact surface and a second electrode member having a second substantially planar contact surface facing the first contact surface. A wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces is positioned between the first and second contact surfaces with the first and second wafer surfaces engaging the first and second contact surfaces, respectively. The contact surfaces may apply a load to the wafer surfaces. Preferably, the electrode members have a combined thermal mass which is substantially greater than a thermal mass of the wafer. The wafer may be formed by slicing a rod of varistor material. The device may include a housing including the first substantially planar contact surface and a sidewall, the housing defining a cavity within which the second electrode is disposed.



OVERVOLTAGE PROTECTION DEVICE INCLUDING WAFER OF VARISTOR MATERIAL

Field of the Invention

The present invention relates to voltage surge protection devices and, more particularly, to a voltage surge protection device including a wafer of varistor material.

Background of the Invention

Frequently, excessive voltage is applied across service lines which deliver power to residences and commercial and institutional facilities. Such excess voltage or voltage spikes may result from lightning strikes, for example. The voltage surges are of particular concern in telecommunications distribution centers, hospitals and other facilities where equipment damage caused by voltage surges and resulting down time may be very costly.

Typically, one or more varistors (*i.e.*, voltage dependent resistors) are used to protect a facility from voltage surges. Generally, the varistor is connected directly across an AC input and in parallel with the protected circuit. The varistor has a characteristic clamping voltage such that, responsive to a voltage increase beyond a prescribed voltage, the varistor forms a low resistance shunt path for the overvoltage current that reduces the potential for damage to the sensitive components. Typically, a line fuse may be provided in the protective circuit and this line fuse is blown or weakened by the essentially short circuit created by the shunt path.

Varistors have been constructed according to several designs for different applications. For heavy duty applications (e.g., surge current capability in the range of from about 60 to 100 kA) such as protection of telecommunications facilities, block varistors are commonly employed. A block varistor typically includes a disk shaped varistor element potted in a plastic housing. The varistor disk is formed by pressure casting a metal oxide material, such as zinc oxide, or other suitable material such as silicon carbide. Copper, or other electrically conductive material, is flame sprayed onto the opposed surfaces of the disk. Ring shaped electrodes are bonded to the coated opposed surfaces and the disk and electrode assembly is enclosed within the plastic housing. Examples of such block varistors include Product No. SIOV—B860K250 available from Siemens Matsushita Components GmbH & Co. KG and Product No. V271BA60 available from Harris Corporation.

Another varistor design includes a high energy varistor disk housed in a disk diode case. The diode case has opposed electrode plates and the varistor disk is positioned therebetween. One or both of the electrodes include a spring member disposed between the electrode plate and the varistor disk to hold the varistor disk in place. The spring member or members provide only a relatively small area of contact with the varistor disk.

The varistor constructions described above often perform inadequately in service. Often, the varistors overheat and catch fire. Overheating may cause the electrodes to separate from the varistor disk, causing arcing and further fire hazard. There may be a tendency for pinholing of the varistor disk to occur, in turn causing the varistor to perform outside of its specified range. During high current impulses, varistor disks of the prior art may crack due to piezoelectric effect, thereby degrading performance. Failure of such varistors has led to new governmental regulations for minimum performance specifications. Manufacturers of varistors have found these new regulations difficult to meet.

Summary of the Invention

In accordance with one aspect of the invention, there is provided an overvoltage protection device including a housing including a first substantially planar electrical contact surface and an electrically conductive, metal sidewall, the housing defining a cavity therein and having an opening in communication with the cavity. The overvoltage protection device also includes an electrode member including a substantially planar second electrical contact surface facing the first electrical contact surface and disposed within the cavity, a portion of the electrode extending out of the cavity and through the opening. The overvoltage protection device further includes a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, the wafer positioned within the cavity and between the first and second electrical contact surfaces with the first and second wafer surfaces engaging and in electrical contact with the first and second electrical contact surfaces, respectively. In response to an overvoltage surge condition between the housing and the electrode, the wafer provides a shunt path for surge current, thereby preventing an overvoltage condition between the housing and the electrode.

The first and second electrical contact surfaces may apply a load to the first and second wafer surfaces.

The load may be at least 264 lbs.

The load may be between about 528 and 1056 lbs.

The device may further include adjustable means maintaining the load such that the amount of the load may be selectively adjusted.

The device may further include biasing means for maintaining the load.

The biasing means may include a spring member biasing at least one of the first and second electrical contact surfaces against the wafer.

The device may further include a plurality of spring members biasing at least one of the first and second electrode members against the wafer.

The spring member may include a spring washer.

The spring member may include a Belleville washer.

The device may further include an end cap positioned in the opening, the end cap maintaining the load.

The device may further include a clip operative to limit displacement between the end cap and the housing to maintain the load.

The housing may include a slot formed therein and the clip engages the slot.

The housing may include a threaded portion and the end cap may include a threaded portion engaging the housing threaded portion whereby the end cap may be operable to selectively adjust and maintain the load.

The device may further include a spring member interposed between the end cap and the wafer.

The device may further include an electrically insulating member interposed between the second contact surface and the opening.

The device may further include an end cap positioned in the opening and having a hole formed therein. The electrode member may include a head positioned in the cavity between the end cap and the first electrical contact surface and a shaft extending out of the cavity and through the end cap hole.

The device may further include an electrically insulating ring member having a hole formed therein, the insulating ring member interposed between the head and the end cap and the shaft may extend through the insulating ring member hole.

The insulating ring member may include a main body ring portion and a projecting collar, the projecting collar surrounding the shaft and extending through the end cap hole.

The device may further include a spring washer having a hole formed therein, the spring washer interposed between the head and the end cap and the shaft may extend through the spring washer hole.

The device may include an electrically insulating ring member and a spring washer, the electrically insulating ring member having a hole formed therein and interposed between head and the end cap, the spring washer having a hole formed therein and interposed between head and the electrically insulating ring member, the shaft extending through each of the electrically insulating ring member hole and the spring washer hole.

The housing and the electrode member may have a combined thermal mass which is substantially greater than a thermal mass of the wafer.

The housing may include an electrode wall and second electrode member may include a head, each of the electrode wall and the head contacting one of the wafer surfaces and having a thermal mass which is substantially greater than the wafer thermal mass.

The thermal masses of the electrode wall and the head may be each at least twice the wafer thermal mass.

The thermal masses of the electrode wall and the head may be each at least ten times the wafer thermal mass.

The housing may be unitarily formed of metal.

The wafer may be formed by slicing a rod of varistor material.

The rod may be formed by at least one of extruding and casting.

The varistor material may be selected from the group consisting of a metal oxide compound and silicon carbide.

The wafer may include a coating of conductive metal on at least one of the first and second wafer surfaces.

The wafer may have a substantially circular peripheral edge and each of the first and second disk surfaces may be substantially coextensive with the circular peripheral edge.

Each of the first and second contact surfaces may be continuous and substantially free of voids.

In accordance with another aspect of the invention, there is provided an overvoltage protection device including a housing including an electrode wall and an electrically conductive, metal sidewall, the electrode wall and the sidewall defining a cavity and an opening in communication with the cavity, the electrode wall having a thermal mass and a first substantially planar electrical contact surface. The overvoltage protection device also includes an electrode member including a head positioned in the cavity and a shaft extending out of the cavity and through the opening, the head having a thermal mass and a substantially planar second electrical contact surface facing the first electrical contact surface. The overvoltage protection device further includes a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, the wafer positioned within the cavity and between the first and second electrical contact surfaces with the first and second wafer surfaces engaging the first and second electrical contact surfaces, respectively, the wafer having a thermal mass. The overvoltage protection device also includes an end cap positioned in the opening, the end cap having a hole through which the shaft extends. The overvoltage protection device further includes a spring member interposed between the end cap and the head, and the spring member biasing at least one of electrode wall and the head against the wafer to apply a load to the first and second wafer surfaces. Each of the head thermal mass and the electrode wall thermal mass is substantially greater than the thermal mass of the wafer.

The load may be at least 264 lbs.

The thermal masses of the electrode wall and the head may be each at least ten times the wafer thermal mass.

The wafer may be formed by slicing a rod of the varistor material.

The device may further include a clip and the housing may include a slot formed therein. The clip may be cooperative with the slot to limit displacement of the end cap relative to the housing and to maintain the load.

The housing may include a threaded portion and the end cap may include a threaded portion engaging the housing threaded portion whereby the end cap may be operable to selectively adjust and maintain the load.

The device may further include an electrically insulating ring member, the insulator ring member having a hole formed therein and interposed between the head and the end cap, the spring member having a hole formed therein and interposed between head and the insulating ring member whereby the spring member biases the head against the wafer, and the shaft may extend through each of the insulating ring member hole and the spring member hole.

The insulating ring member may include a main body ring portion and a projecting collar, the projecting collar surrounding the shaft and extending through the end cap hole.

In accordance with another aspect of the invention, there is provided an overvoltage protection device for use with a varistor wafer of the type having first and second opposed, substantially planar wafer surfaces. The device includes a housing including a first substantially planar electrical contact surface and an electrically conductive, metal sidewall, the housing defining a cavity therein and having an opening in communication with the cavity. The device also includes an electrode member including a substantially planar second electrical contact surface facing the first electrical contact surface and disposed within the cavity, a portion of the electrode extending out of the cavity and through the opening. The housing and the electrode member are relatively arranged and configured to receive the wafer within the cavity such that the wafer is positioned between the first and second electrical contact surfaces with the first and second electrical contact surfaces engaging and in electrical contact with the first and second wafer surfaces, respectively. In response to an overvoltage surge condition between the housing and the electrode, the wafer provides a shunt path for surge current, thereby preventing an overvoltage condition between the housing and the electrode.

In accordance with another aspect of the invention, there is provided an overvoltage protection device including a first electrode member having a first substantially planar contact surface. The overvoltage protection device includes a second electrode member having a second substantially planar contact surface facing the first contact surface. The device also includes a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, the wafer positioned between the first and second contact surfaces with the first and second wafer surfaces engaging the first and second contact surfaces, respectively. The device further includes biasing means including a Belleville washer biasing at least one of the first and second contact surfaces against the wafer to apply a load to the first and second wafer surfaces.

The load may be at least 264 lbs.

The load may be between about 528 and 1056 lbs.

The device may further include a plurality Belleville washers biasing at least one of the first and second electrode members against the wafer.

The spring member may include a spring washer.

The spring member may include a Belleville washer.

