



US00RE45883E

(19) **United States**  
(12) **Reissued Patent**  
**Ohbayashi et al.**

(10) **Patent Number:** **US RE45,883 E**  
(45) **Date of Reissued Patent:** **Feb. 9, 2016**

(54) **TUBULAR SENSOR WITH AN INNER PROJECTION**

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(21) Appl. No.: **14/306,142**

(22) Filed: **Jun. 16, 2014**

**Related U.S. Patent Documents**

Reissue of:

(64) Patent No.: **8,569,635**  
Issued: **Oct. 29, 2013**  
Appl. No.: **13/120,284**  
PCT Filed: **Oct. 2, 2009**  
PCT No.: **PCT/JP2009/005096**  
§ 371 (c)(1),  
(2) Date: **Mar. 22, 2011**  
PCT Pub. No.: **WO2010/041395**  
PCT Pub. Date: **Apr. 15, 2010**

(30) **Foreign Application Priority Data**

Oct. 9, 2008 (JP) ..... 2008-262525  
Oct. 9, 2008 (JP) ..... 2008-262526  
Sep. 7, 2009 (JP) ..... 2009-205471

(51) **Int. Cl.**  
**G01B 7/00** (2006.01)  
**B65H 45/12** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B65H 45/12** (2013.01)

(58) **Field of Classification Search**

CPC ..... G01G 23/01; G01L 5/161  
USPC ..... 73/1.13; 177/136  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,559,474 A \* 2/1971 Gurol et al. .... 73/862.635  
3,618,376 A \* 11/1971 Shul et al. .... 73/862.045  
3,866,157 A \* 2/1975 Birkholtz ..... 338/5  
4,079,624 A \* 3/1978 Kurtz ..... 73/862.625  
4,094,192 A \* 6/1978 Watson et al. .... 73/862.044  
4,498,231 A \* 2/1985 Rand ..... 29/621.1  
4,911,024 A \* 3/1990 McMaster ..... 73/862.045

(Continued)

FOREIGN PATENT DOCUMENTS

JP 04-305132 10/1992  
JP 04-305132 A 10/1992

(Continued)

OTHER PUBLICATIONS

Notice of Allowance issued in U.S. Appl. No. 13/120,284 dated Aug. 23, 2013.

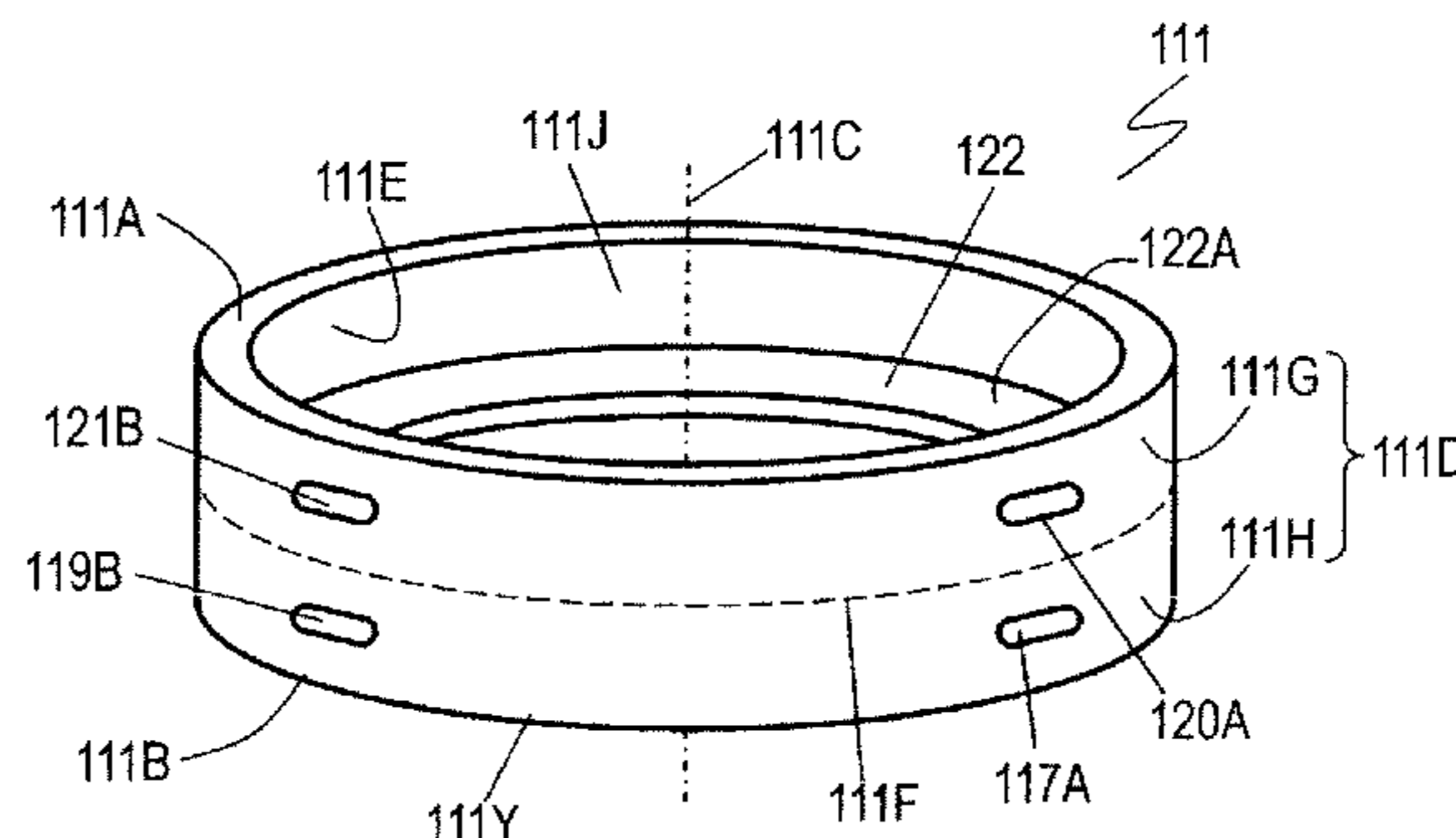
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(57) **ABSTRACT**

A weight sensor includes a deformable body, a first strain resistor provided on an outer side surface of the deformable body, and a pressing member applying a load to the deformable body. The deformable body includes a tubular portion having a tubular shape extending along a center axis and surrounding the center axis, and a projection projecting from an inner surface of the tubular portion. The pressing member moves along the center axis so as to apply a moment to the tubular portion. The resistances of the strain resistors change greatly, allowing the weight sensor to measure a load with high sensitivity.

**19 Claims, 22 Drawing Sheets**



(56)

**References Cited**

U.S. PATENT DOCUMENTS

4,932,253 A \* 6/1990 McCoy ..... 73/152.61  
 5,063,788 A \* 11/1991 Ch'Hayder et al. .... 73/862.043  
 5,291,788 A \* 3/1994 Oohata et al. .... 73/727  
 5,490,427 A \* 2/1996 Yee et al. .... 73/767  
 5,889,214 A \* 3/1999 Kang et al. .... 73/862.044  
 5,942,697 A \* 8/1999 Hesthamar et al. .... 73/862.69  
 5,948,996 A \* 9/1999 Takeuchi et al. .... 73/862.043  
 5,969,268 A \* 10/1999 Sommerfeld et al. ... 73/862.041  
 6,005,199 A 12/1999 Harada et al.  
 6,037,550 A \* 3/2000 Bradley ..... 177/136  
 6,038,933 A \* 3/2000 Meyer ..... 73/862.045  
 6,129,168 A \* 10/2000 Lotito et al. .... 180/273  
 6,711,960 B2 3/2004 Kobayashi et al.  
 6,768,065 B2 \* 7/2004 Bertenburg et al. .... 177/144  
 6,792,815 B2 \* 9/2004 McDearmon et al. ... 73/862.041  
 6,797,892 B2 \* 9/2004 Golla ..... 177/144  
 6,865,961 B2 \* 3/2005 Wolf et al. .... 73/862.69  
 6,969,809 B2 \* 11/2005 Rainey ..... 177/136  
 7,112,749 B2 \* 9/2006 DiPaola et al. .... 177/136  
 7,252,012 B2 \* 8/2007 Kim ..... 73/803

2002/0038728 A1\* 4/2002 Dingman ..... 177/1  
 2005/0120809 A1\* 6/2005 Ramming ..... 73/862.044  
 2007/0084294 A1 4/2007 Kobayashi et al.  
 2008/0022784 A1\* 1/2008 Wehinger et al. .... 73/862.621  
 2008/0066562 A1\* 3/2008 Sakurai et al. .... 73/862.044  
 2008/0148805 A1\* 6/2008 Mahoney et al. .... 73/1.08  
 2009/0007696 A1\* 1/2009 Morimoto ..... 73/862.045

FOREIGN PATENT DOCUMENTS

JP 05-209796 8/1993  
 JP 05-209796 A 8/1993  
 JP 06-207866 7/1994  
 JP 06-207866 A 7/1994  
 JP 08-005475 1/1996  
 JP 08-005475 A 1/1996  
 JP 11-132874 5/1999  
 JP 11-132874 A 5/1999  
 JP 2002-357491 12/2002  
 JP 2002-357491 A 12/2002  
 JP 2005-106800 4/2005  
 JP 2005-106800 A 4/2005