In accordance with another aspect of the invention, there is provided a method for assembling an overvoltage protection device. The method involves providing a first electrode member having a first substantially planar contact surface and providing a second electrode member having a second substantially planar contact surface facing the first contact surface. The method also involves providing a biasing means including a Belleville washer and placing a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces between the first and second contact surfaces such that the first and second wafer surfaces engage the first and second contact surfaces, respectively. The method further involves biasing the biasing means to apply a load between the first and second contact surfaces and against the first and second wafer surfaces and maintaining the load during an overvoltage event.

The step of biasing may include deflecting the Belleville washer.

In accordance with another aspect of the invention, the device may include a metal housing and further components may be configured to prevent or minimize the expulsion of flame, sparks and/or varistor material upon overvoltage failure of the varistor wafer.

Advantageously, the device reduces heat induced destruction or degradation of the varistor water as well as any tendency for the varistor water to produce sparks or flame. The relatively large thermal masses of the electrodes and the substantial contact areas between the electrodes and the varistor wafer also provide a more uniform temperature distribution in the varistor wafer, thereby reducing hot spots and resultant localized depletion of the varistor material.

Advantageously, the device responds to overvoltage conditions more efficiently and predictably, and high current spots which may cause pinholing are more likely to be avoided. Also, the tendency for the varistor wafer to warp responsive to high current impulses is prevented or reduced by the mechanical reinforcement provided by the electrodes. Moreover, during an overvoltage event, the device would be expected to provide lower inductance and lower resistance because of the more uniform and efficient current distribution through the varistor wafer.

Brief Description of the Drawings

The accompanying drawings which form a part of the specification, illustrate key embodiments of the present invention. The drawings and description together, serve to fully explain the invention. In the drawings,

Figure 1 is an exploded, perspective view of a varistor device according to the present invention;

Figure 2 is a top perspective view of the varistor device of **Figure 1**;

Figure 3 is a cross-sectional view of the varistor device of **Figure 1** taken along the line **3-3** of **Figure 2**;

Figure 4 is a perspective view of a varistor wafer;

Figure 5 is an exploded, perspective view of a varistor device according to a second embodiment of the present invention;

Figure 6 is a top perspective view of the varistor device of **Figure 5**;

Figure 7 is a bottom perspective view of the varistor device of **Figure 5**;

Figure 8 is a view of the varistor device of **Figure 5**, in which the varistor device is mounted in an electrical service utility box;

Figure 9 is an exploded, perspective view of a varistor device according to a third embodiment of the present invention;

Figure 10 is a top, perspective view of the varistor device of **Figure 9**; and

Figure 11 is a cross-sectional view of the varistor device of **Figure 9** taken along the line **11-11** of **Figure 10**.

Detailed Description of the Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

With reference to **Figures 1-3**, an overvoltage protection device according to a first embodiment of the present invention is shown therein and designated **100**. The device **100** includes a housing **120** of generally cylindrical shape. The housing is preferably formed of aluminum. However, any suitable conductive metal may be used. The housing has a center wall **122** (**Figure 3**), cylindrical walls **124** extending from the center wall in opposite directions, and a housing electrode ear **129** extending outwardly from the walls **124**. The housing is preferably unitary and axially symmetric as shown. The cylindrical walls **124** and the center wall **122** form cavities **121** on either side of the center wall, each cavity communicating with a respective opening **126**.

A piston-shaped electrode **130** is positioned in each of the cavities **121**. Shafts **134** of the electrodes **130** project outwardly through the respective openings **126**. The electrodes **130** are preferably formed of aluminum. However, any suitable conductive metal may be used. Additionally, and as discussed in greater detail below, a varistor wafer **110**, spring washers **140**, an insulator ring **150** and an end cap **160** are disposed in each cavity **121**.

In use, the device **100** may be connected directly across an AC or DC input, for example, in an electrical service utility box. Service lines are connected directly or indirectly to the electrode shafts **134** and the housing electrode ear **129** such that an electrical flow path is provided through the electrodes **130**, the varistor wafers **110**, the housing center wall **122** and the housing electrode ear **129**. In the absence of an overvoltage condition, the varistor wafers **110** provide high resistances such that no current flows through the device **100** as it appears electrically as an open circuit. In the event of an overvoltage condition (relative to the design voltage of the device), the resistances of the varistor wafers decrease rapidly, allowing current to flow through the device **100** and create a shunt path for current flow to protect other components of an associated electrical system. The general use and application of overvoltage protectors such as varistors is well known to those of skill in the art and, accordingly, will not be further detailed herein.

As will be appreciated from the Figures, the device **100** is axially symmetric, the upper and lower halves of the device **100** being constructed in the same manner. Accordingly, the device **100** will be described hereinafter with respect to the upper portion only, it being understood that such description applies equally to the lower portion.

Turning to the construction of the device **100** in greater detail, the electrode **130** has a head **132** and an integrally formed shaft **134**. As best seen in **Figure 3**, the head **132** has a substantially planar contact surface **132A** which faces a substantially planar contact surface **122A** of the housing center wall **122**. The varistor wafer **110** is interposed between the contact surfaces **122** and **132**. As described in more detail below, the head **132** and the center wall **122** are mechanically loaded against the varistor wafer **110** to ensure firm and uniform engagement between the surfaces **112** and **132A** and between the surfaces **114** and **122A**. A threaded bore **136** is formed in the end of the shaft **134** to receive a bolt for securing a bus bar or other electrical connector to the electrode **130**.

With reference to **Figure 4**, the varistor wafer **110** has a first substantially planar contact surface **112** and a second, opposed, substantially planar contact surface **114**. As used herein, the term "wafer" means a substrate having a thickness which is relatively small compared to its diameter, length or width dimensions. The varistor wafer **110** is preferably disk shaped. However, the varistor wafer may be formed in other shapes. The thickness **T** and the diameter **D** of the varistor **110** will depend on the varistor characteristics desired for the particular application. Preferably, and as shown, the varistor wafer **110** includes a wafer **111** of varistor material coated on either side with a conductive coating **112A, 114A,** so that the exposed surfaces of the coatings **112A** and **114A** serve as the contact surfaces **112** and **114**. Preferably, the coatings **112A, 114A** are formed of aluminum, copper or solder.

The varistor material may be any suitable material conventionally used for varistors, namely, a material exhibiting a nonlinear resistance characteristic with applied voltage. Preferably, the resistance becomes very low when a prescribed voltage is exceeded. The varistor material may be a doped metal oxide or silicon carbide, for example. Suitable metal oxides include zinc oxide compounds.

The varistor material wafer **111** is preferably formed by first forming a rod or block(not shown) of the varistor material and then slicing the wafer **111** from the rod using a diamond cutter or other suitable device. The rod may be formed by extruding or casting a rod of the varistor material and thereafter sintering the rod at high temperature in an oxygenated environment. This method of forming allows for the formation of a wafer having more planar surfaces and less warpage or profile fluctuation than would typically be obtained using a casting process. The coatings **112A**, **114A** are preferably formed of aluminum or copper and may be flame sprayed onto the opposed sides of the wafer **111**.

While the device **100** as shown in **Figure 1** includes two spring washers **140**, more or fewer may be used. Each spring washer **140** includes a hole **142** which receives the shaft **134** of the electrode **130**. Each spring washer **140** surrounds a portion of the shaft **134** immediately adjacent to the head **132** and abuts the rear face of the head **132** or the preceding spring washer **140**. Each hole **142** preferably has a diameter of between about 0.012 and 0.015 inch greater than the corresponding diameter of the shaft **134**. The spring washers **140** are preferably formed of a resilient material and, more preferably, the spring washers **140** are Belleville washers formed of spring steel.

The insulator ring **150** overlies and abuts the outermost spring washer **140**. The insulator ring **150** has a hole **152** formed therein which receives the shaft **134**. Preferably, the diameter of the hole **152** is between about 0.005 and 0.007 inch greater than the corresponding diameter of the shaft **134**. The insulator ring **150** is preferably formed of an electrically insulating material having high melting and combustion temperatures. More preferably, the insulator ring **150** is formed of polycarbonate, ceramic or a high temperature polymer.

The end cap **160** overlies and abuts the insulator ring **150**. The end cap **160** has a hole **162** which receives the shaft **134**. Preferably, the diameter of the hole **162** is between about 0.500 and 0.505 inch greater than the corresponding diameter of the shaft **134** to provide a sufficient clearance gap **165** (**Figure 2**) to avoid electrical arcing between the end cap **160** and the electrode shaft **134** during non-overvoltage conditions. Threads **168** on the peripheral wall of the end cap **160** engage complementary threads **128** formed in the housing **120**. Holes **163** are formed in the end cap to receive a tool (not shown) for rotating the end cap **160** with respect to the housing **120**. Other means for receiving a tool, for example, a hex-shaped slot, may be provided in place of or in addition to the holes **163**. The end cap **160** has an annular ridge **167** which is received within the inner diameter of the housing **120**. The housing **120** includes a rim **127** to prevent overinsertion of the end cap **150**. Preferably, the end cap is formed of aluminum.

As noted above and as best shown in **Figure 3**, the electrode head **132** and the center wall **122** are loaded against the varistor wafer **110** to ensure firm and uniform engagement between the surfaces **112** and **132A** and between the surfaces **114** and **122A**. This aspect of the device **100** may be appreciated by considering a method according to the present invention for assembling the device **100**. The varistor wafer **110** is placed in the cavity **121** such that the wafer surface **114** engages the contact surface **122A**. The electrode **130** is inserted into the cavity **121** such that the contact surface **132A** engages the varistor wafer surface **112**. The spring washers **140** are slid down the shaft **134** and placed over the head **132**. The insulator ring **150** is slid down the shaft **134** and over the outermost spring washer **140**. The end cap **160** is slid down the shaft **134** and screwed into the opening **126** by engaging the threads **168** with the threads **128** and rotating.

Once the device **100** has been assembled as just described, the end cap **160** is selectively torqued to force the insulator ring **150** downwardly so that it partially deflects the spring washers **140**. The loading of the end cap **160** onto the insulator ring **150** and from the insulator ring onto the spring washers **140** is in turn transferred to the head **132**. In this way, the varistor wafer **110** is sandwiched (clamped) between the head **132** and the center wall **122**.

Preferably, the device **100** is designed such that the desired loading will be achieved when the spring washers **150** are only partially deflected and, more preferably, when the spring washers are fifty percent (50%) deflected. In this way, variations in manufacturing tolerances of the other components of the device **100** may be accommodated.

The amount of torque applied to the end cap **160** will depend on the desired amount of load between the varistor wafer **110** and the head **132** and the center wall **122**. Preferably, the amount of the load of the head and the center wall against the varistor wafer is at least 264 lbs. More preferably, the load is between about 528 and 1056 lbs. Preferably, the coatings **112A** and **114A** have a rough initial profile and the compressive force of the loading deforms the coatings to provide more continuous engagements between the coatings and the contact surfaces **122A** and **132A**.