\* cited by examiner

Fig. 1

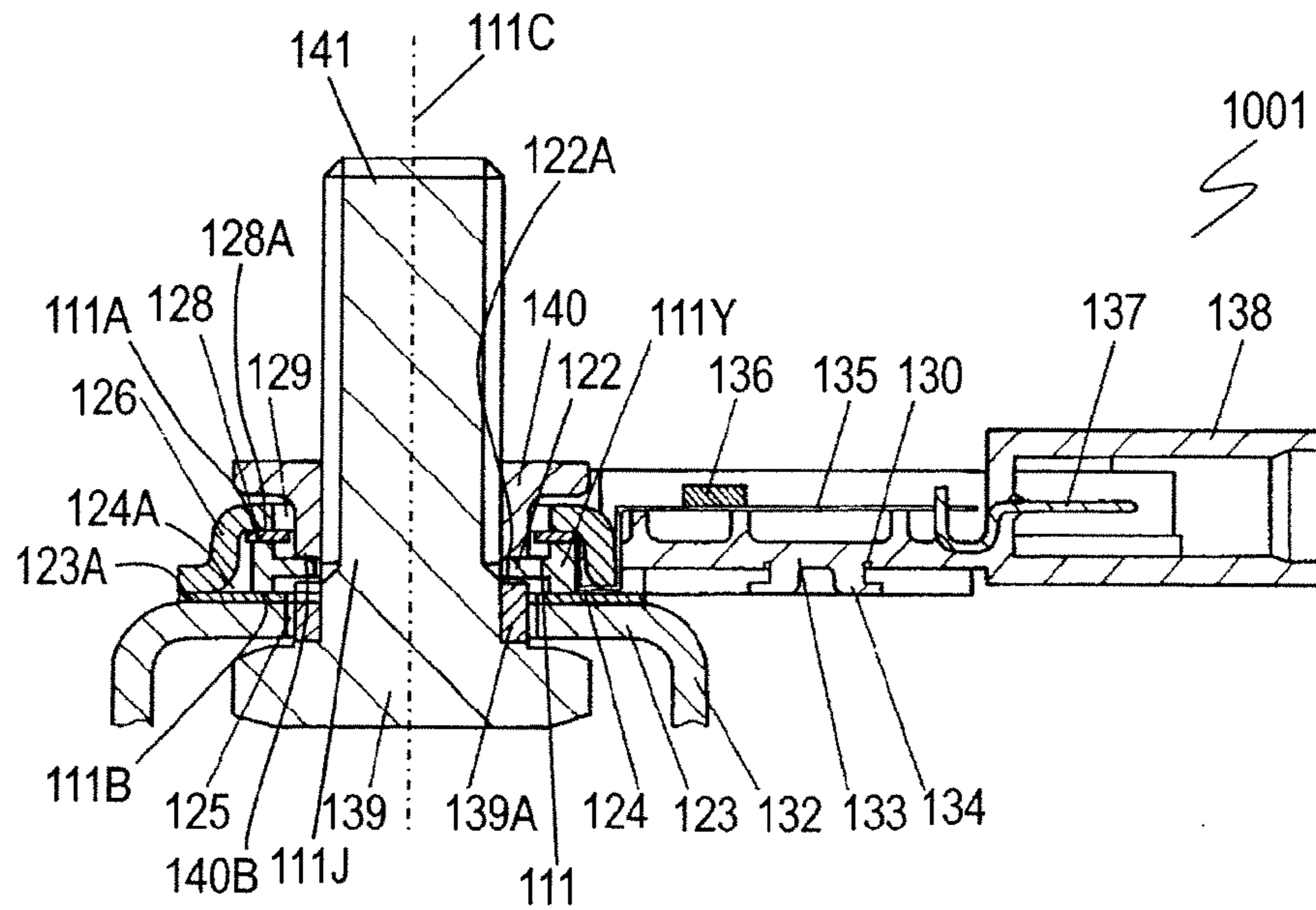


Fig. 2

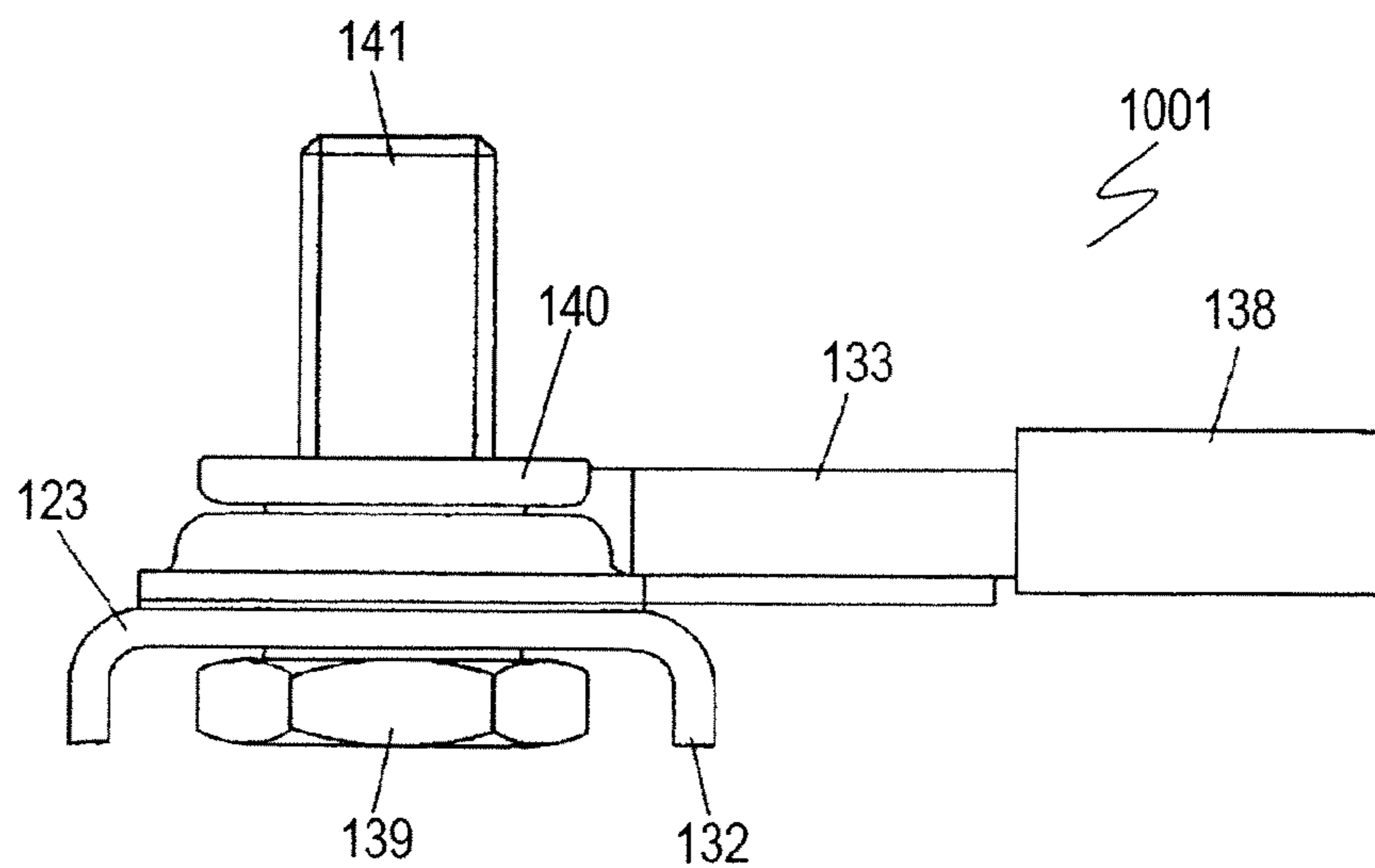


Fig. 3A

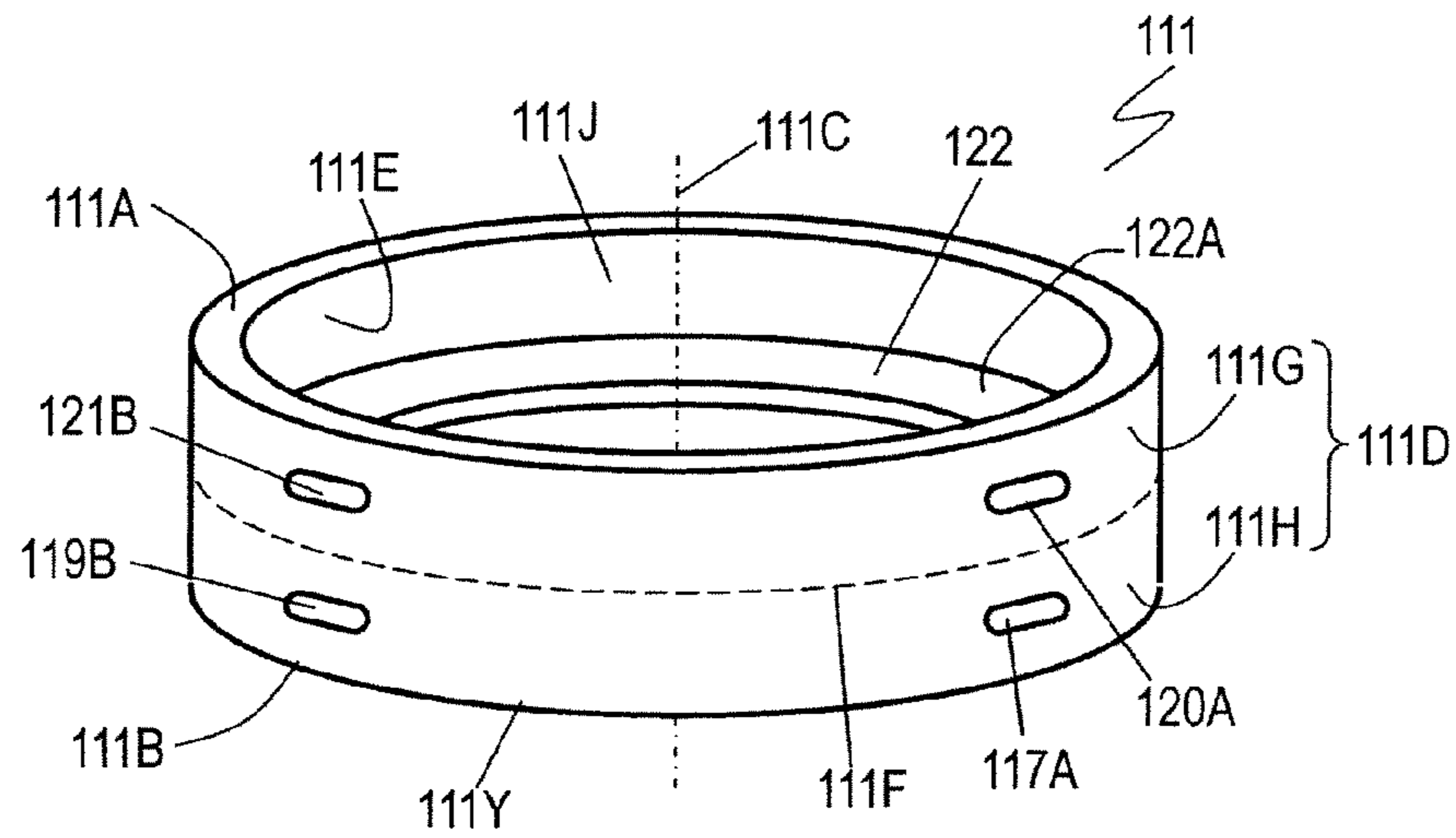


Fig. 3B

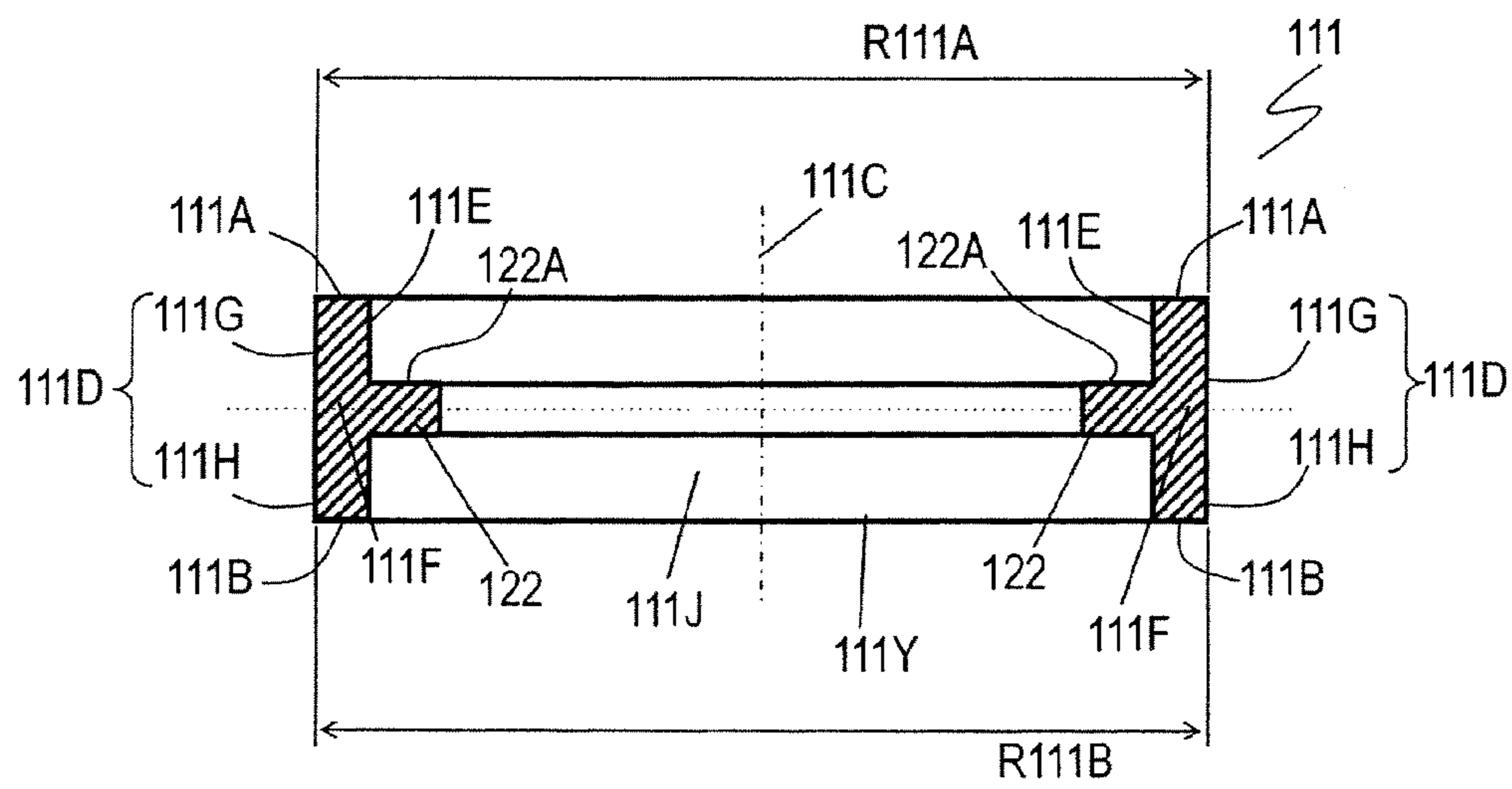


Fig. 3C

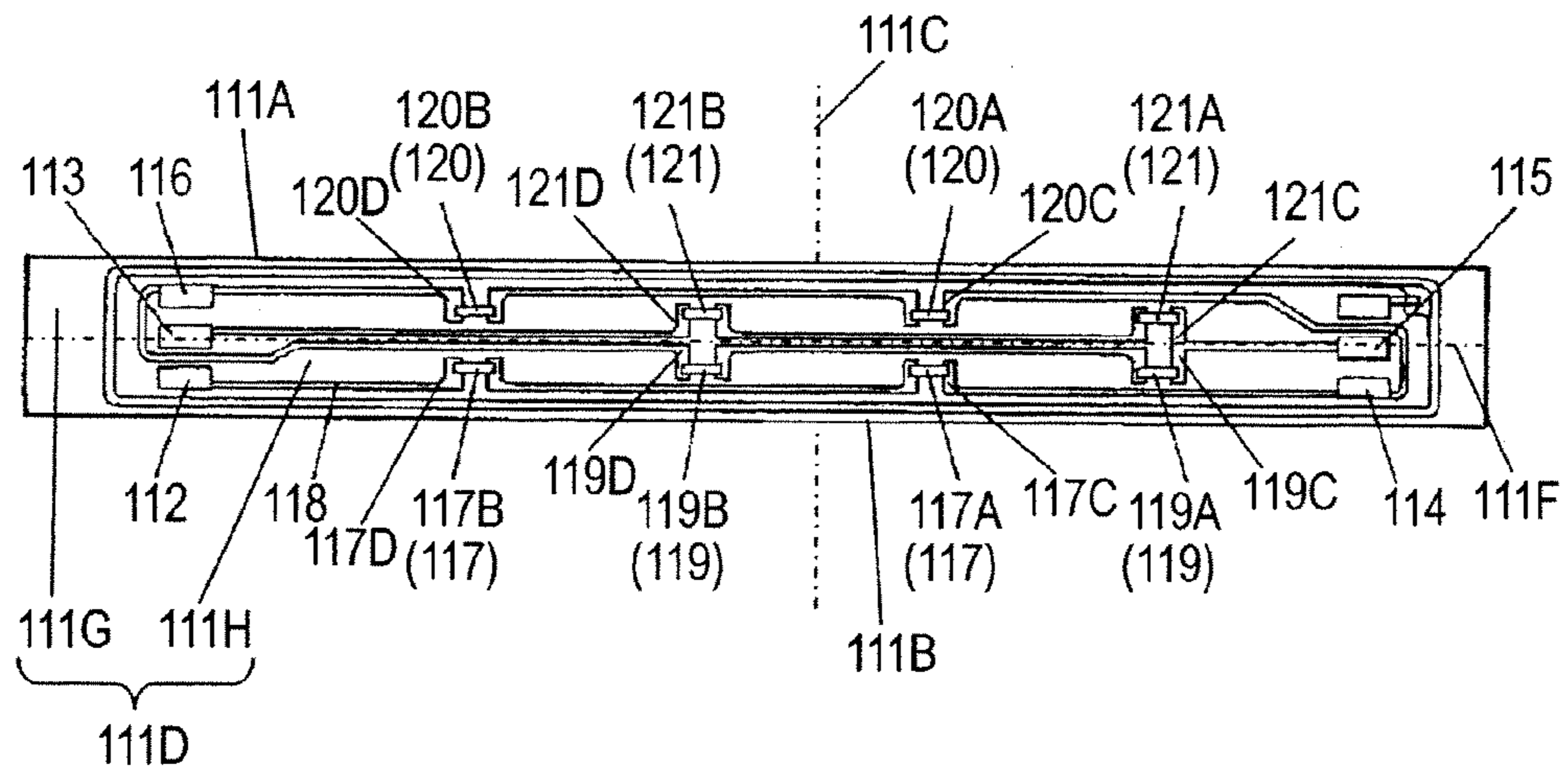


Fig. 4