Alternatively, or additionally, the desired load amount may be obtained by selecting an appropriate number and or sizes of spring washers **140**. The spring washers each require a prescribed amount of load to deflect a prescribed amount and the overall load will be the sum of the spring deflection loads.

Preferably, the area of engagement between the contact surface **132A** and the varistor wafer surface **112** is at least 1.46 square inches. Likewise, the area of engagement between the contact surface **122A** and the varistor wafer surface **114** is preferably at least 1.46 square inches. Preferably, the electrode head **132** has a thickness **H** of at least 0.50 inch. The center wall **122** preferably has a thickness **W** of at least 0.25 inch.

The combined thermal mass of the housing **120** and the electrode **130** should be substantially greater than the thermal mass of the varistor wafer **110**. As used herein, the term "thermal mass" means the product of the specific heat of the material or materials of the object (e.g., the varistor wafer **110**) multiplied by the mass or masses of the material or materials of the object. That is, the thermal mass is the quantity of energy required to raise one gram of the material or materials of the object by one degree centigrade times the mass or masses of the material or materials in the object. Preferably, the thermal masses of each of the electrode head **132** and the center wall **122** are substantially greater than the thermal mass of the varistor wafer **110**. Preferably, the thermal masses of each of the electrode head **132** and the center wall **122** are at least two (2) times the thermal mass of the varistor wafer **110**, and, more preferably, at least ten (10) times as great.

The overvoltage protection device **100** provides a number of advantages for safely, durably and consistently handling extreme and repeated overvoltage conditions. The relatively large thermal masses of the housing **120** and the electrode **130** serve to absorb a relatively large amount of heat from the varistor wafer **110**, thereby reducing heat induced destruction or degradation of the varistor wafer as well as reducing any tendency for the varistor wafer to produce sparks or flame. The relatively large thermal masses and the substantial contact areas between the electrode and the housing and the varistor wafer provide a more uniform temperature distribution in the varistor wafer, thereby minimizing hot spots and resultant localized depletion of the varistor material.

The loading of the electrode and the housing against the varistor wafer as well as the relatively large contact areas provide a more even current distribution through the varistor wafer **10**. As a result, the device **100** responds to overvoltage conditions more efficiently and predictably, and high current spots which may cause pinholing are more likely to be avoided. The tendency for the varistor wafer **110** to warp responsive to high current impulses is reduced by the mechanical reinforcement provided by the loaded head **132** and center wall **122**. The spring washers may temporarily deflect when the varistor wafer expands and return when the varistor wafer again contracts, thereby maintaining the load throughout and between multiple overvoltage events. Moreover, during an overvoltage event, the device **100** will generally provide lower inductance and lower resistance because of the more uniform and efficient current distribution through the varistor wafer.

The device **100** also serves to prevent or minimize the expulsion of flame, sparks and/or varistor material upon overvoltage failure of the varistor wafer **110**. The strength of the metal housing as well as the configuration of the electrode **130**, the insulator ring **150** and the end cap **160** serve to contain the products of a varistor wafer failure. In the event that the varistor destruction is so severe as to force the electrode **130** away from the varistor and melt the insulator ring **150**, the electrode **130** will be displaced into direct contact with the end cap **160**, thereby shorting the electrode **130** and the housing **120** and causing an in-line fuse (not shown) to blow.

While the housing **120** is illustrated as cylindrically shaped, the housing may be shaped differently. The lower half of the device **100** may be deleted, so that the device **100** includes only an upper housing wall **124** and a single varistor wafer, electrode, spring washer or set of spring washers, insulator ring and end cap.

Methods for forming the several components of the device will be apparent to those of skill in the art in view of the foregoing description. For example, the housing **120**, the electrode **130**, and the end cap **160** may be formed by machining, casting or impact molding. Each of these elements may be unitarily formed or formed of multiple components fixedly joined, by welding, for example.

With reference to **Figures 5-8**, a varistor device **200** according to a second embodiment of the present invention is shown therein. The varistor device **200** includes elements **210, 230, 240** and **260** corresponding to elements **110, 130, 140** and **160**, respectively, of the varistor device **100**. The varistor device **200** differs from the varistor device **100** in that the device **200** includes only a single varistor wafer **210** and corresponding components. The varistor device **200** includes a housing **220** which is the same as the housing **120** except as follows. The housing **220** defines only a single cavity **221**, and has only a single surrounding wall **224** extending from the center (or end) wall **222** thereof. Also, the housing **220** has a threaded stud **229** (**Figure 7**) extending from the lower surface of the center (or end) wall **222** rather than a sidewardly extending electrode ear corresponding to the electrode ear **129**. The stud **229** is adapted to engage a threaded bore of a conventional electrical service utility box or the like.

The varistor device **200** further differs from the varistor device **100** in the provision of an insulator ring **251**. The insulator ring **251** has a main body ring **252** corresponding to the insulator ring **150**. The ring **251** further includes a collar **254** extending upwardly from the main body ring **252**. The inner diameter of the collar **254** is sized to receive the shaft **234** of the electrode **230**, preferably in clearance fit. The outer diameter of the collar **254** is sized to pass through the hole **262** of the end cap **260** with a prescribed clearance gap **265** (**Figure 6**) surrounding the collar **254**. The gap **265** allows clearance for inserting the shaft **134** and may be omitted. The main body ring **252** and the collar **254** are preferably formed of the same material as the insulator ring **150**. The main body ring **252** and the collar **254** may be bonded or integrally molded.

With reference to **Figure 8**, the varistor device **200** is shown therein mounted in an electrical service utility box **10**. The varistor device **200** is mounted on a metal platform **12** electrically connected to earth ground. The electrode stud **229** engages and extends through a threaded bore **12A** in the platform **12**. A bus bar **16**, electrically connected a first end of a fuse **14**, is secured to the electrode shaft **234** by a threaded bolt **18** inserted into the threaded bore **236** of the electrode **230**. A second end of the fuse may be connected to an electrical service line or the like. As shown in **Figure 8**, a plurality of varistor devices **200** may be connected in parallel in a utility box **10**.

With reference to **Figures 9-11**, a varistor device **300** according to a third embodiment of the present invention is shown therein. The varistor device **300** includes elements **310, 330, 340** and **351** corresponding to elements **210, 230, 240** and **251**, respectively. The varistor device **300** also includes a flat metal washer **345** interposed between the uppermost spring washer **340** and the insulator ring **351**, the shaft **334** extending through a hole **346** formed in the washer **345**. The washer **345**, which may be incorporated into the devices **100, 200**, serves to distribute the mechanical load of the uppermost spring washer **340** to prevent the spring washer from cutting into the insulator ring **351**. The housing **320** is the same as the housing **220** except as follows.

The housing **320** of device **300** does not have a rim corresponding to the rim **127** or threads corresponding to the threads **128**. Also, the housing **320** has an internal annular slot **323** formed in the surrounding sidewall **324** and extending adjacent the opening **326** thereof.

The varistor device **300** also differs from the varistor devices **100, 200** in the manner in which the electrode **330** and the center wall **322** are loaded against the varistor wafer **310**. In place of the end caps **160, 260**, the varistor device **300** has an end cap **360** and a resilient clip **370**. The clip **370** is partly received in the slot **323** and partly extends radially inwardly from the inner wall of the housing **320** to limit outward displacement of the end cap **360**. The clip **370** is preferably formed of spring steel. The end cap **360** is preferably formed of aluminum.

The varistor device **300** may be assembled in the same manner as the varistor devices **100, 200** except as follows. The end cap **360** is placed over the shaft **334** and the collar **354**, each of which are received in a hole **362**. The washer **345** is placed over the shaft **334** prior to placing the insulator ring **351**. A jig (not shown) or other suitable device is used to force the end cap **360** down, in turn deflecting the spring washers **340**. While the end cap **360** is still under the load of the jig, the clip **370** is compressed, preferably by engaging apertures **372** with pliers or another suitable tool, and inserted into the slot **323**. The clip **370** is then released and allowed to return to its original diameter, whereupon it partly fills the slot and partly extends radially inward into the cavity **321** from the slot **323**. The clip **370** and the slot **323** thereby serve to maintain the load on the end cap **360**.

Means other than those described above may be used to load the electrode and housing against the varistor wafer. For example, the electrode and end cap may be assembled and loaded, and thereafter secured in place using a staked joint.

In each of the aforedescribed devices **100, 200, 300**, multiple varistor wafers (not shown) may be stacked and sandwiched between the electrode head and the center wall. The outer surfaces of the uppermost and lowermost varistor wafers would serve as the wafer contact surfaces. However, the properties of the varistor wafer are preferably modified by changing the thickness of a single varistor wafer rather than stacking a plurality of varistor wafers.

As discussed above, the spring washers **140** are preferably Belleville washers. Belleville washers may be used to apply relatively high loading without requiring substantial axial space. However, other types of biasing means may be used in addition to or in place of the Belleville washer or washers. Suitable alternative biasing means include one or more coil springs, wave washers or spiral washers.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the Claims. In the Claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Therefore, it is to be understood that the foregoing is illustrative of the present invention and is not to be construed as limited to the specific embodiments disclosed, and that modifications to the disclosed embodiments, as well as other embodiments, are intended to be included within the scope of the appended Claims. The invention is defined by the following Claims, with equivalents of the Claims to be included therein.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An overvoltage protection device comprising:

a) a housing including a first substantially planar electrical contact surface and an electrically conductive, metal sidewall, said housing defining a cavity therein and having an opening in communication with said cavity;

b) an electrode member including a substantially planar second electrical contact surface facing said first electrical contact surface and disposed within said cavity, a portion of said electrode extending out of said cavity and through said opening; and

c) a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, said wafer positioned within said cavity and between said first and second electrical contact surfaces with said first and second wafer surfaces engaging and in electrical contact with said first and second electrical contact surfaces, respectively; and

d) wherein, in response to an overvoltage surge condition between the housing and the electrode, the wafer provides a shunt path for surge current, thereby preventing an overvoltage condition between the housing and the electrode.

2. The device of Claim **1** wherein said first and second electrical contact surfaces apply a load to said first and second wafer surfaces.

3. The device of Claim **2** wherein said load is at least **264** lbs.

4. The device of Claim **2** wherein said load is between about **528** and **1056** lbs.

5. The device of Claim **2** including adjustable means maintaining said load such that the amount of said load may be selectively adjusted.

6. The device of Claim **2** including biasing means for maintaining said load.

7. The device of Claim **6** wherein said biasing means includes a spring member biasing at least one of said first and second electrical contact surfaces against said wafer.

8. The device of Claim **7** including a plurality of spring members biasing at least one of said first and second electrode members against said wafer.

9. The device of Claim **7** wherein said spring member includes a spring washer.

10. The device of Claim **7** wherein said spring member includes a Belleville washer.

11. The device of Claim **2** including an end cap positioned in said opening, said end cap maintaining said load.

12. The device of Claim **11** including a clip operative to limit displacement between said end cap and said housing to maintain said load.

13. The device of Claim **12** wherein said housing includes a slot formed therein and said clip engages said slot.

14. The device of Claim **11** wherein said housing includes a threaded portion and said end cap includes a threaded portion engaging said housing threaded portion whereby said end cap is operable to selectively adjust and maintain said load.

15. The device of Claim **11** including a spring member interposed between said end cap and said wafer.

16. The device of Claim **1** including an electrically insulating member interposed between said second contact surface and said opening.

17. The device of Claim **1** including an end cap positioned in said opening and having a hole formed therein, wherein said electrode member includes a head positioned in said cavity between said end cap and said first electrical contact surface and a shaft extending out of said cavity and through said end cap hole.

18. The device of Claim **17** including an electrically insulating ring member having a hole formed therein, said insulating ring member interposed between said head and said end cap, wherein said shaft extends through said insulating ring member hole.

19. The device of Claim **18** wherein said insulating ring member includes a main body ring portion and a projecting collar, said projecting collar surrounding said shaft and extending through said end cap hole.

20. The device of Claim **17** including a spring washer having a hole formed therein, said spring washer interposed between said head and said end cap, wherein said shaft extends through said spring washer hole.

21. The device of Claim **17** including an electrically insulating ring member and a spring washer, said electrically insulating ring member having a hole formed therein and interposed between head and said end cap, said spring washer having a hole formed therein and interposed between head and said electrically insulating ring member, wherein said shaft extends through each of said electrically insulating ring member hole and said spring washer hole.

22. The device of Claim **1** wherein said housing and said electrode member have a combined thermal mass which is substantially greater than a thermal mass of said wafer.

23. The device of Claim **22** wherein said housing includes an electrode wall and second electrode member includes a head, each of said electrode wall and said head contacting one of said wafer surfaces and having a thermal mass which is substantially greater than said wafer thermal mass.

24. The device of Claim **23** wherein said thermal masses of said electrode wall and said head are each at least twice said wafer thermal mass.

25. The device of Claim **23** wherein said thermal masses of said electrode wall and said head are each at least ten times said wafer thermal mass.

26. The device of Claim **1** wherein said housing is unitarily formed of metal.

27. The device of Claim **1** wherein said wafer is formed by slicing a rod of varistor material.

28. The device of Claim **27** wherein said rod is formed by at least one of extruding and casting.

29. The device of Claim **27** wherein said varistor material is selected from the group consisting of a metal oxide compound and silicon carbide.

30. The device of Claim **27** wherein said wafer includes a coating of conductive metal on at least one of said first and second wafer surfaces.

31. The device of Claim **27** wherein said wafer has a substantially circular peripheral edge and each of said first and second disk surfaces are substantially coextensive with said circular peripheral edge.

32. The device of Claim **1** wherein each of said first and second contact surfaces is continuous and substantially free of voids.

33. An overvoltage protection device comprising:

a) a housing including an electrode wall and an electrically conductive, metal sidewall, said electrode wall and said sidewall defining a cavity and an opening in communication with said cavity, said electrode wall having a thermal mass and a first substantially planar electrical contact surface;

b) an electrode member including a head positioned in said cavity and a shaft extending out of said cavity and through said opening, said head having a thermal mass and a substantially planar second electrical contact surface facing said first electrical contact surface;

c) a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, said wafer positioned within said cavity and between said first and second electrical contact surfaces with said first and second wafer surfaces engaging said first and second electrical contact surfaces, respectively, said wafer having a thermal mass;

d) an end cap positioned in said opening, said end cap having a hole through which said shaft extends;

e) a spring member interposed between said end cap and said head, and said spring member biasing at least one of said electrode wall and said head against said wafer to apply a load to said first and second wafer surfaces; and

f) wherein each of said head thermal mass and said electrode wall thermal mass is substantially greater than said thermal mass of said wafer.

34. The device of Claim **33** wherein said load is at least **264** lbs.

35. The device of Claim **33** wherein said thermal masses of said electrode wall and said head are each at least ten times said wafer thermal mass.

36. The device of Claim **33** wherein said wafer is formed by slicing a rod of said varistor material.

37. The device of Claim **33** including a clip and wherein said housing includes a slot formed therein, said clip cooperative with said slot to limit displacement of said end cap relative to said housing and to maintain said load.

38. The device of Claim **33** wherein said housing includes a threaded portion and said end cap includes a threaded portion engaging said housing threaded portion whereby said end cap is operable to selectively adjust and maintain said load.

39. The device of Claim **33** including an electrically insulating ring member, said insulating ring member having a hole formed therein and interposed between said head and said end cap, said spring member having a hole formed therein and interposed between head and said insulating ring member whereby said spring member biases said head against said wafer, wherein said shaft extends through each of said insulating ring member hole and said spring member hole.

40. The device of Claim **39** wherein said insulating ring member includes a main body ring portion and a projecting collar, said projecting collar surrounding said shaft and extending through said end cap hole.

41. An overvoltage protection device for use with a varistor wafer of the type having first and second opposed, substantially planar wafer surfaces, said device comprising:

a) a housing including a first substantially planar electrical contact surface and an electrically conductive, metal sidewall, said housing defining a cavity therein and having an opening in communication with said cavity; and

b) an electrode member including a substantially planar second electrical contact surface facing said first electrical contact surface and disposed within said cavity, a portion of said electrode extending out of said cavity and through said opening, said housing and said electrode member relatively arranged and configured to receive the wafer within said cavity such that the wafer is positioned between said first and second electrical contact surfaces with said first and second electrical contact surfaces engaging and in electrical contact with the first and second wafer surfaces, respectively; and

c) wherein, in response to an overvoltage surge condition between the housing and the electrode, the wafer provides a shunt path for surge current, thereby preventing an overvoltage condition between the housing and the electrode.

42. An overvoltage protection device comprising:

a) a first electrode member having a first substantially planar contact surface;

b) a second electrode member having a second substantially planar contact surface facing said first contact surface;

c) a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces, said wafer positioned between said first and second contact surfaces with said first and second wafer surfaces engaging said first and second contact surfaces, respectively; and

d) biasing means including a Belleville washer biasing at least one of said first and second contact surfaces against said wafer to apply a load to said first and second wafer surfaces.

43. The device of Claim **42** wherein said load is at least **264** lbs.

44. The device of Claim **42** wherein said load is between about **528** and **1056** lbs.

45. The device of Claim **42** including a plurality of Belleville washers biasing at least one of said first and second electrode members against said wafer.

46 A method for assembling an overvoltage protection device, said method comprising the steps of:

a) providing a first electrode member having a first substantially planar contact surface;

b) providing a second electrode member having a second substantially planar contact surface facing the first contact surface;

c) providing a biasing means including a Belleville washer;

d) placing a wafer formed of varistor material and having first and second opposed, substantially planar wafer surfaces between the first and second contact surfaces such that the first and second wafer surfaces engage and electrically contact the first and second contact surfaces, respectively;

e) biasing the biasing means to apply a load between the first and second contact surfaces and against the first and second wafer surfaces; and

f) maintaining the load during an overvoltage event.

47. The method of Claim **46** wherein said step of biasing includes deflecting the Belleville washer.

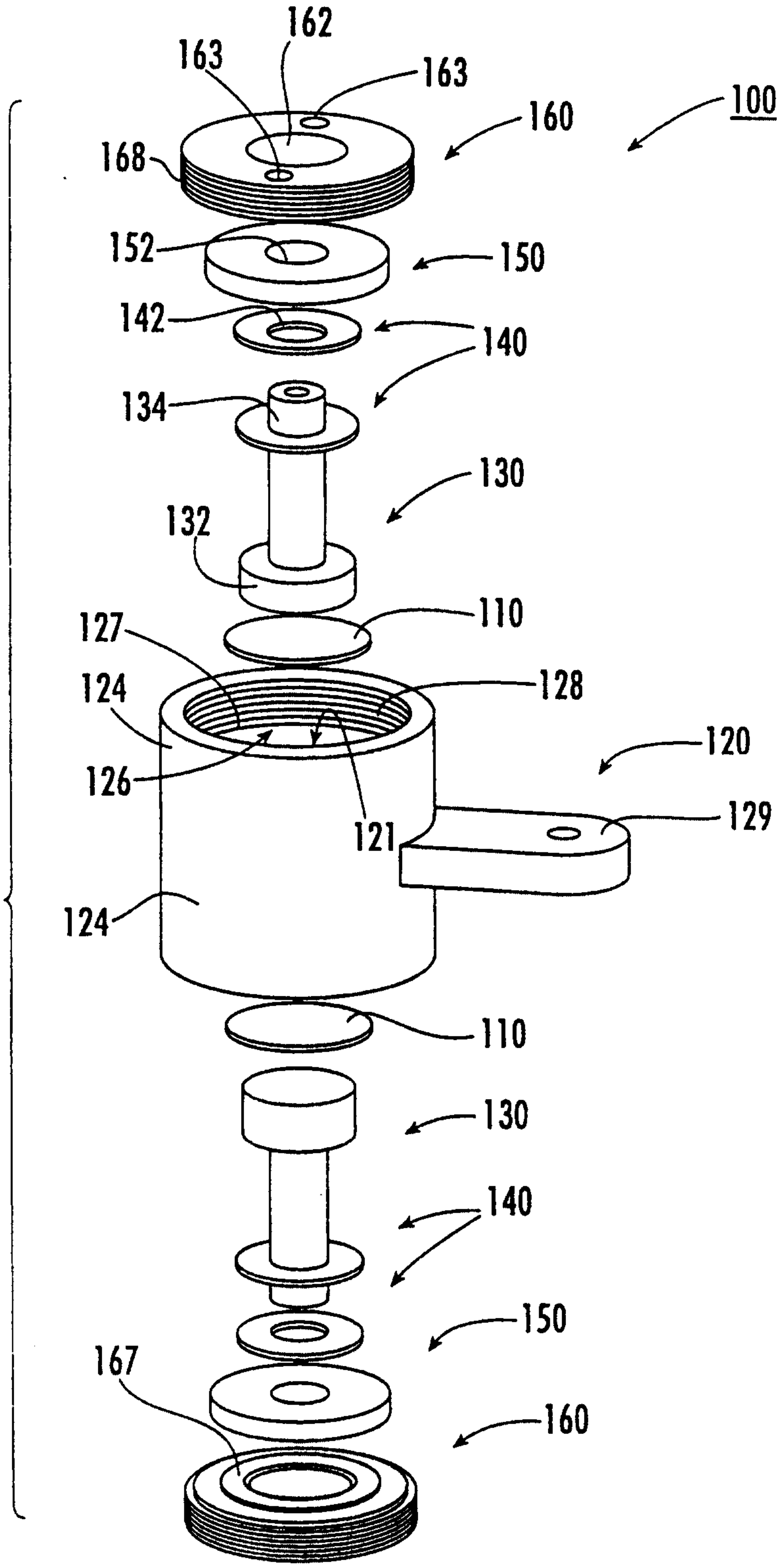

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FIG. 1.