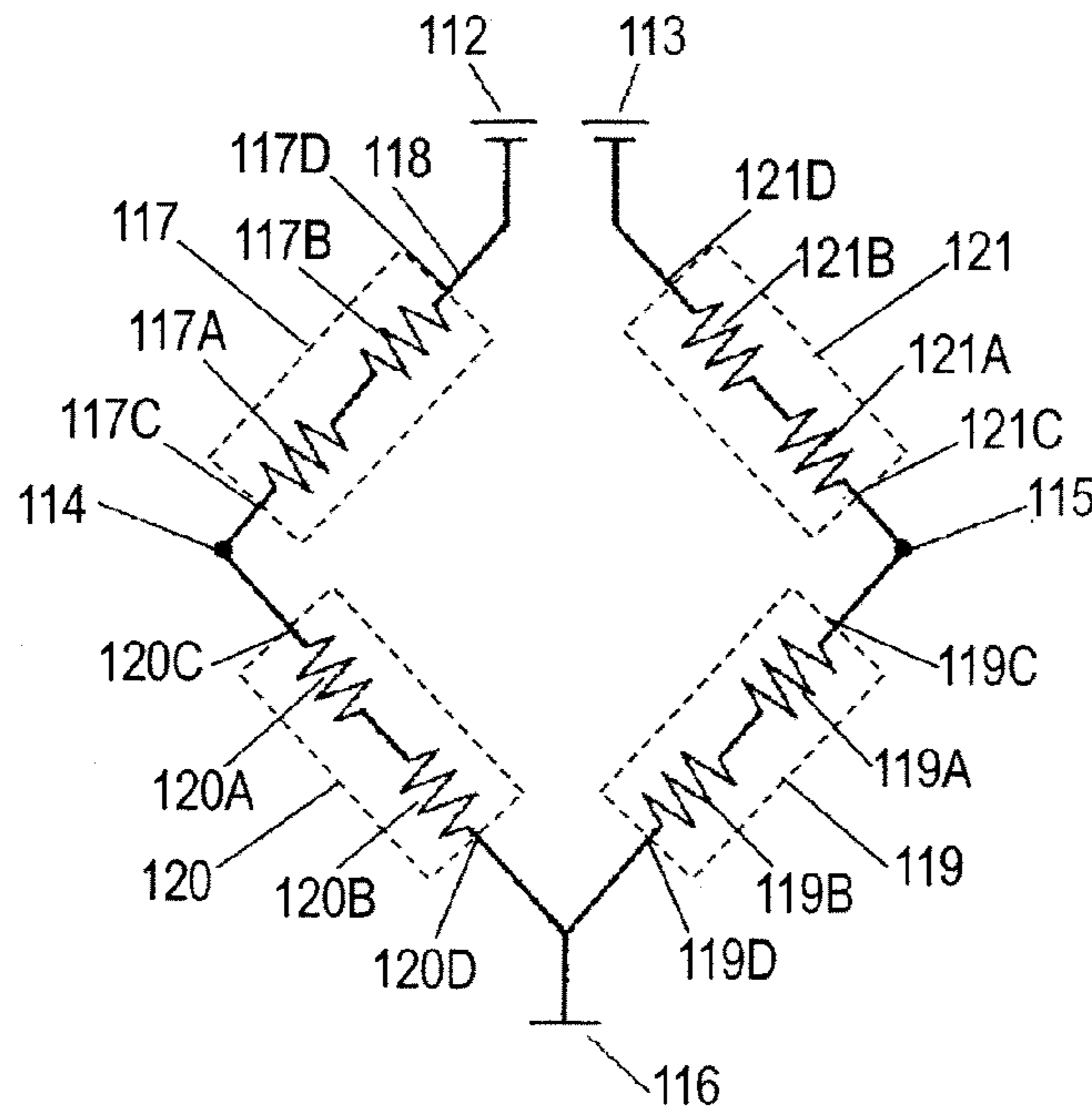


Fig. 5

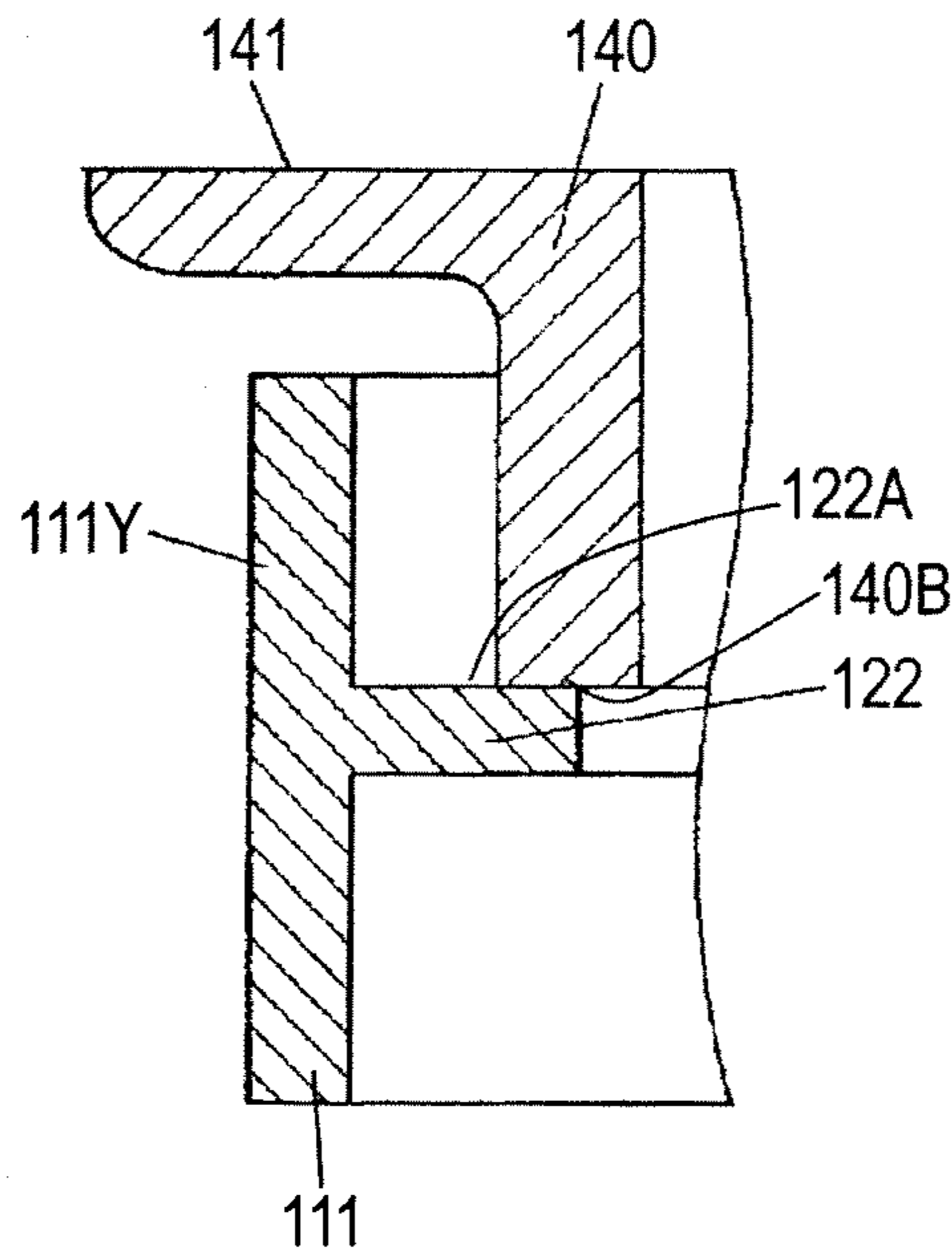


Fig. 6

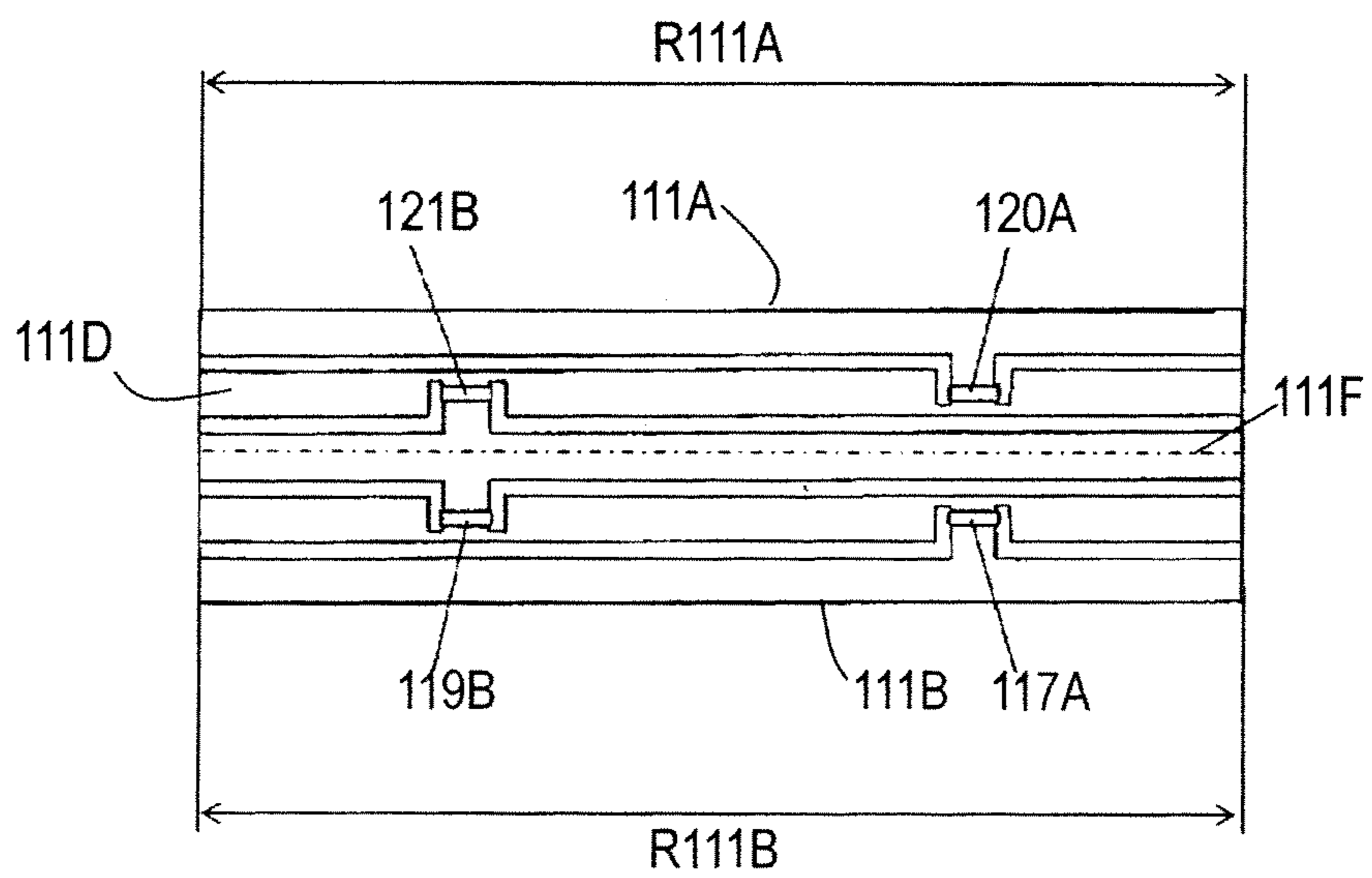


Fig. 7

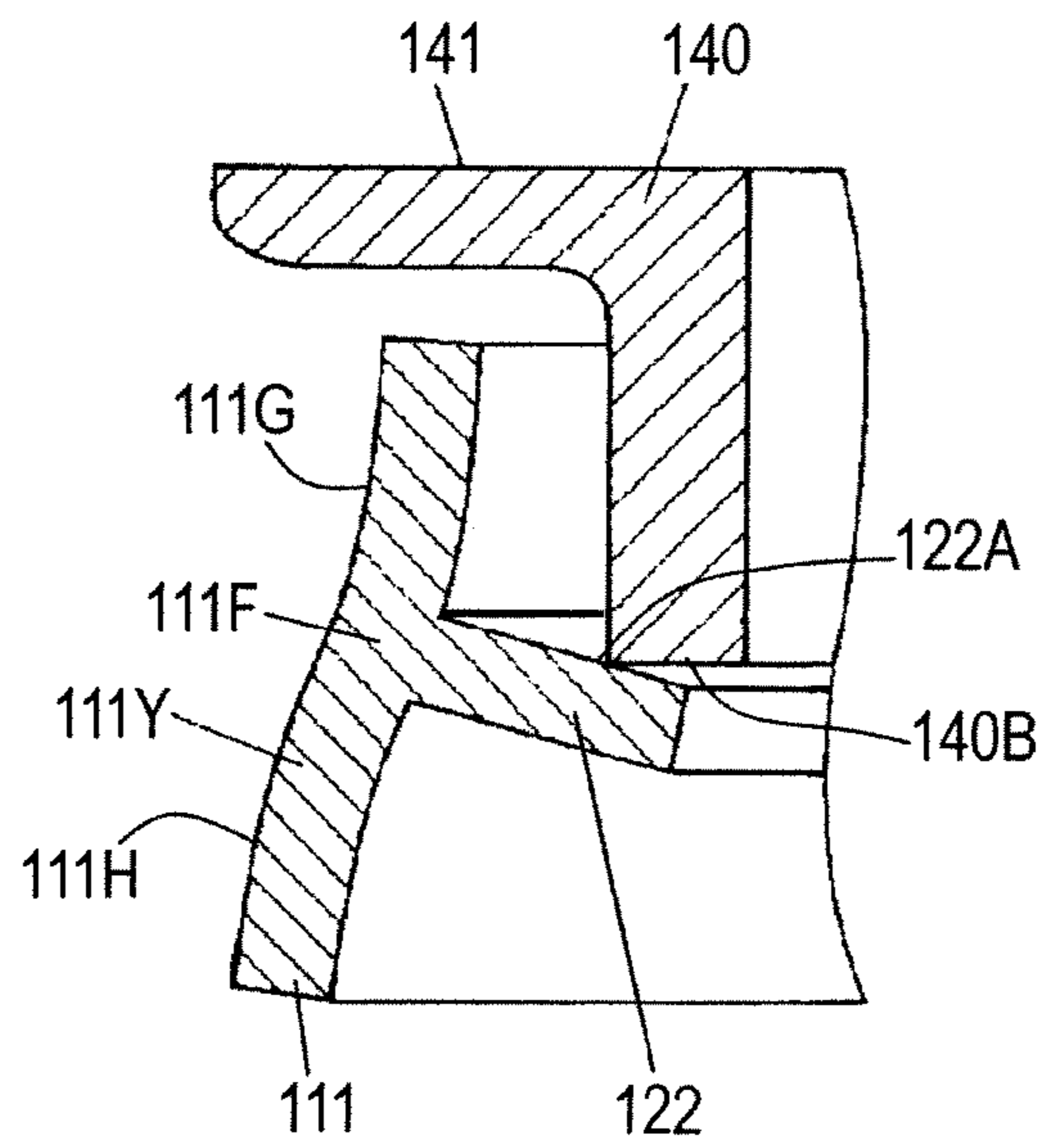


Fig. 8

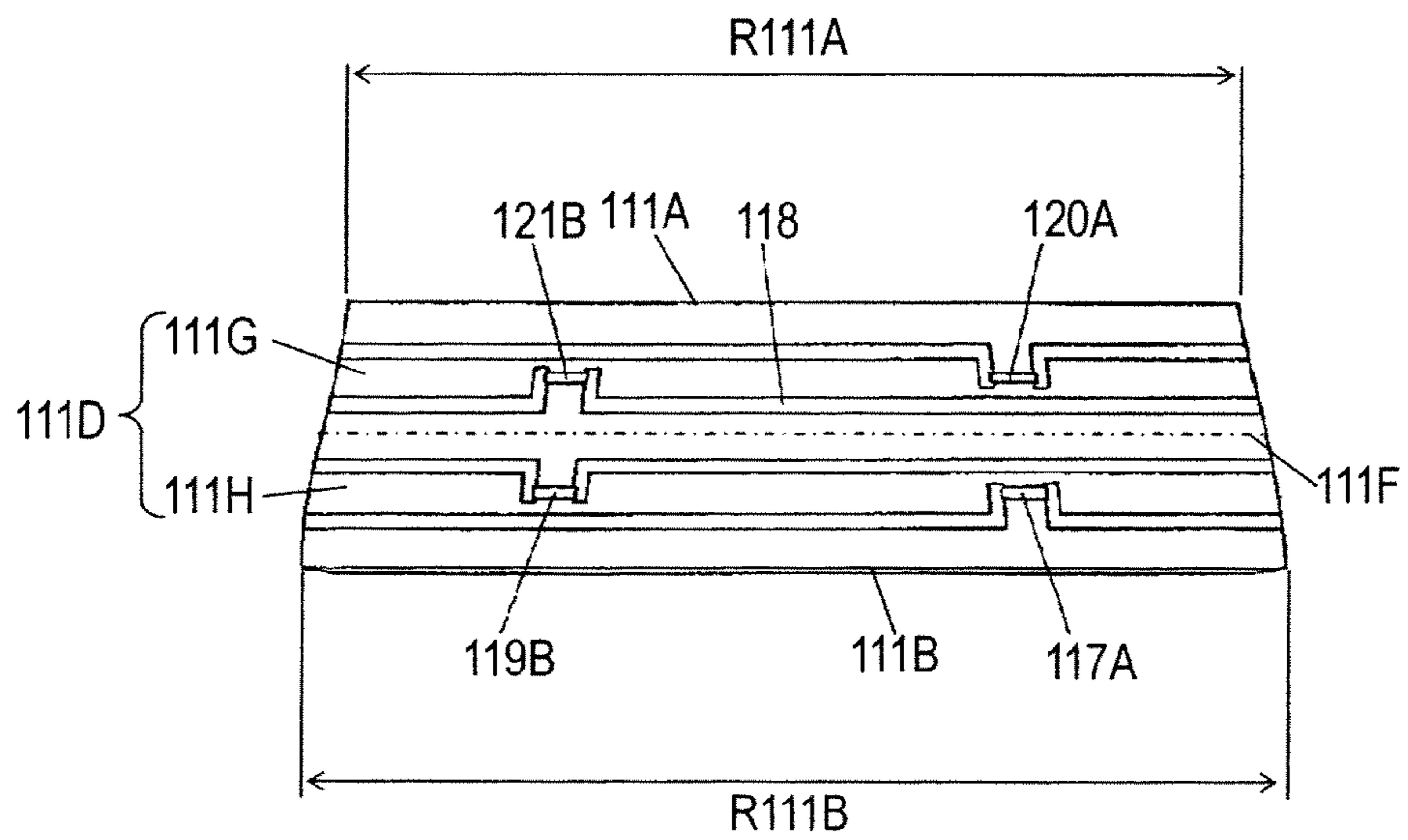


Fig. 9

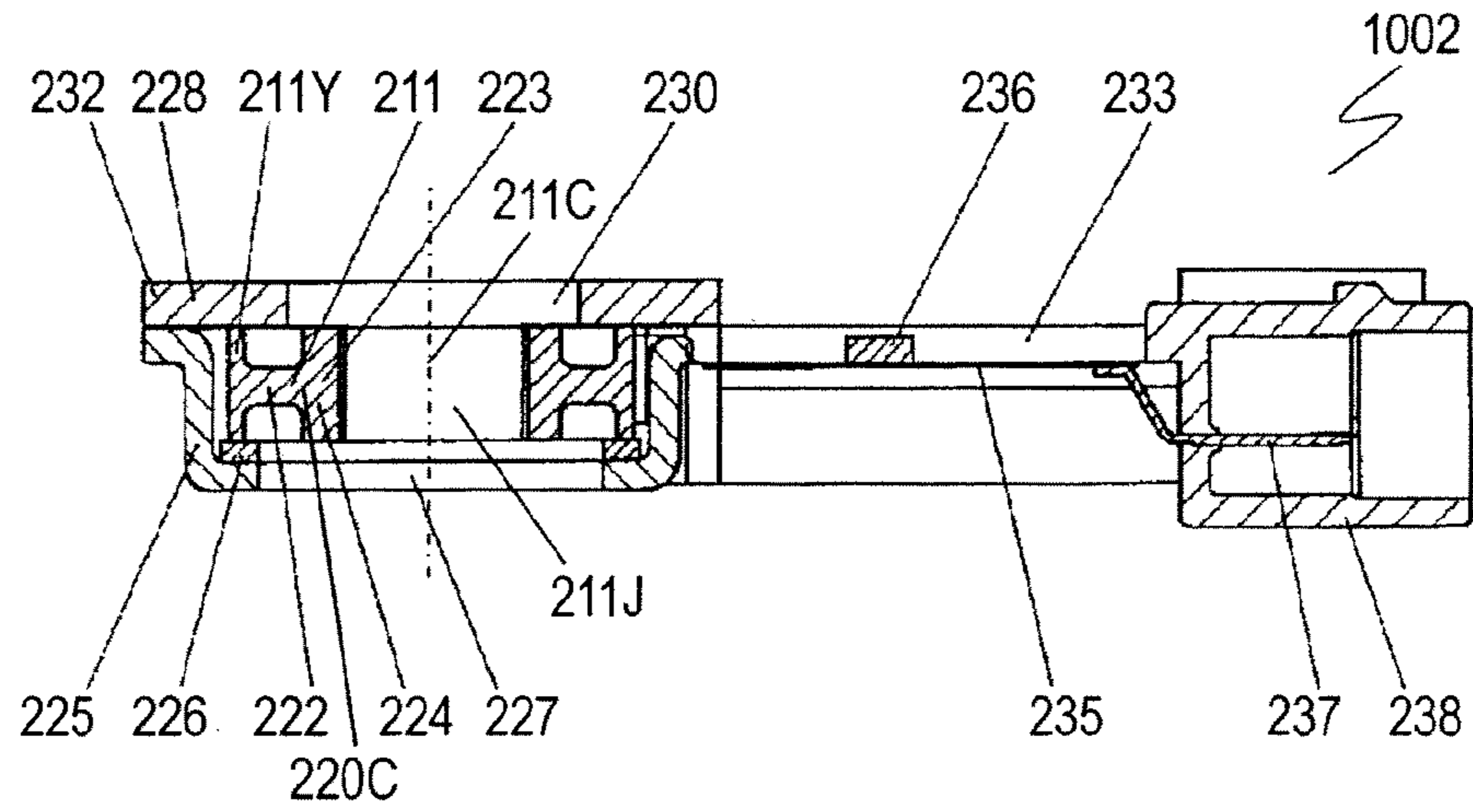


Fig. 10