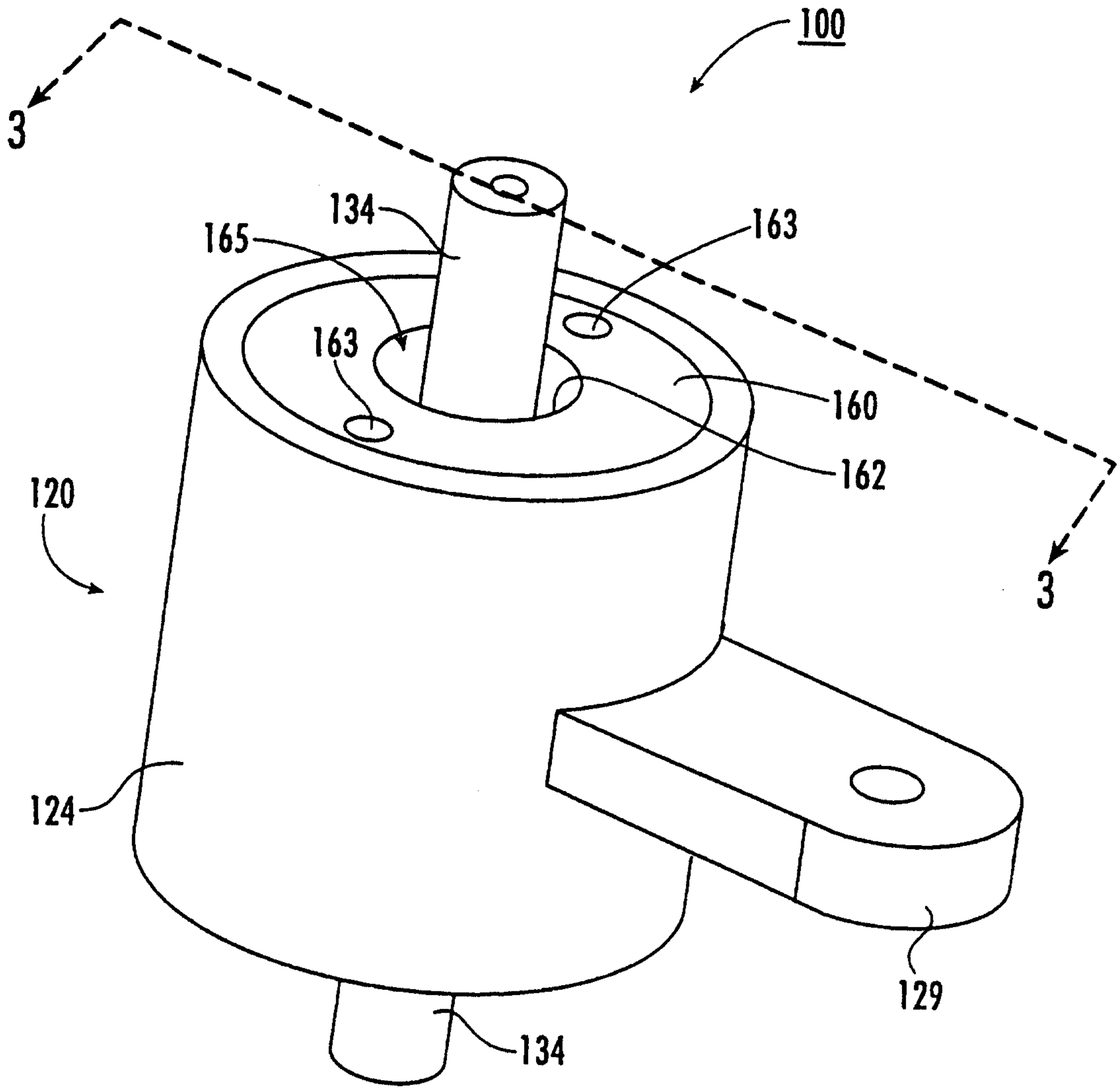

FIG. 2.

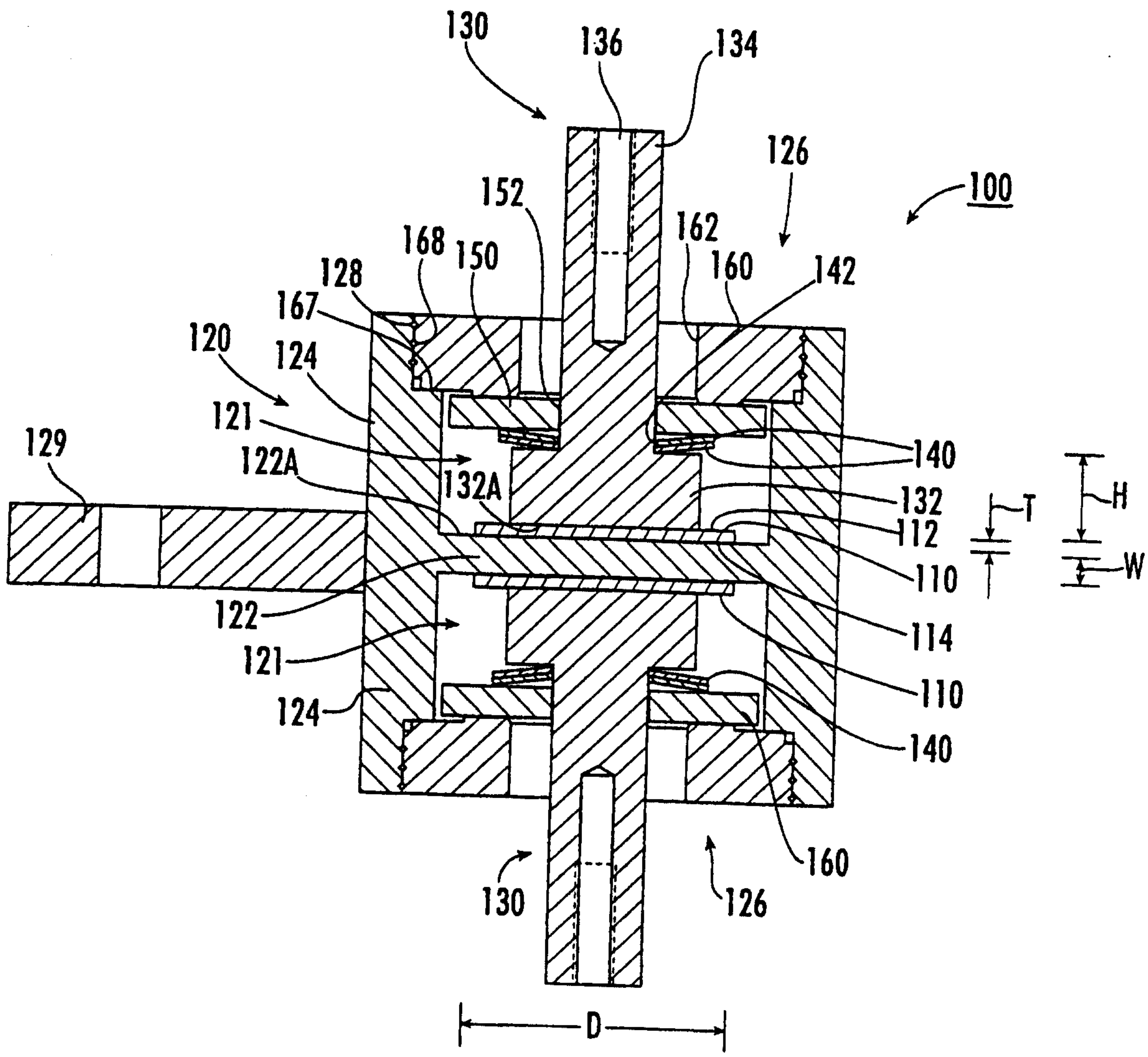

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FIG. 3.

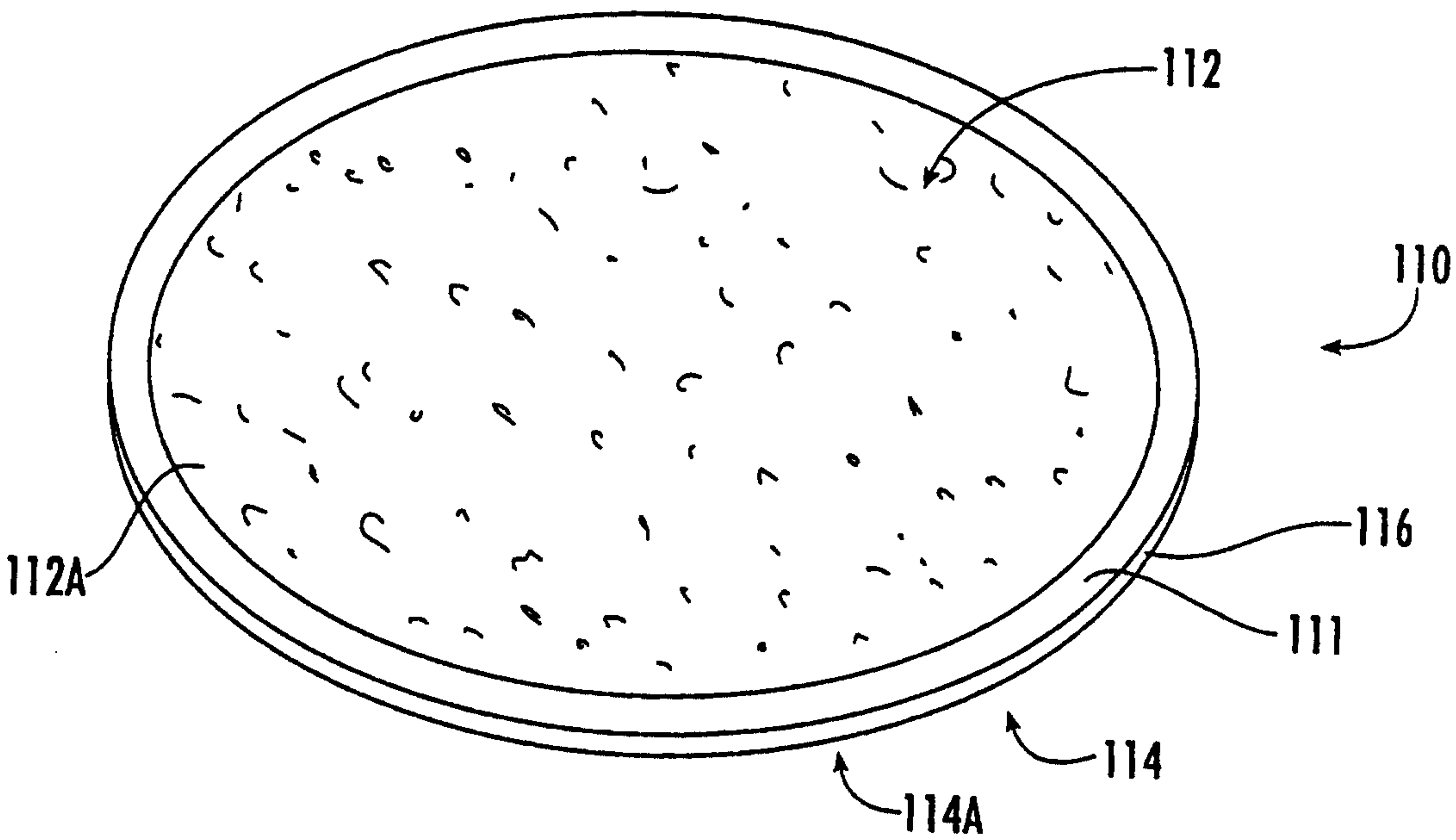

FIG. 4.

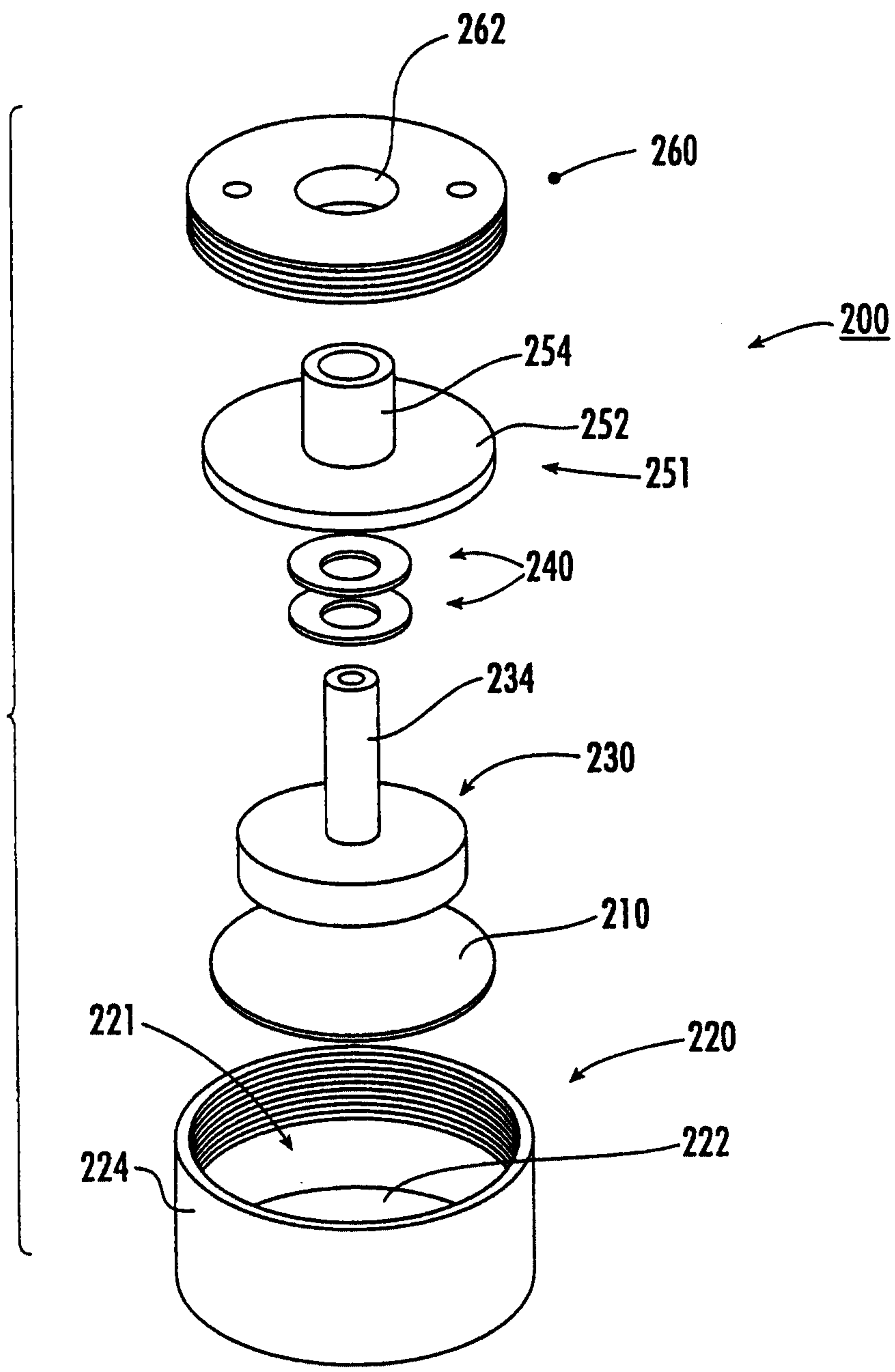

FIG. 5.

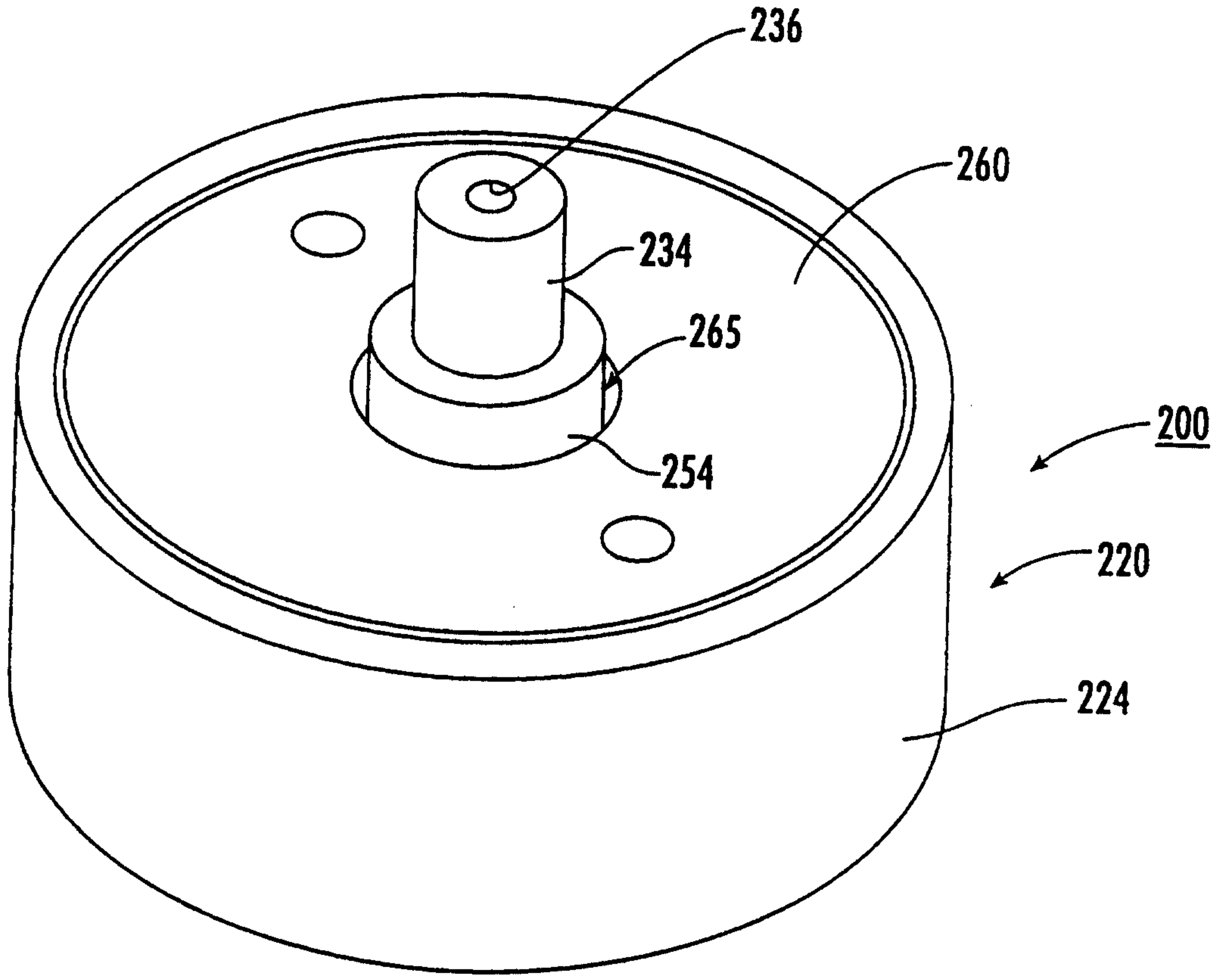

FIG. 6.