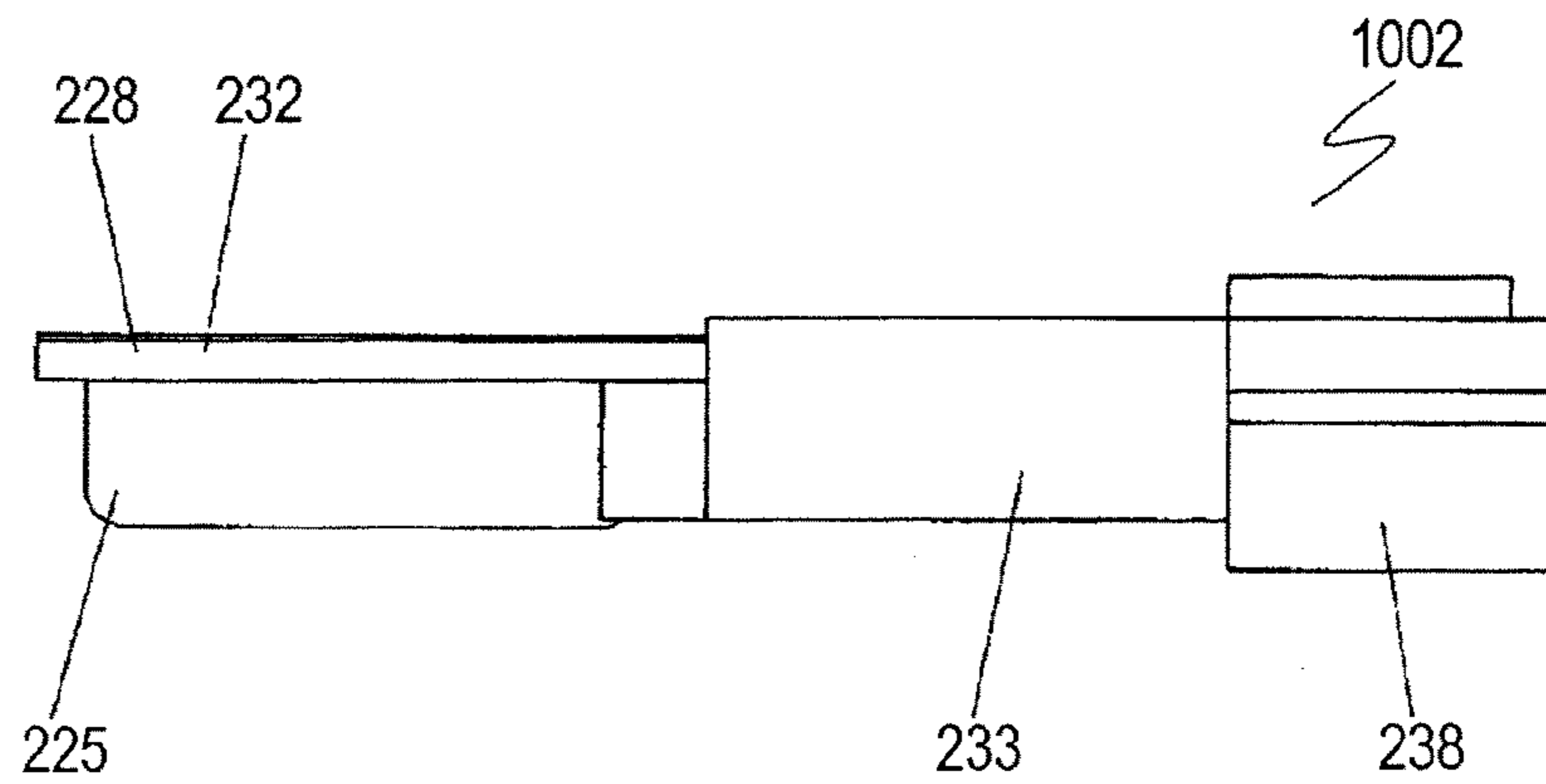




Fig. 11A

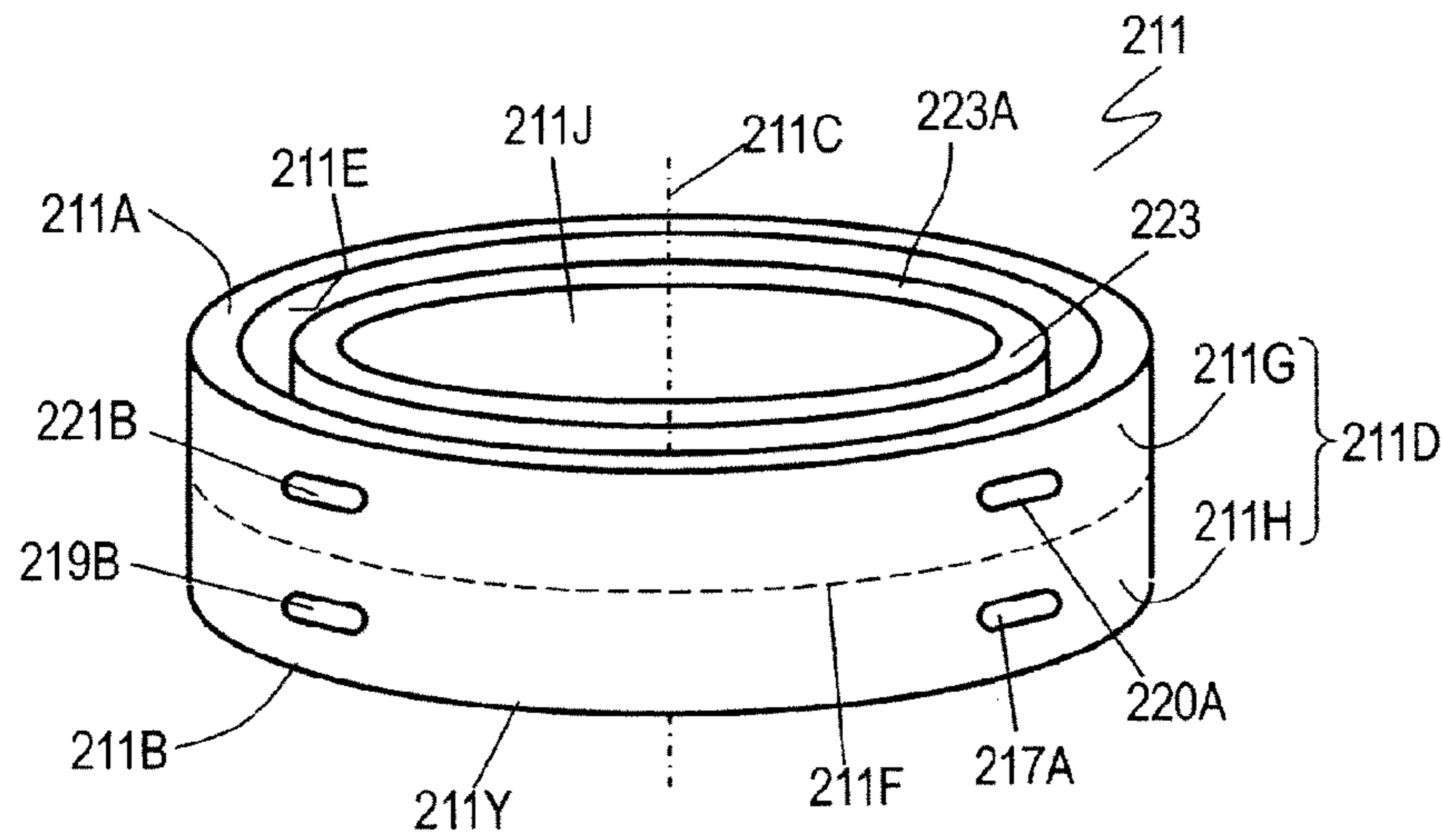


Fig. 11B

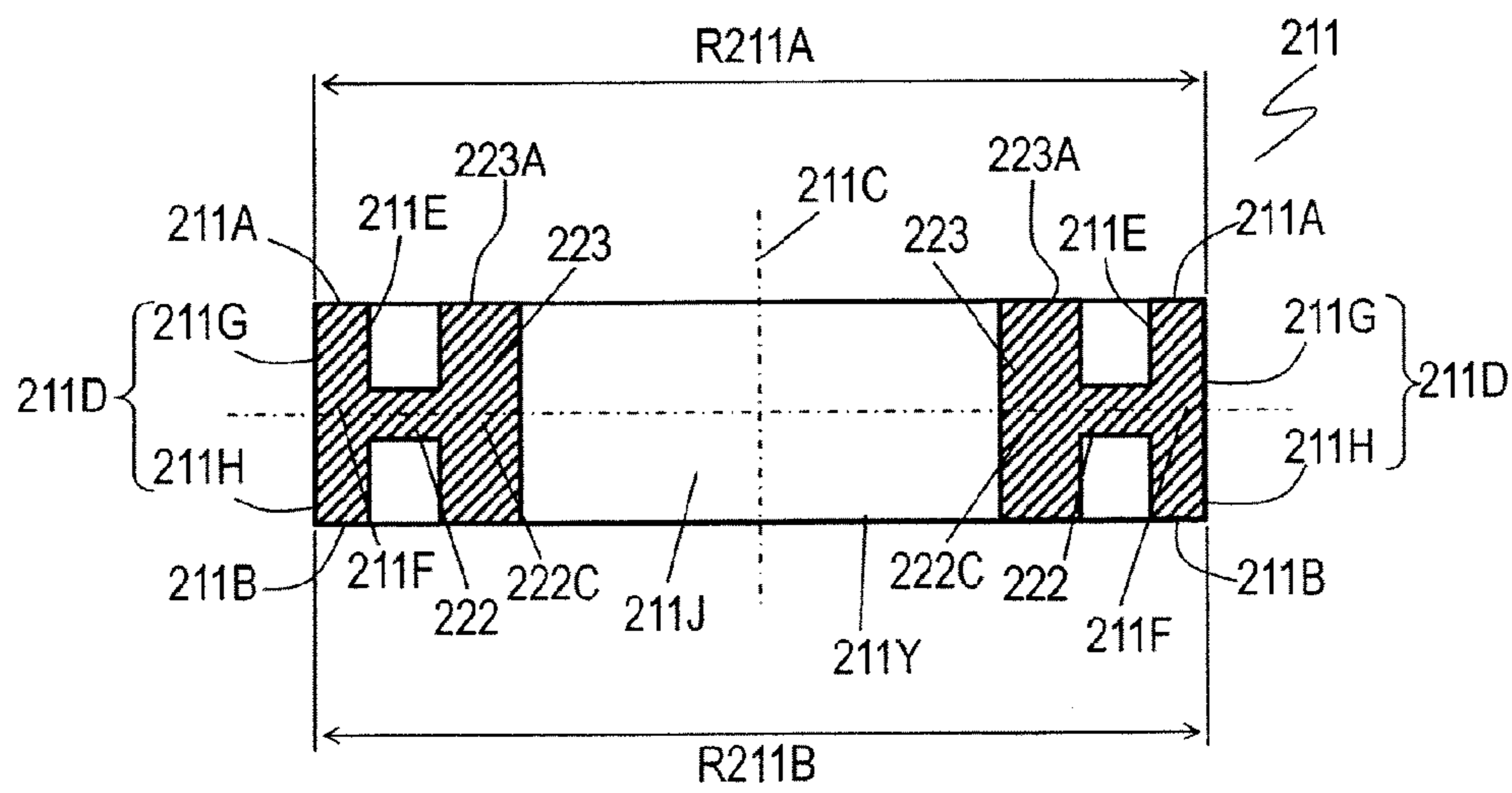


Fig. 11C

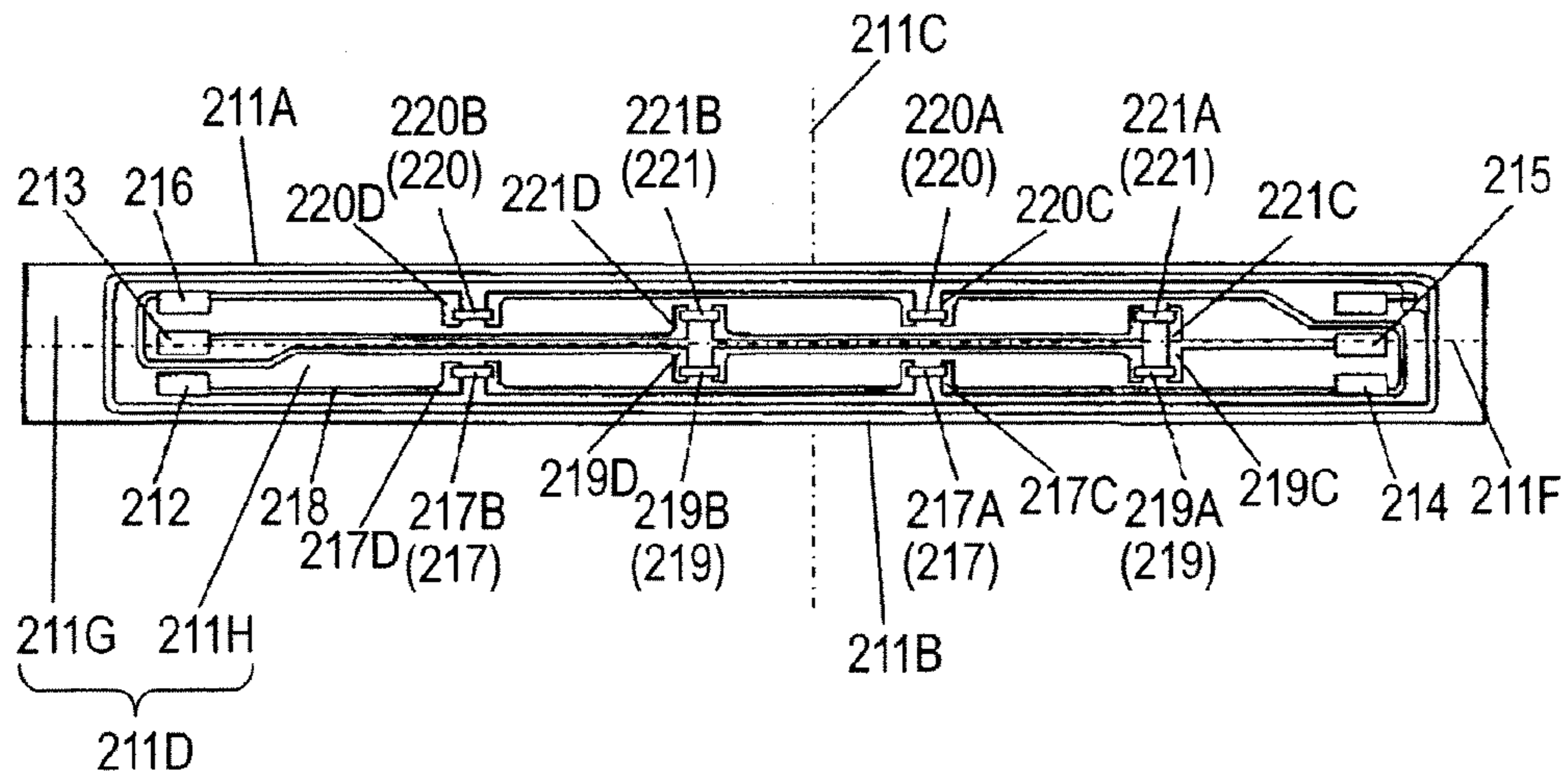


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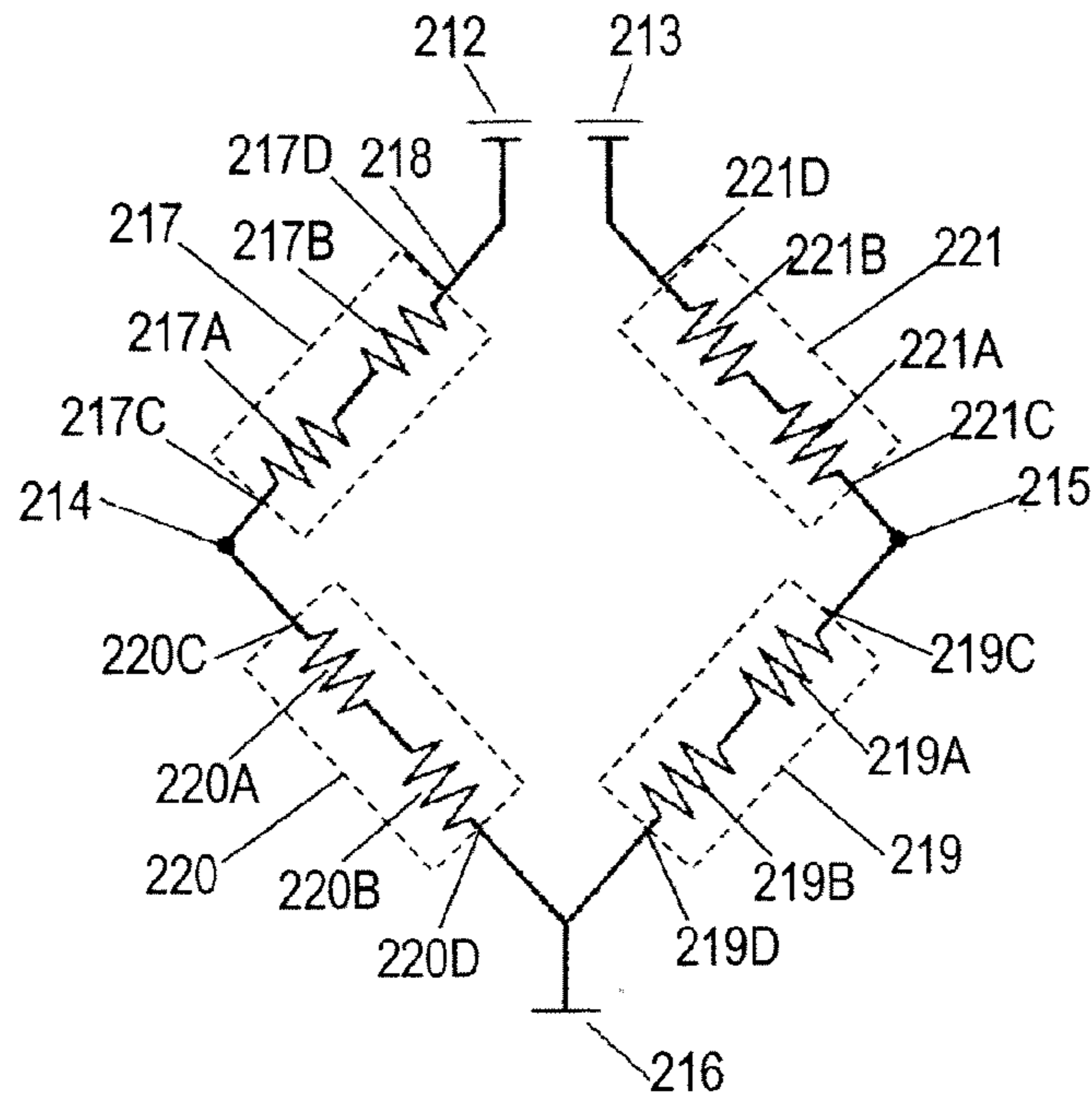


Fig. 13

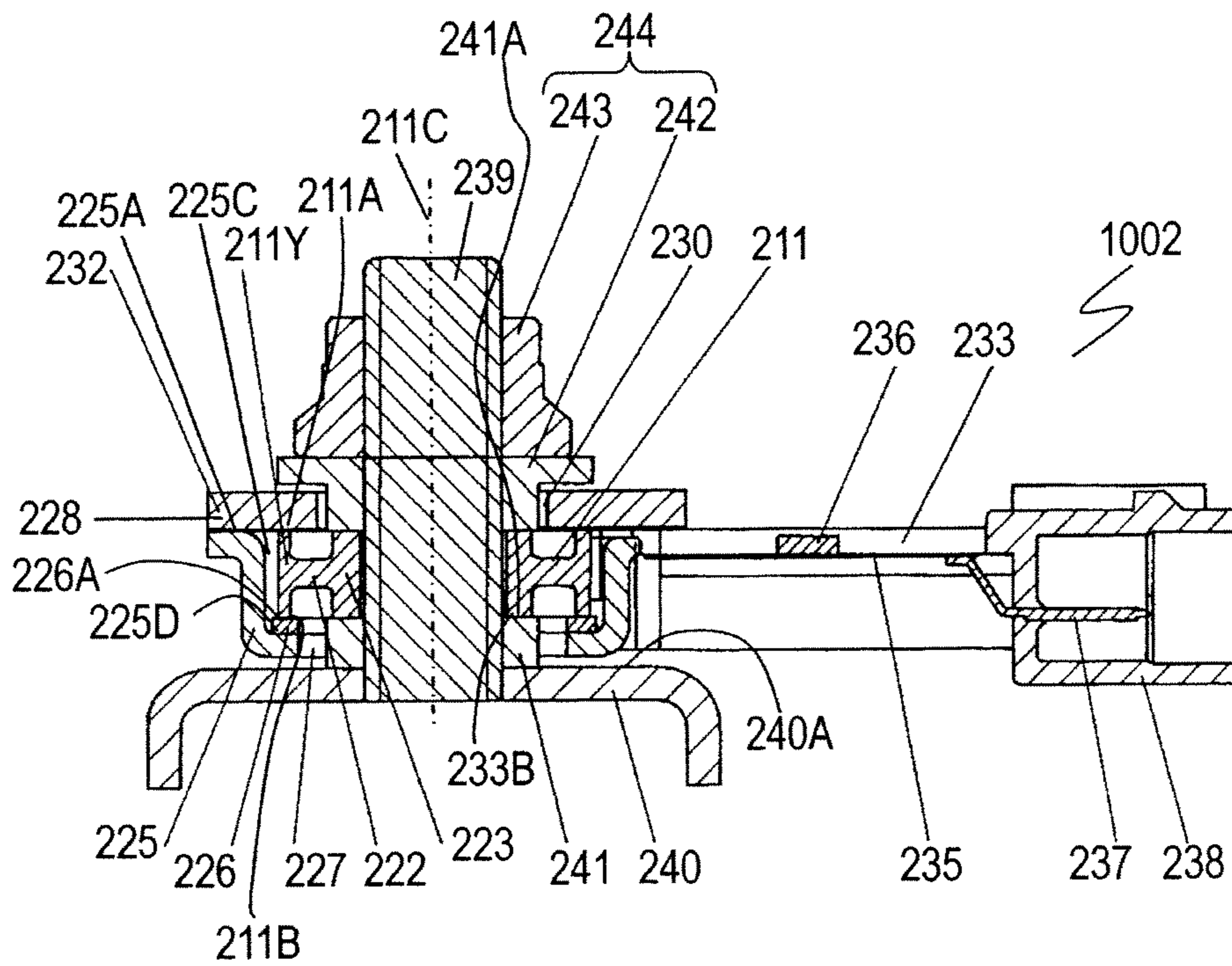


Fig. 14

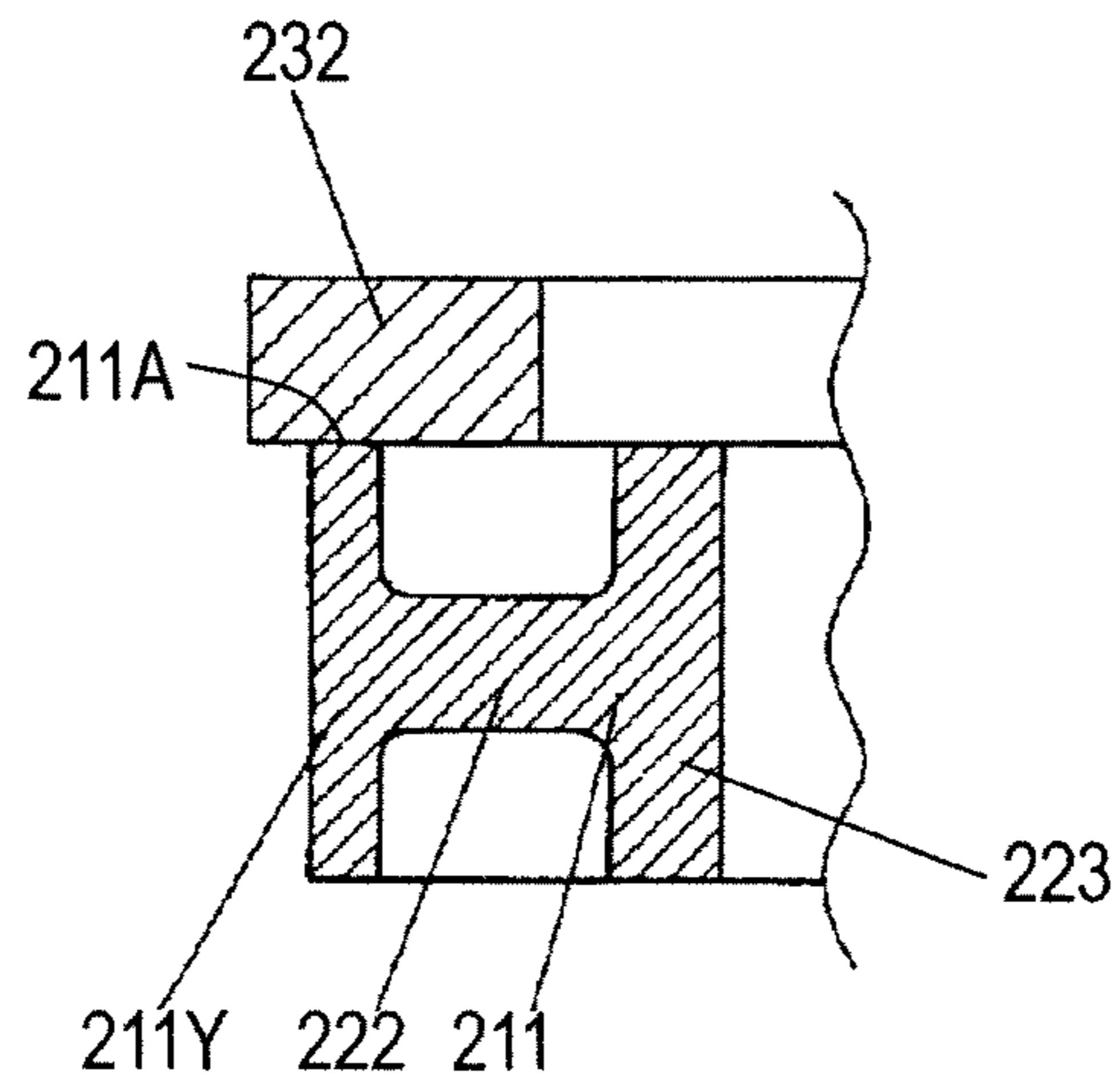


Fig. 15

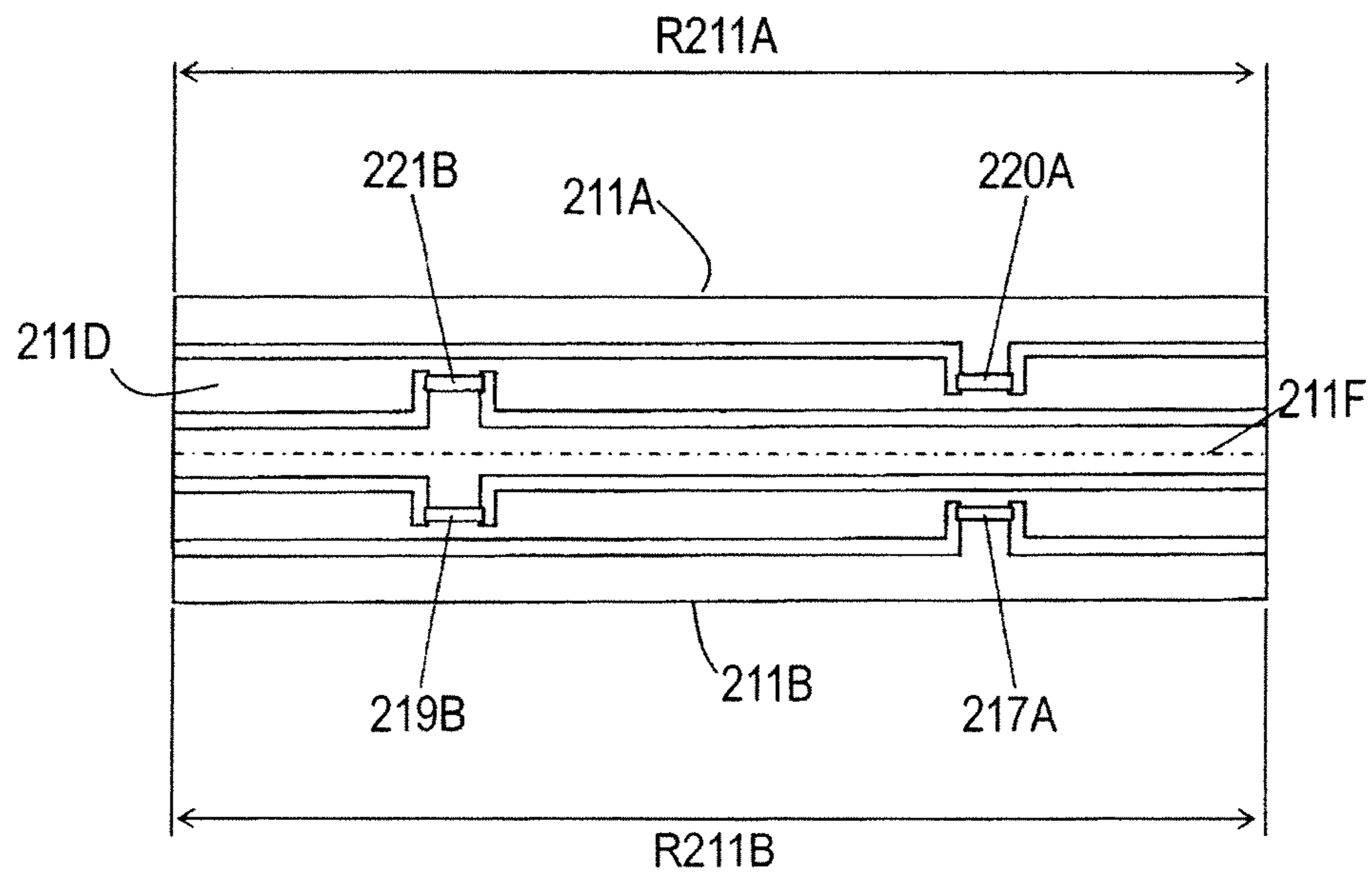


Fig. 16

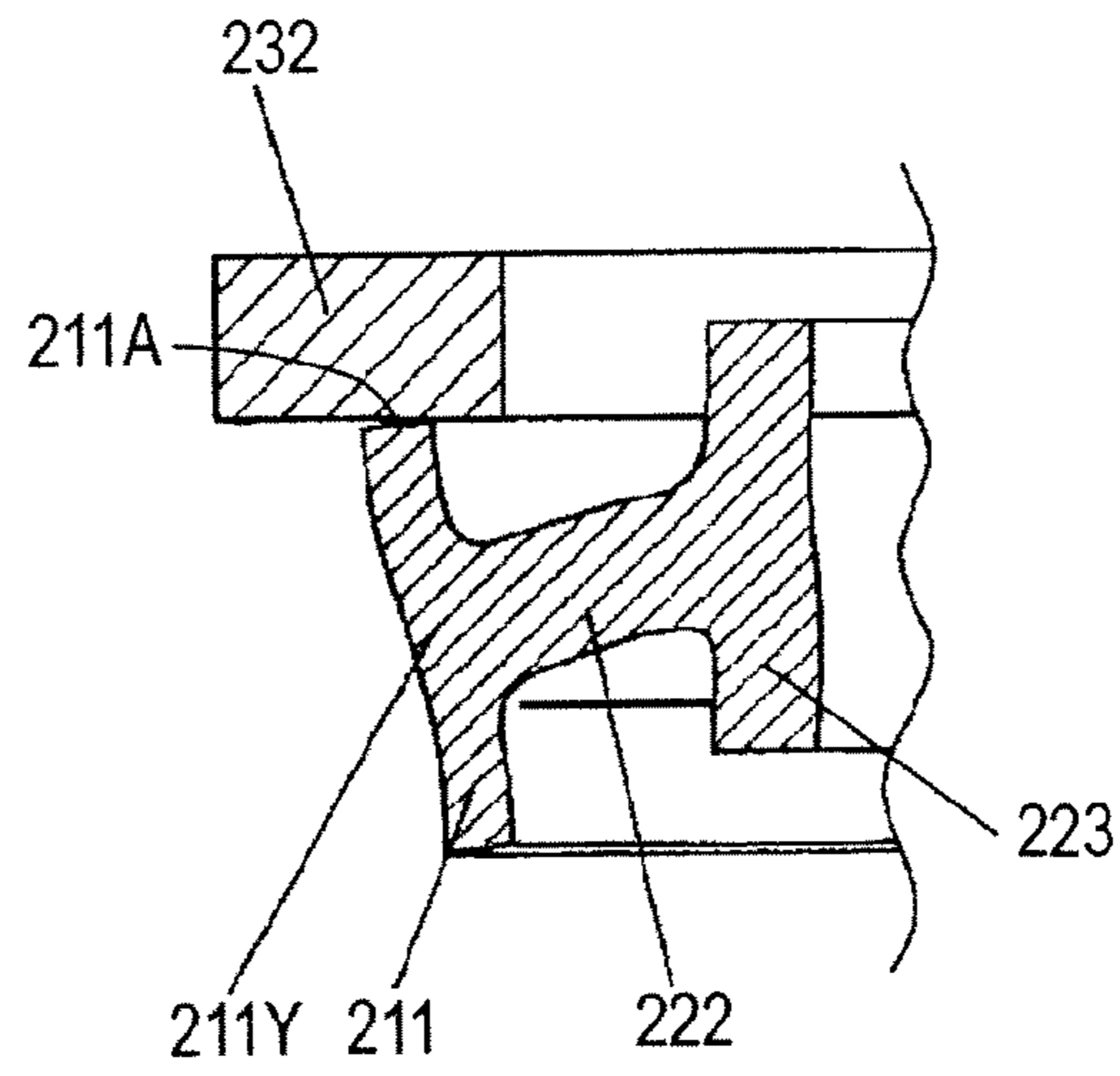


Fig. 17

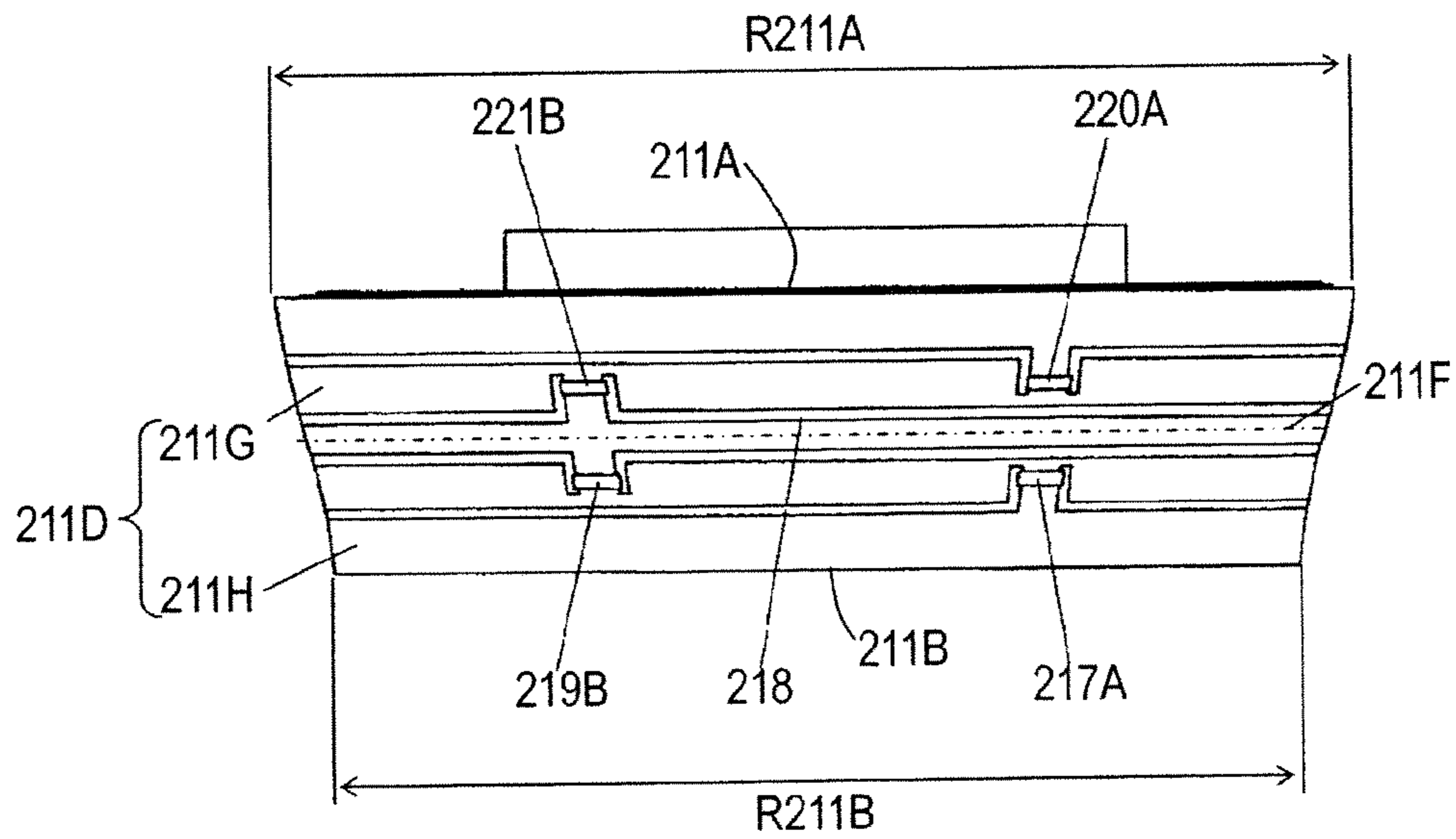