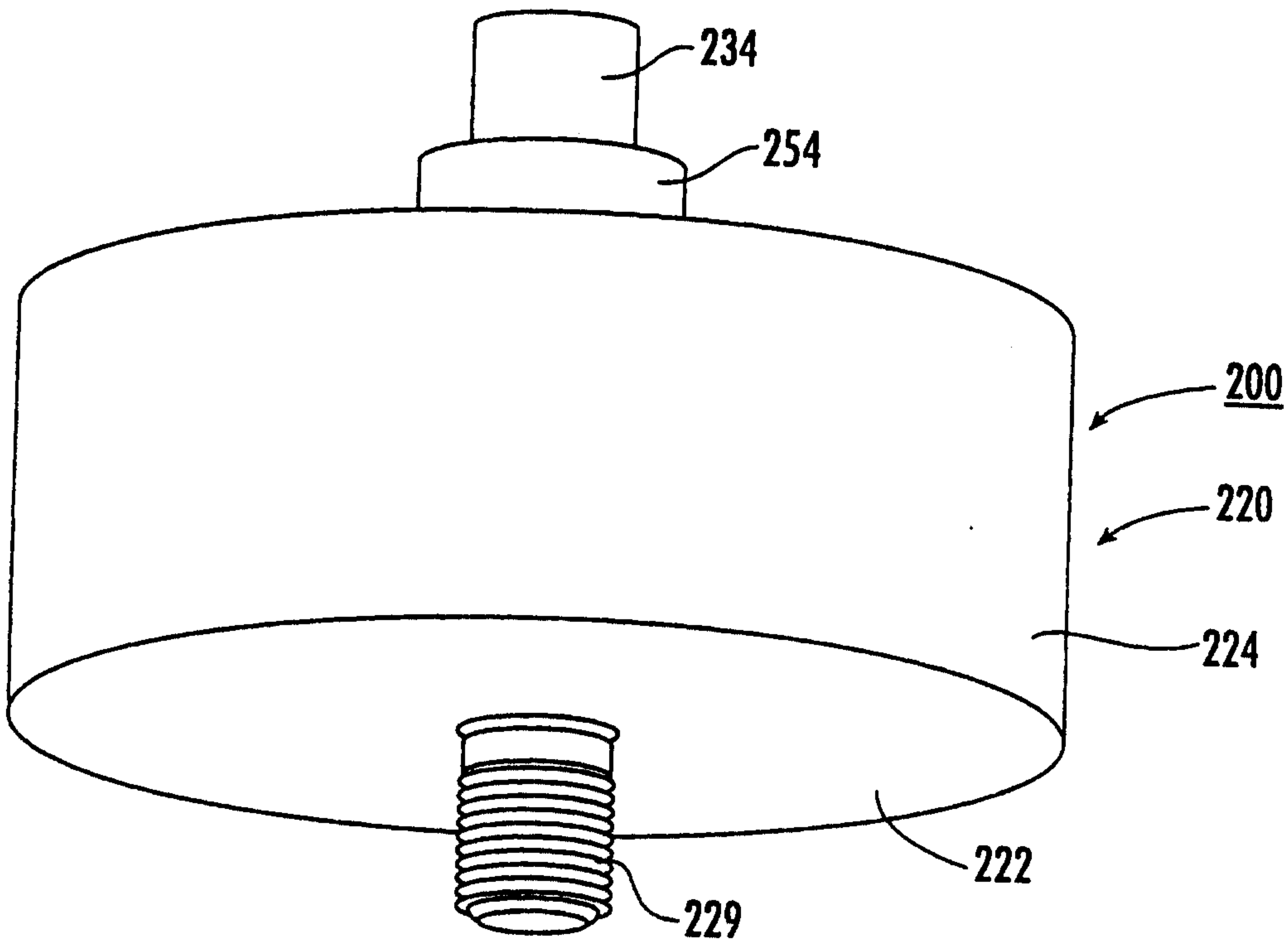

FIG. 7.

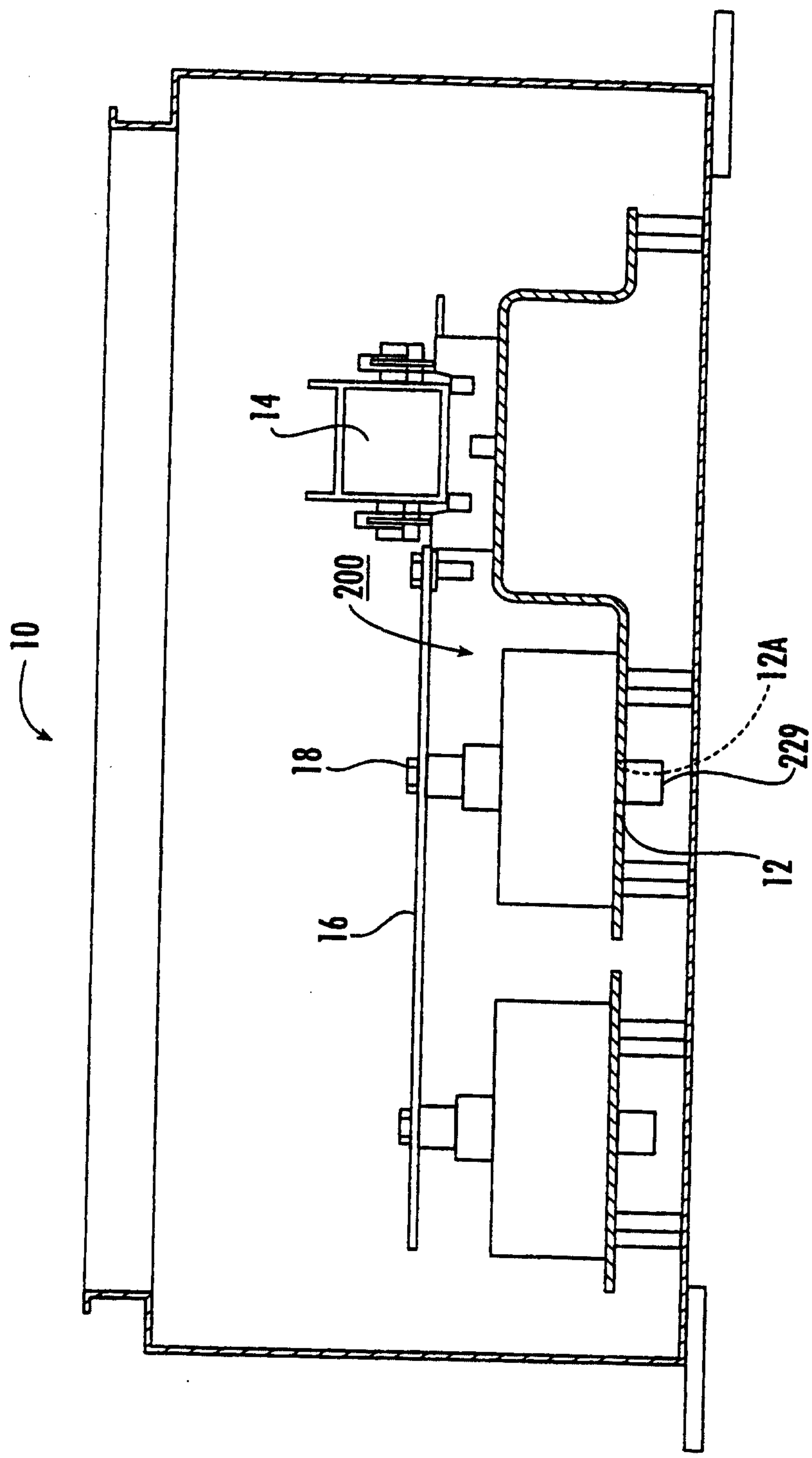

FIG. 8.

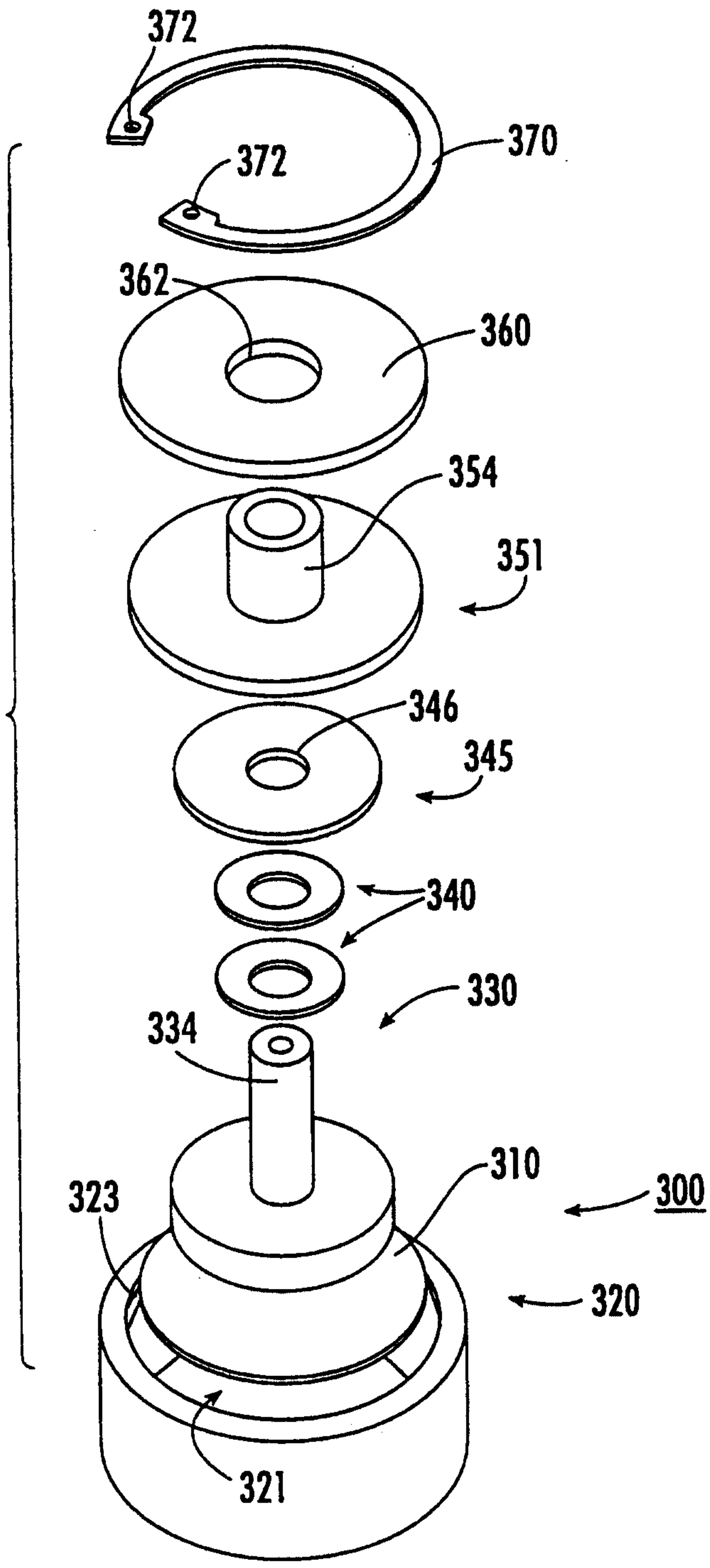
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FIG. 9.