Fig. 18

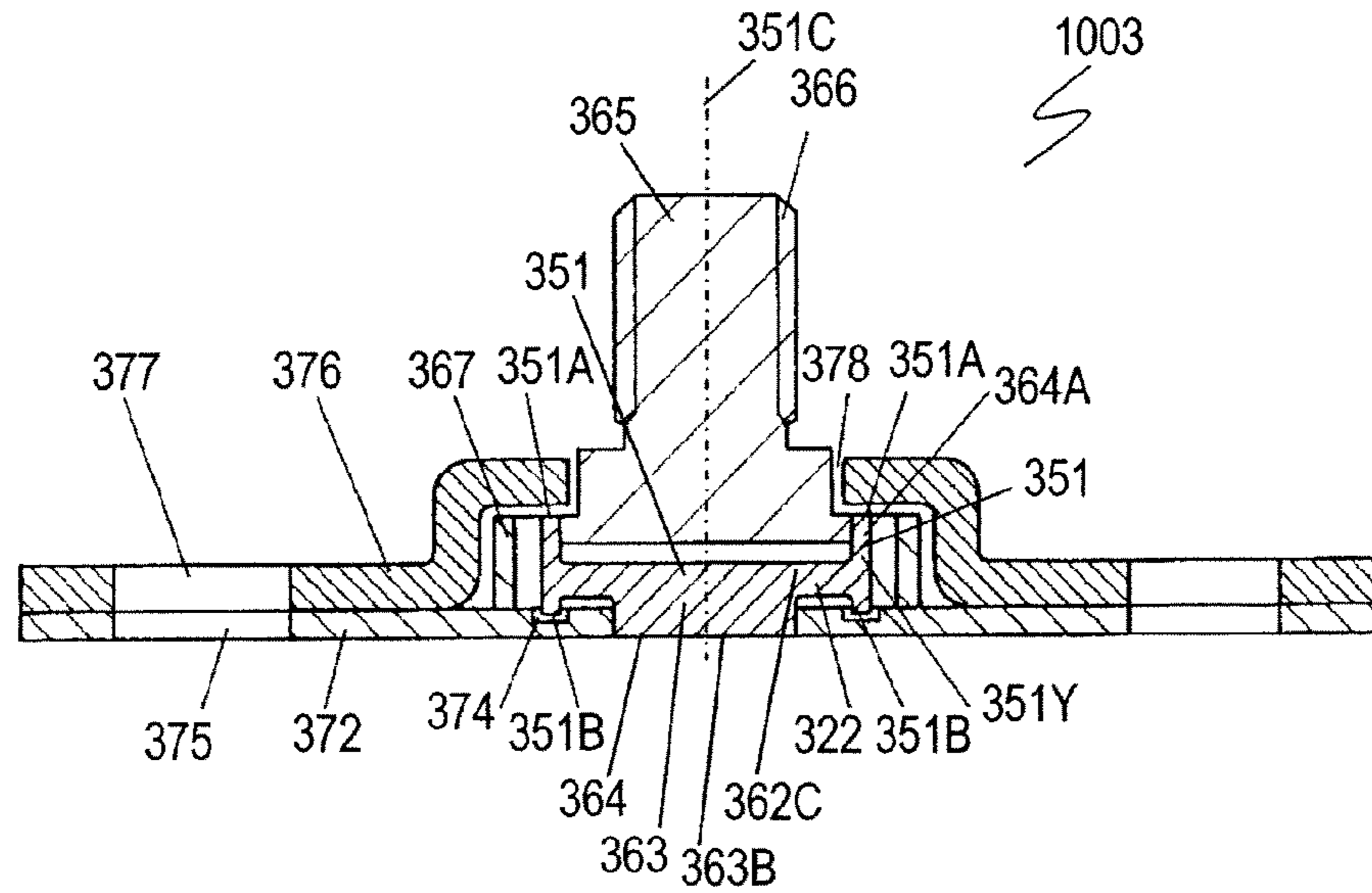


Fig. 19

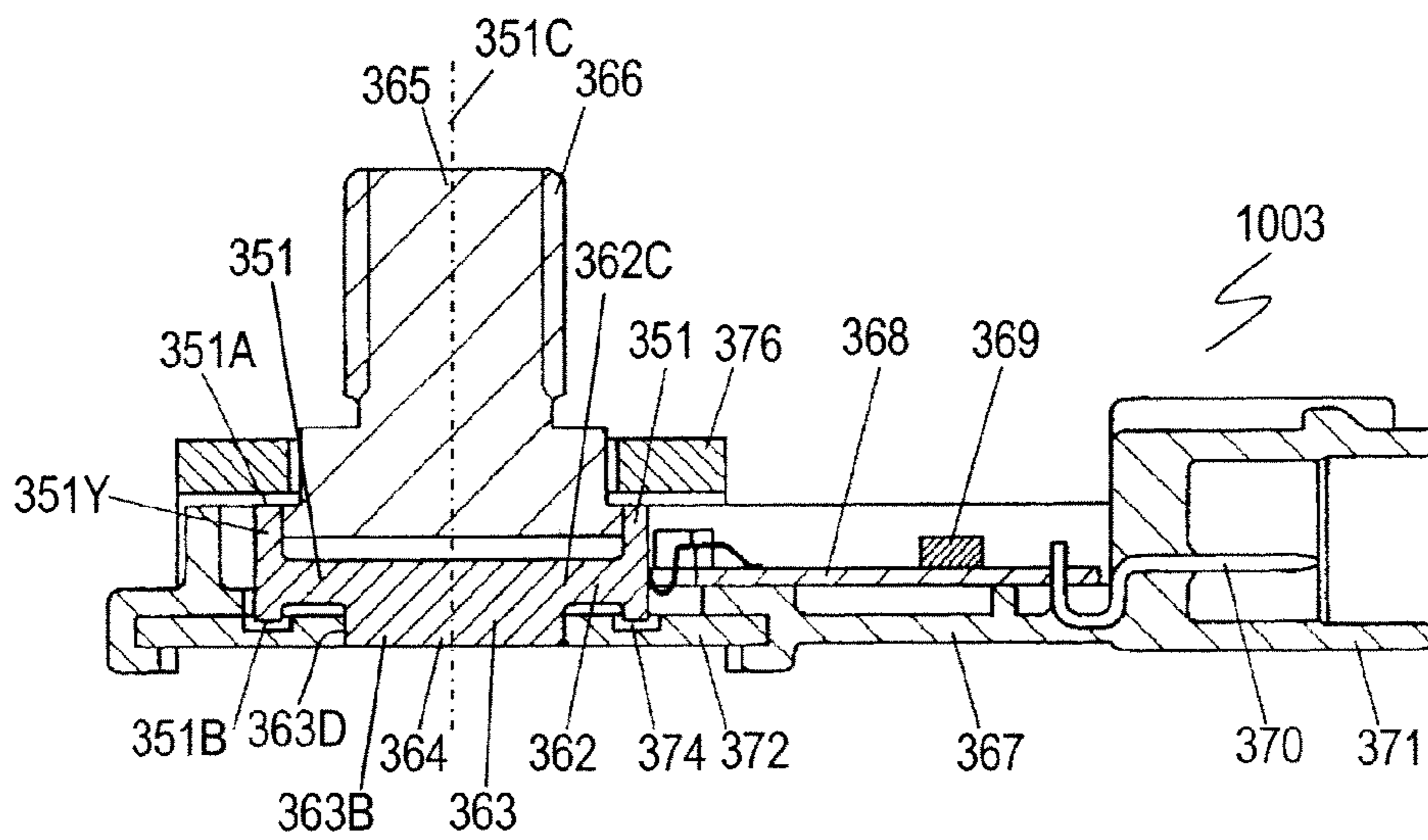


Fig. 20A

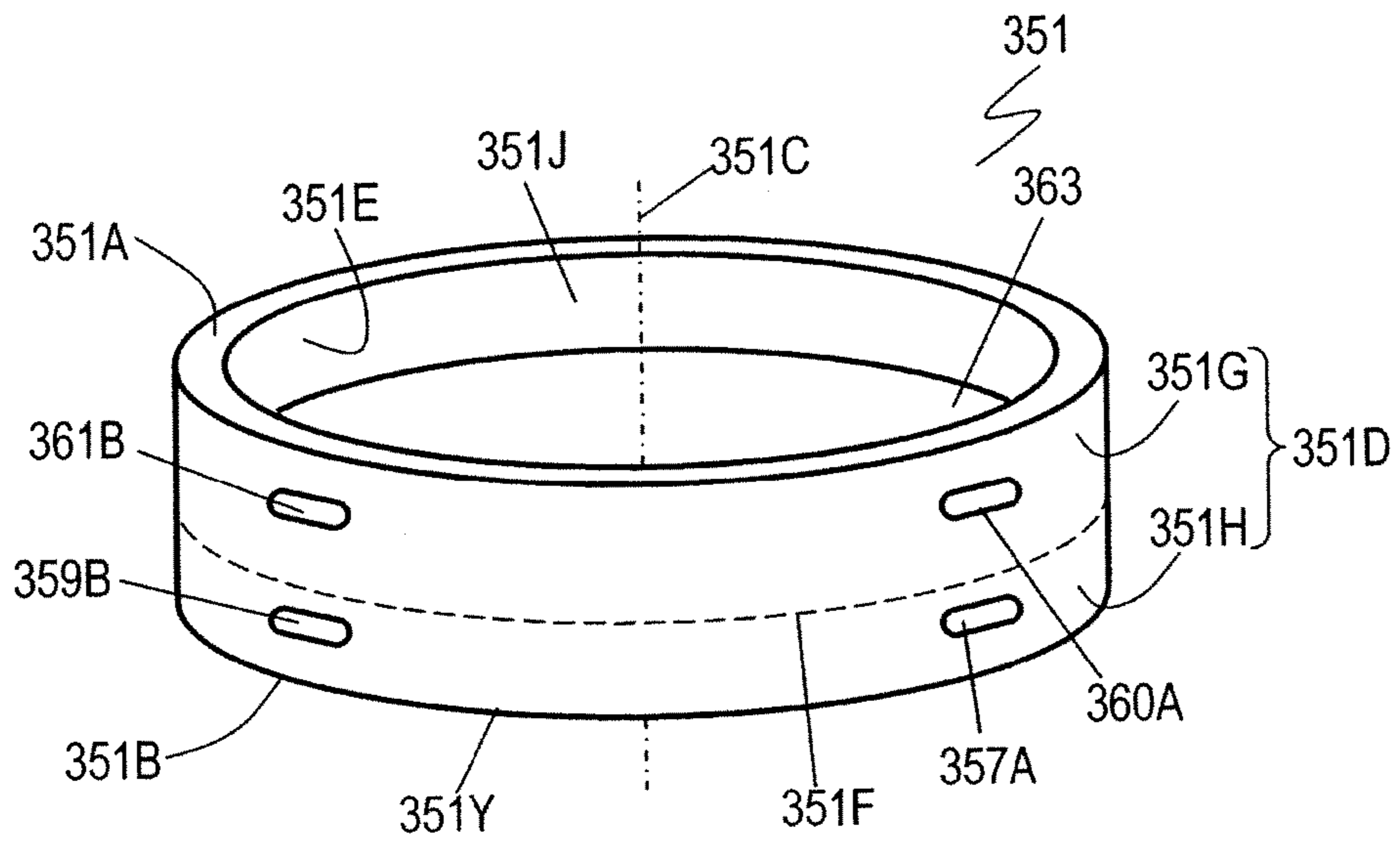


Fig. 20B

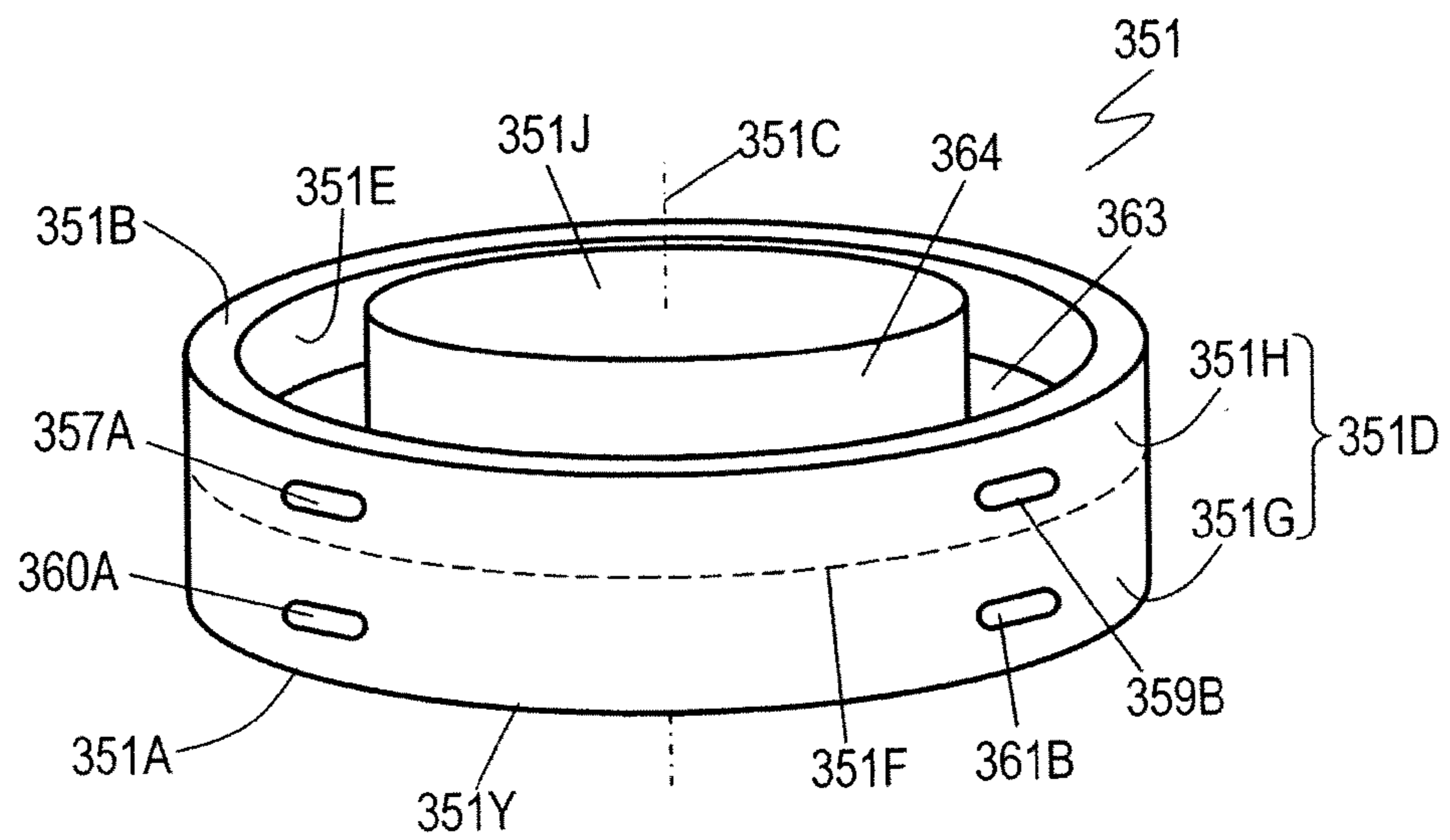


Fig. 20C

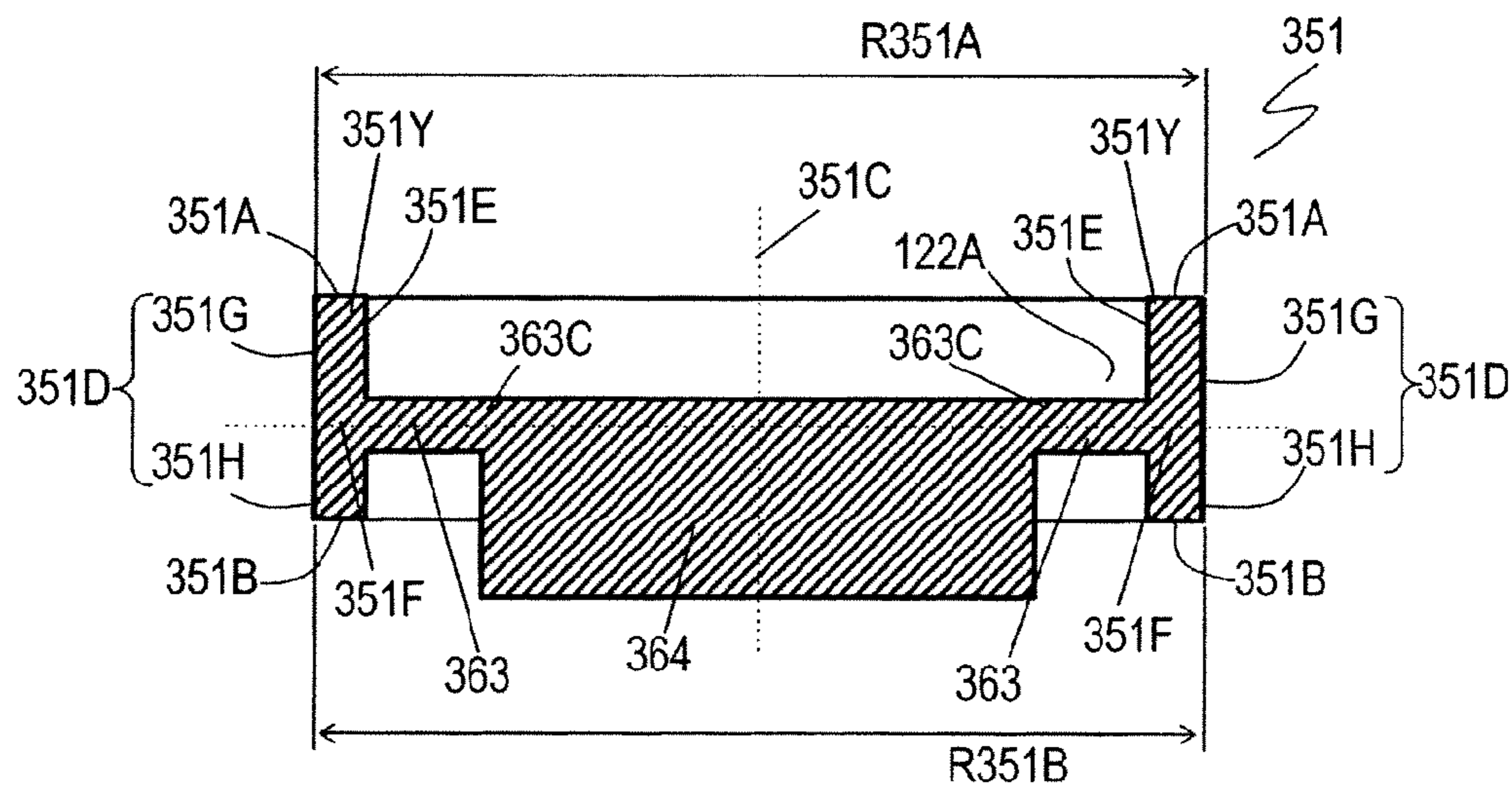