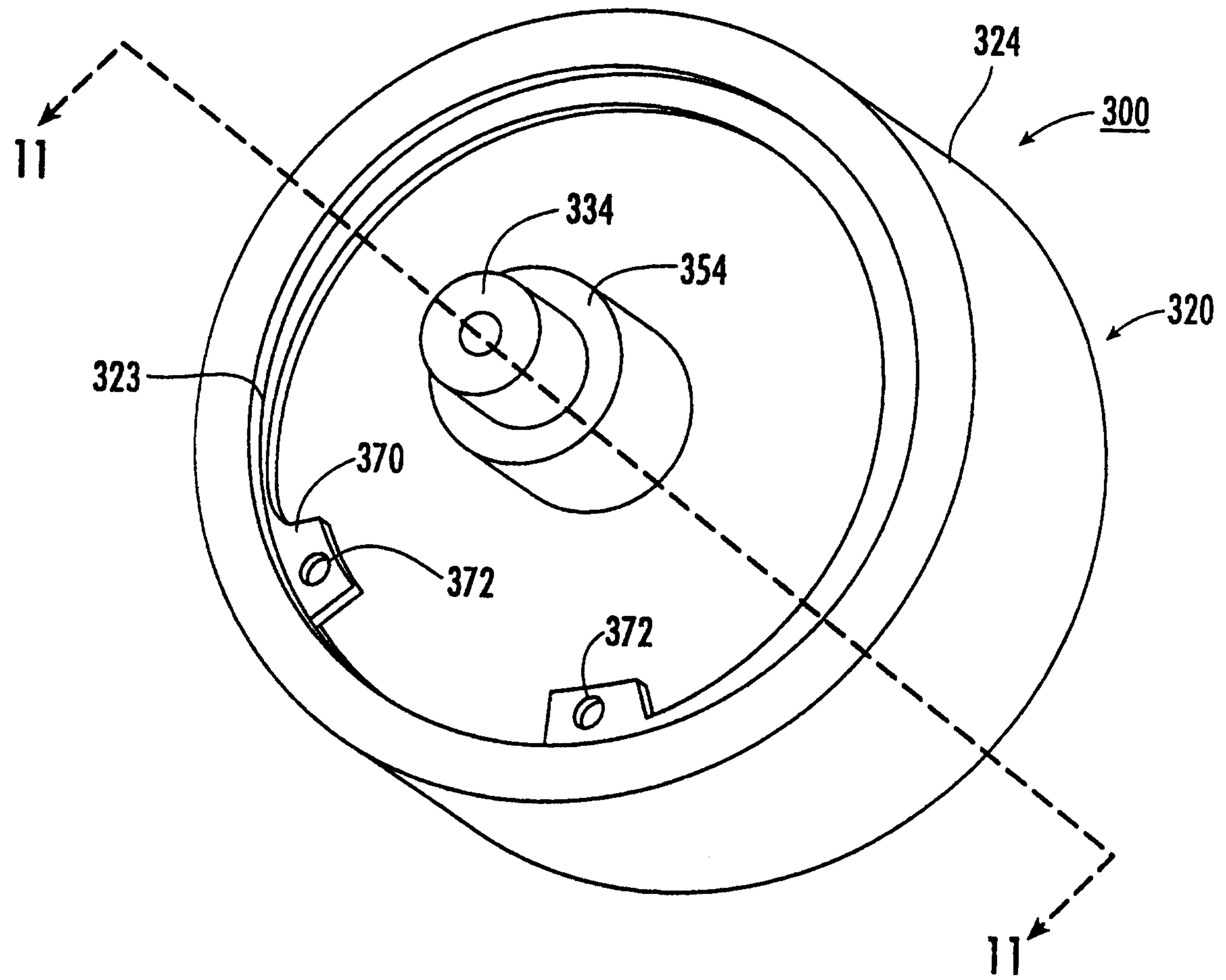


FIG. 10.

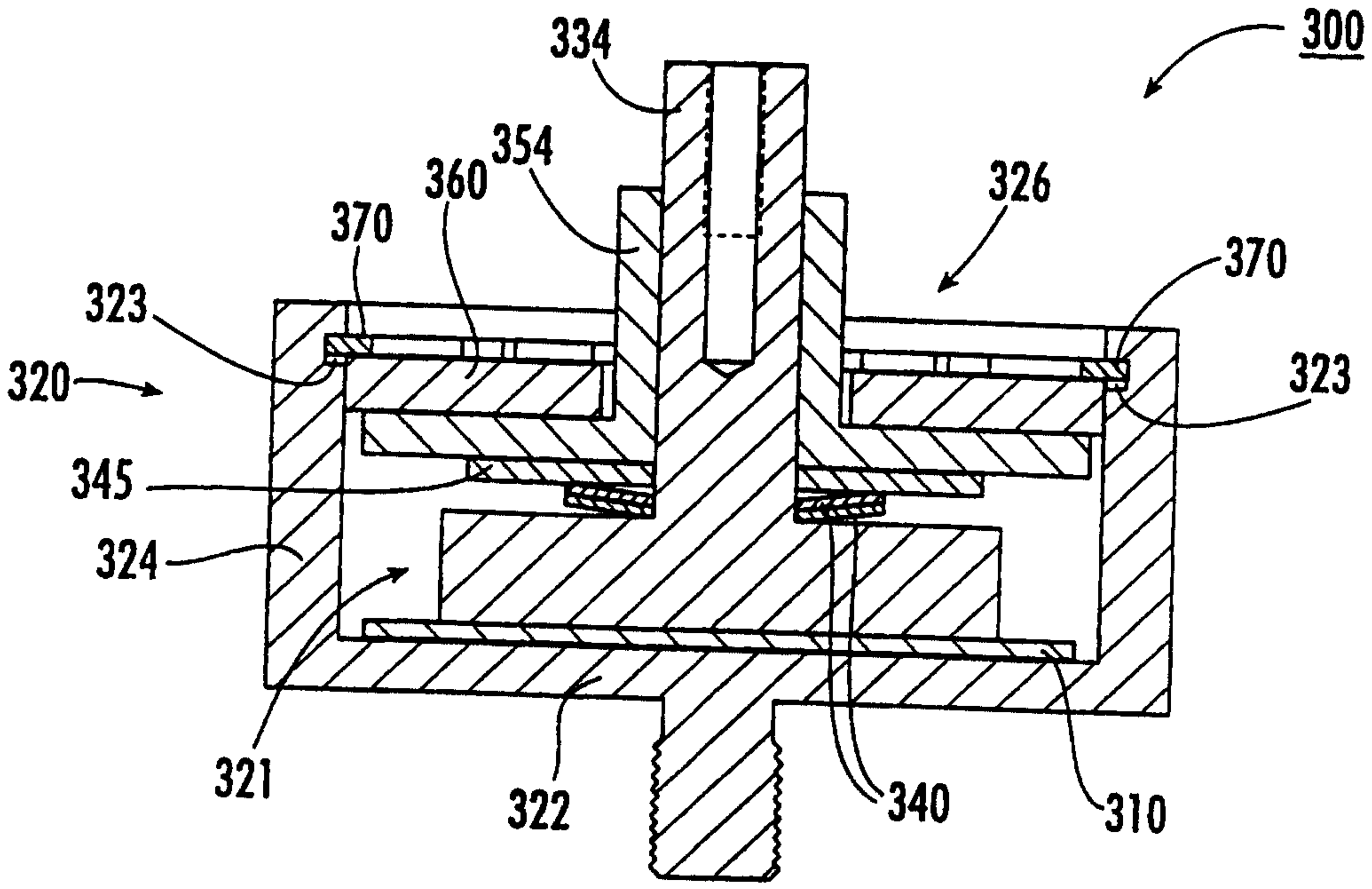
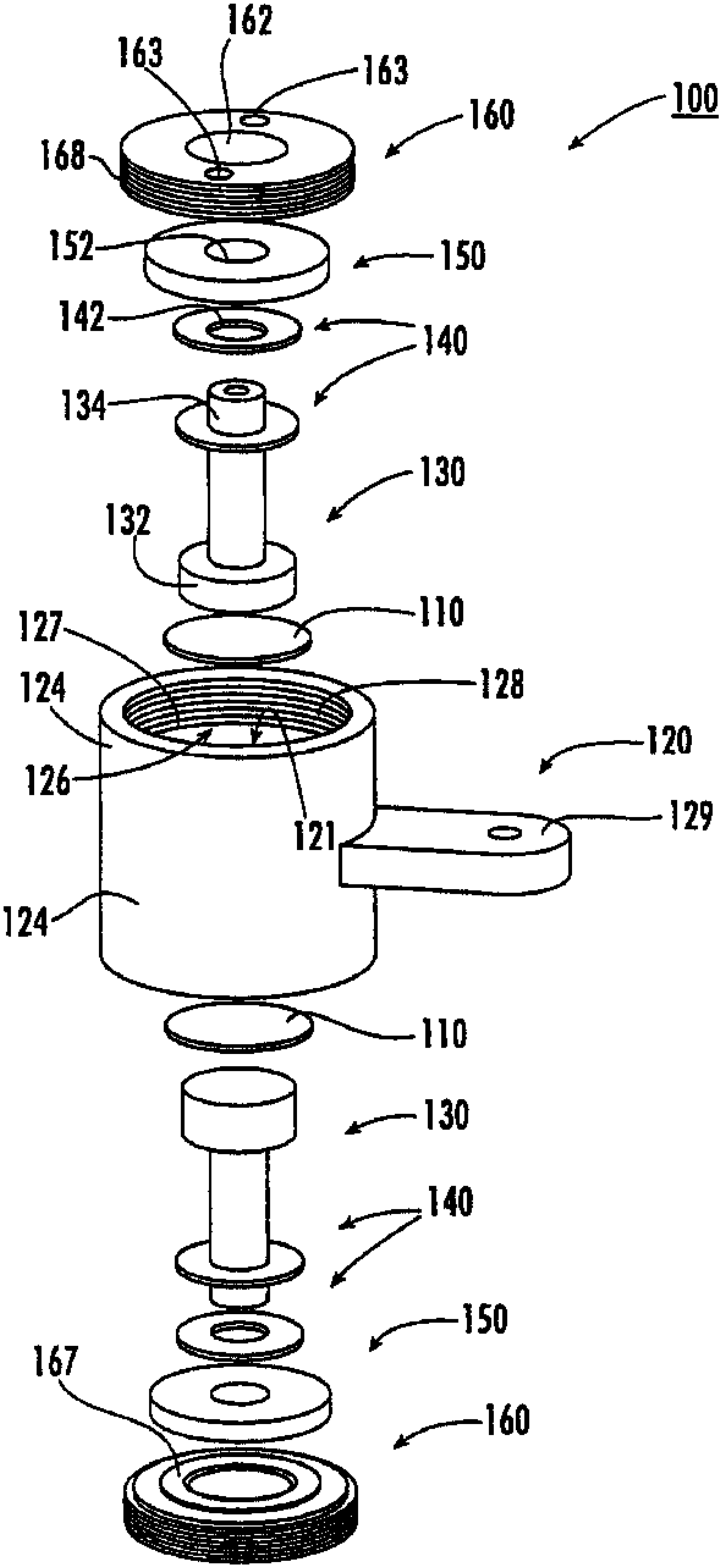


FIG. 11.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