Fig. 20D

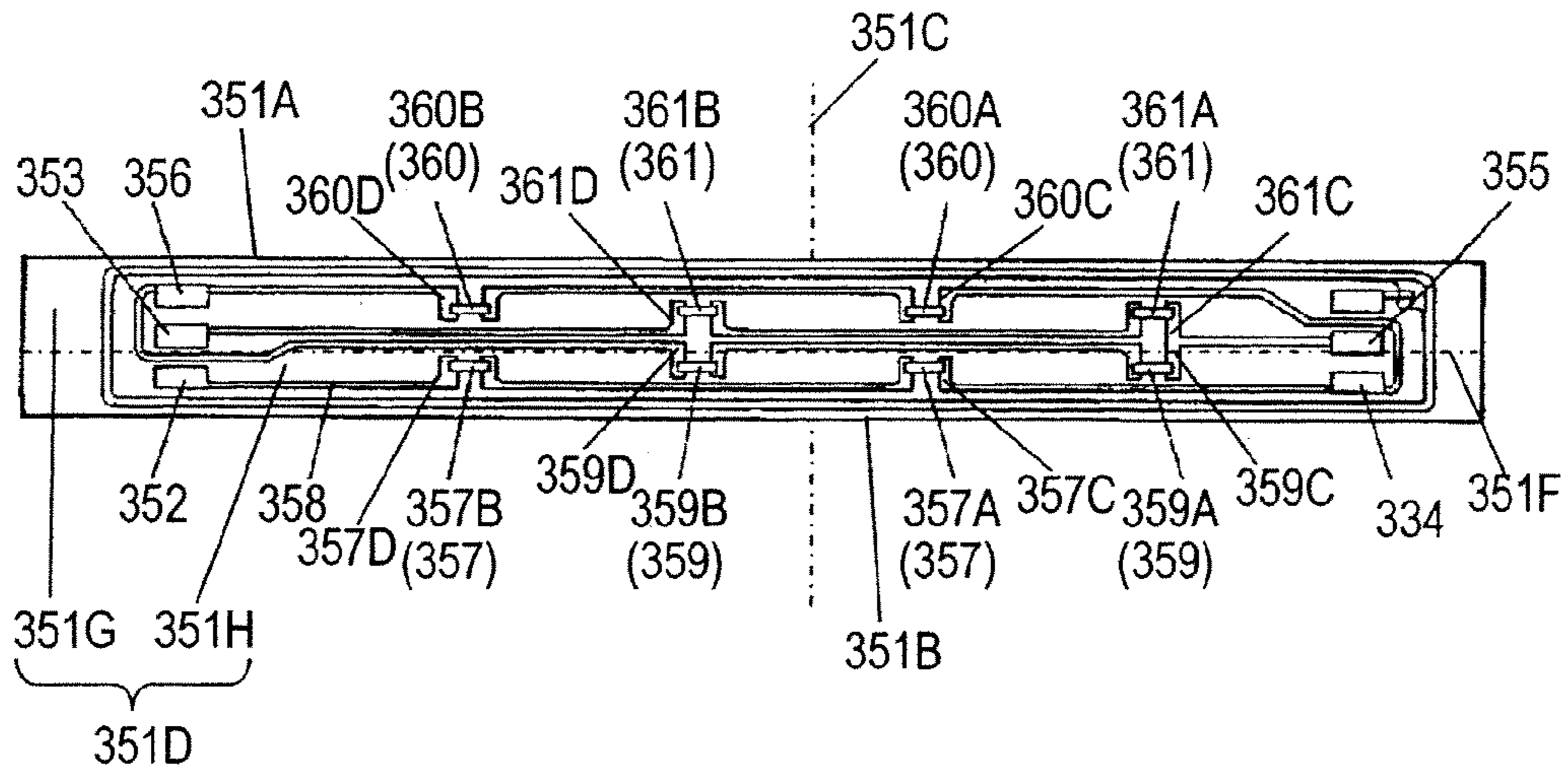


Fig. 21

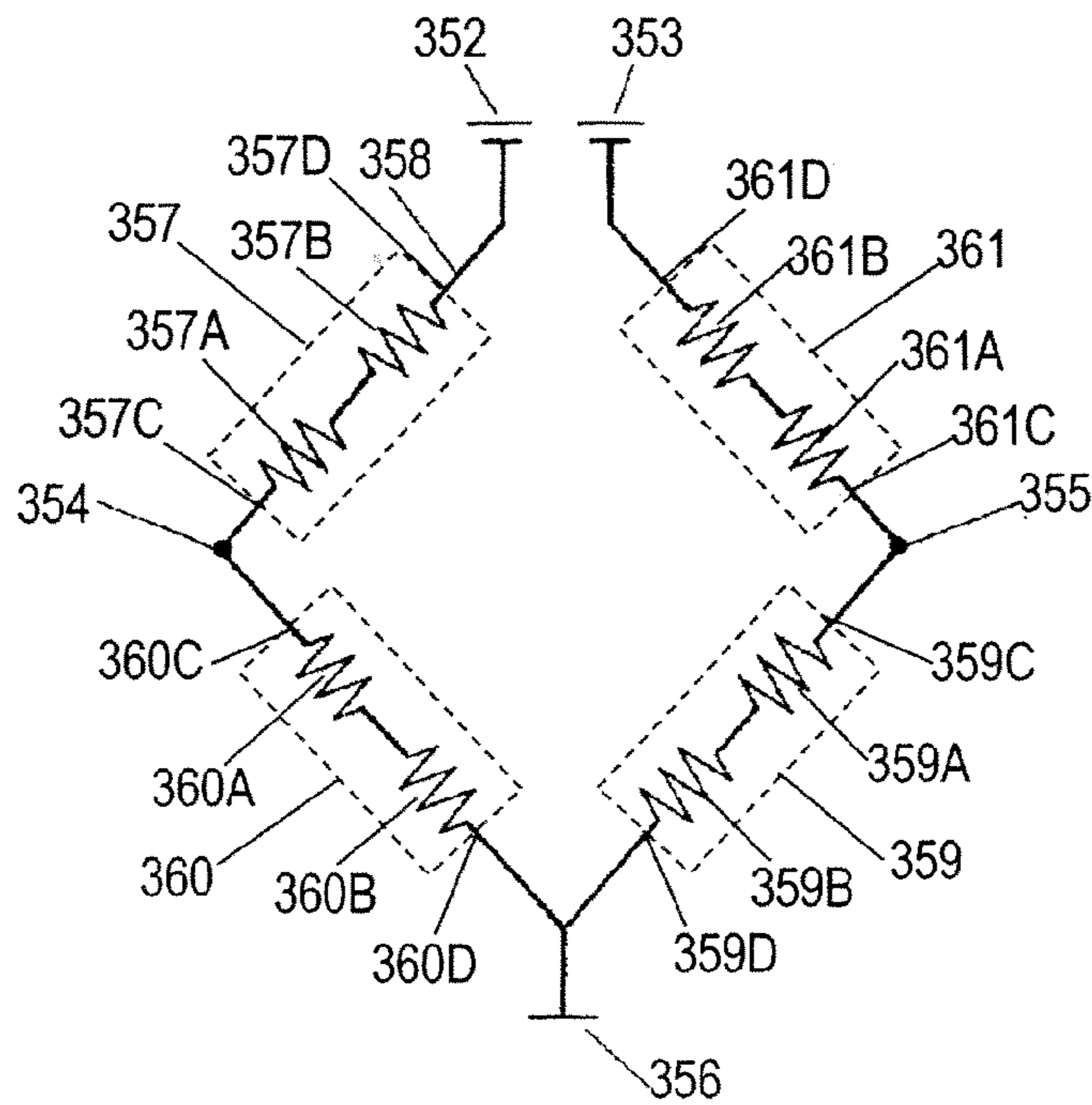


Fig. 22

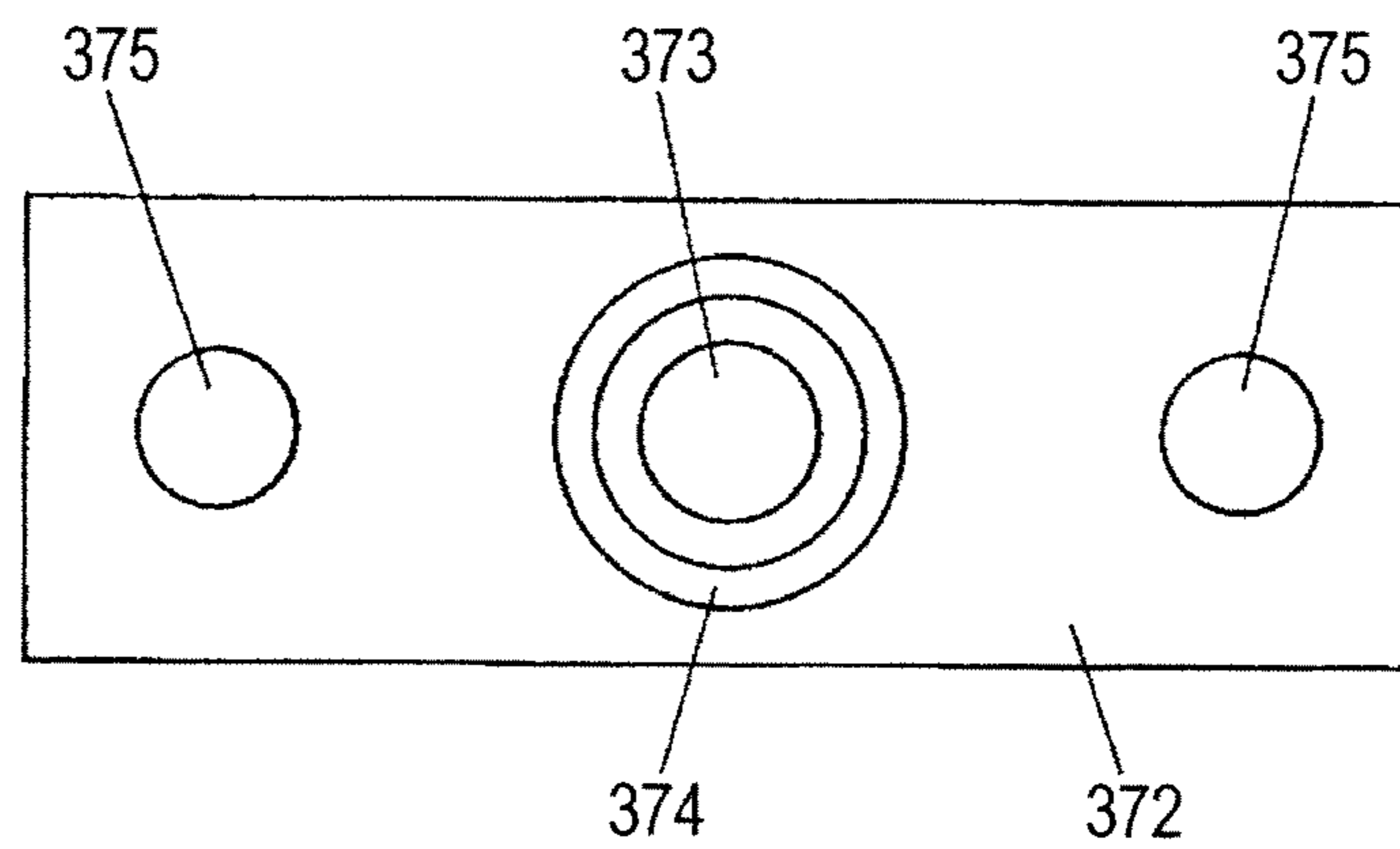


Fig. 23

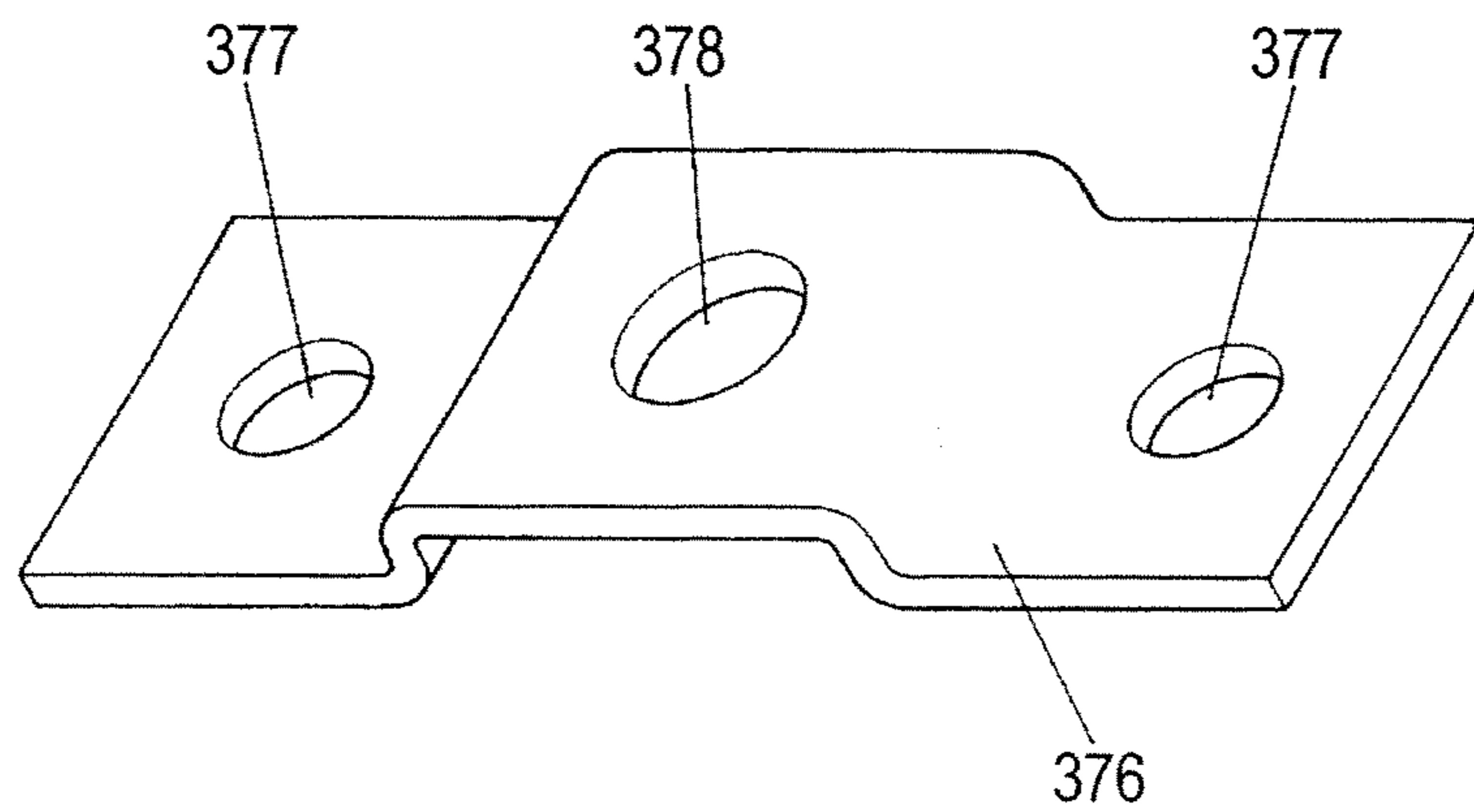


Fig. 24

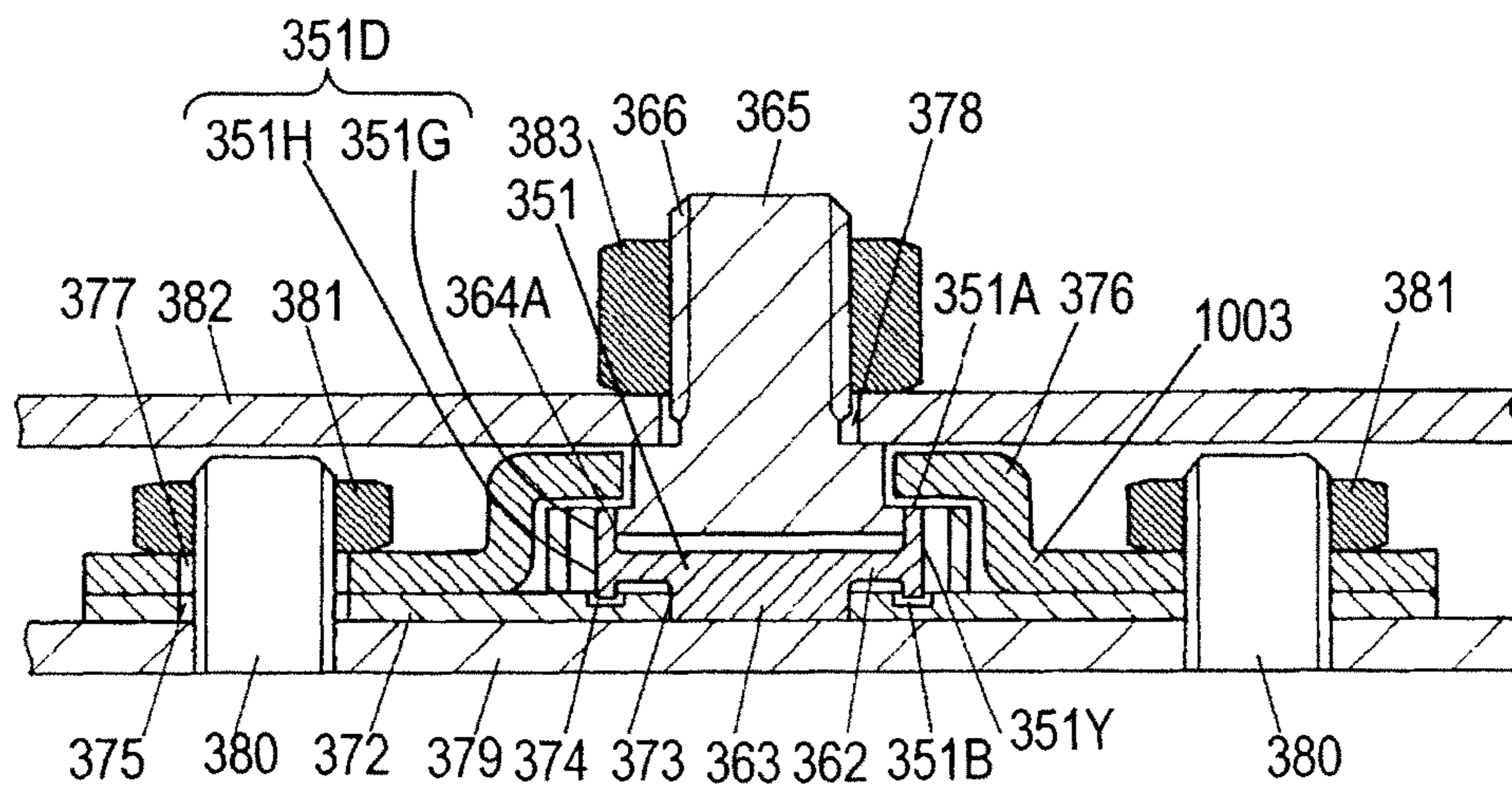


Fig. 25

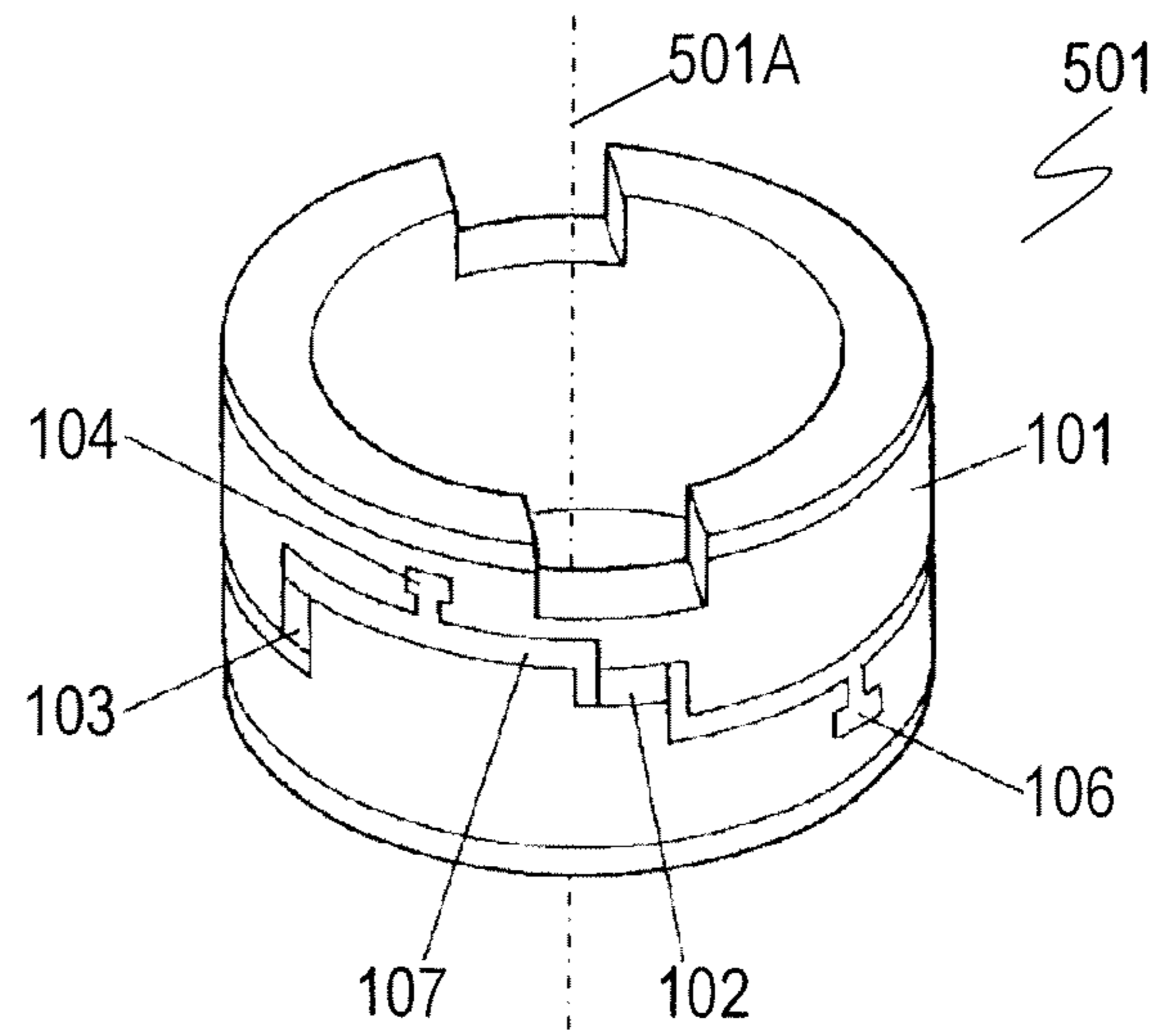


Fig. 26

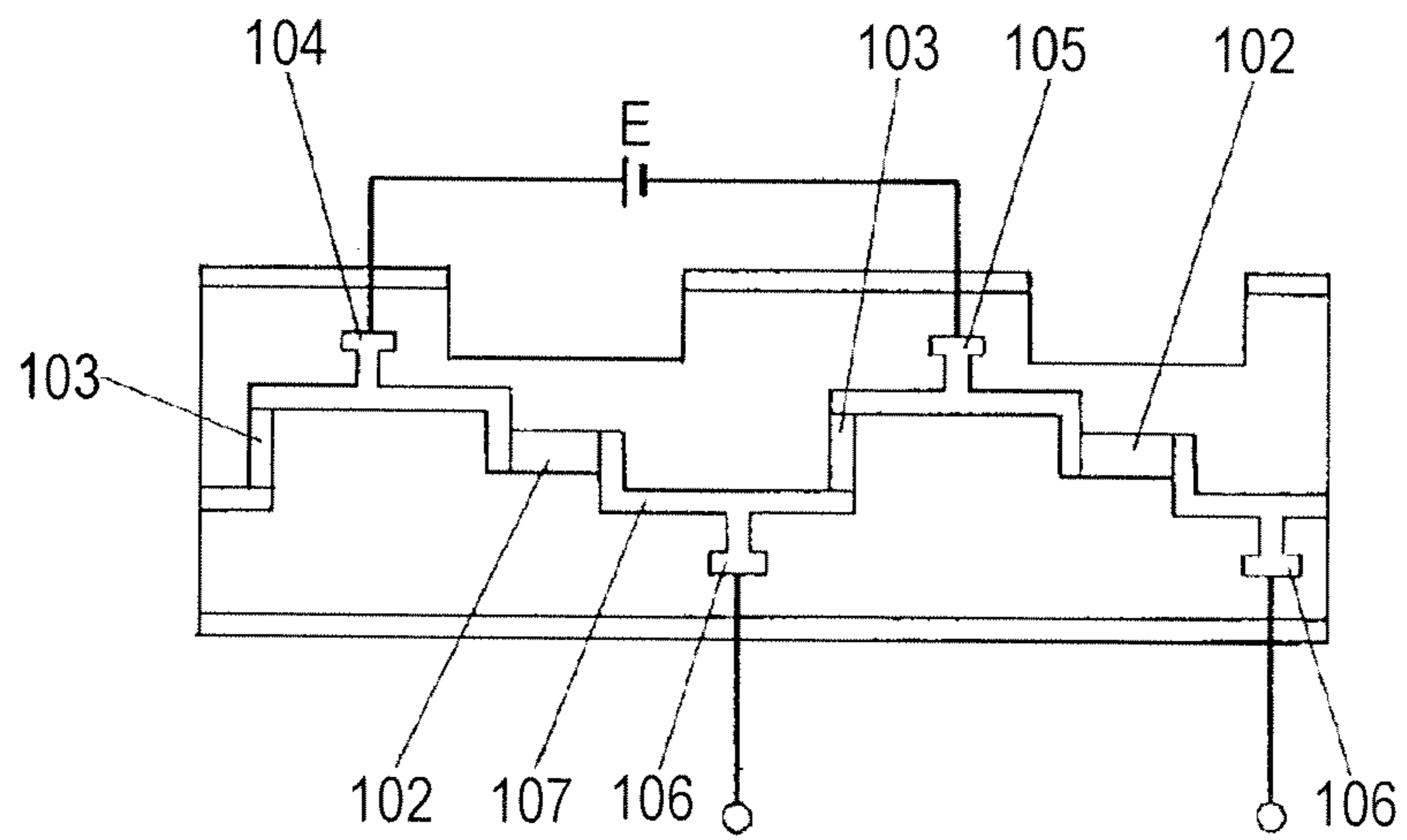


Fig. 27

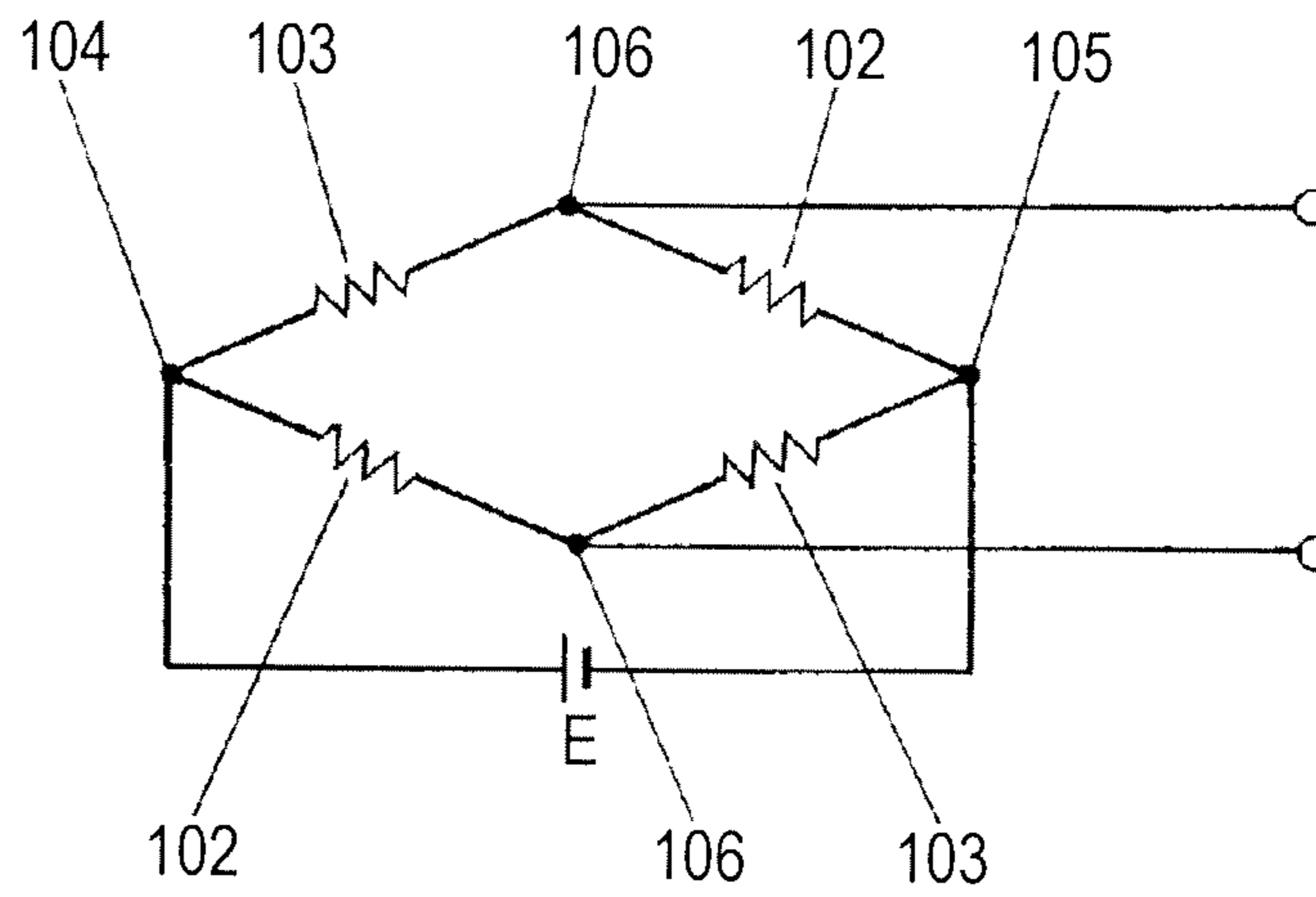


Fig. 28

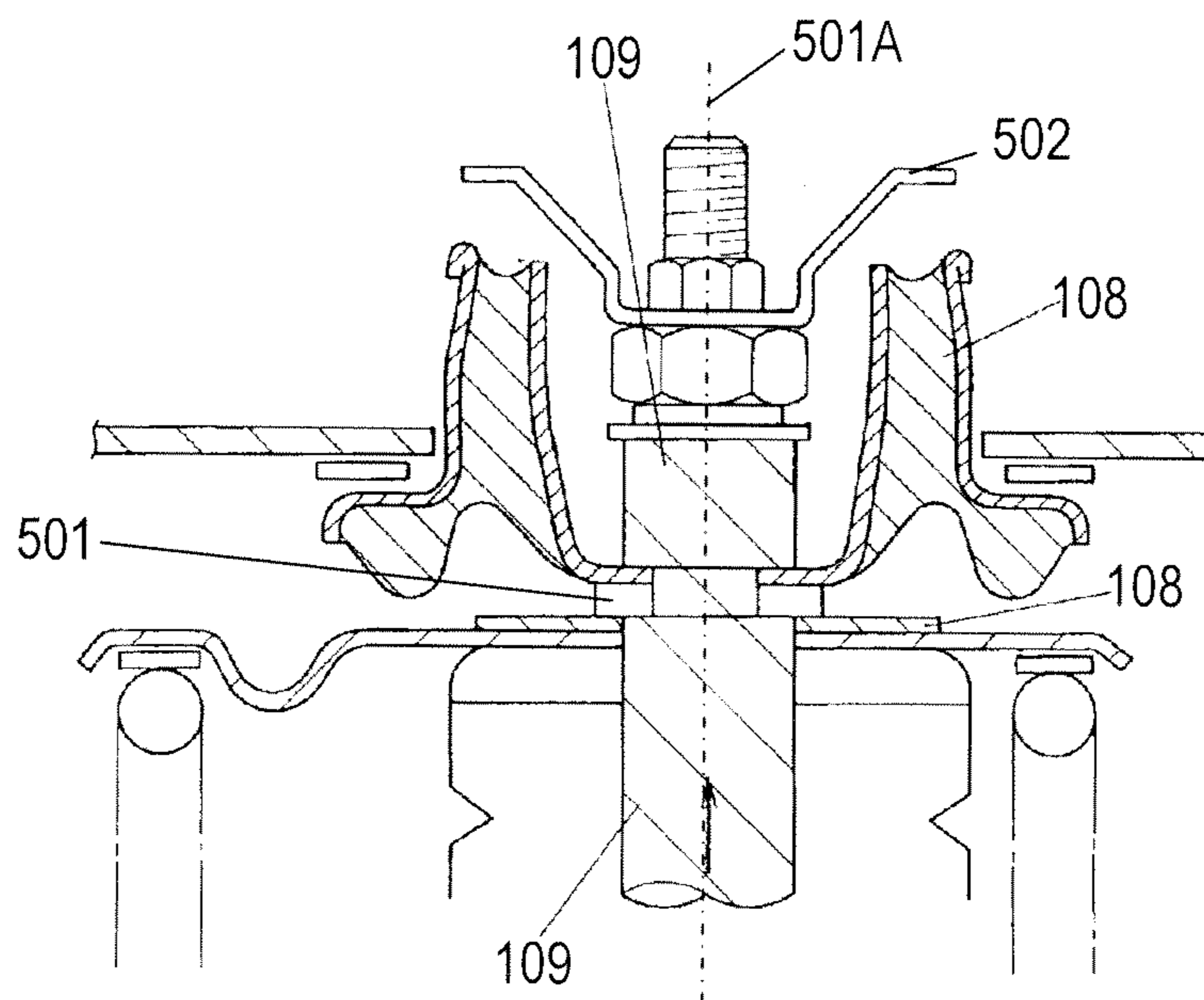


Fig. 29

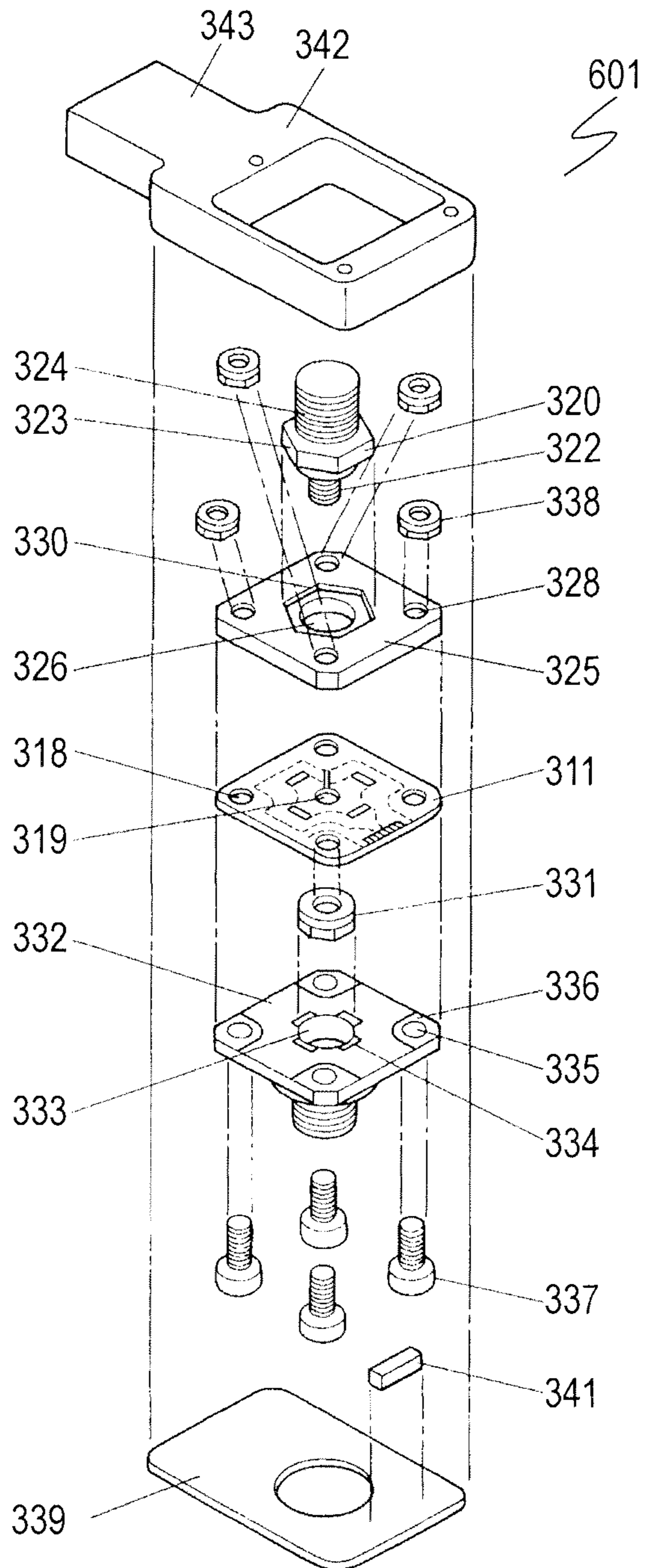


Fig. 30

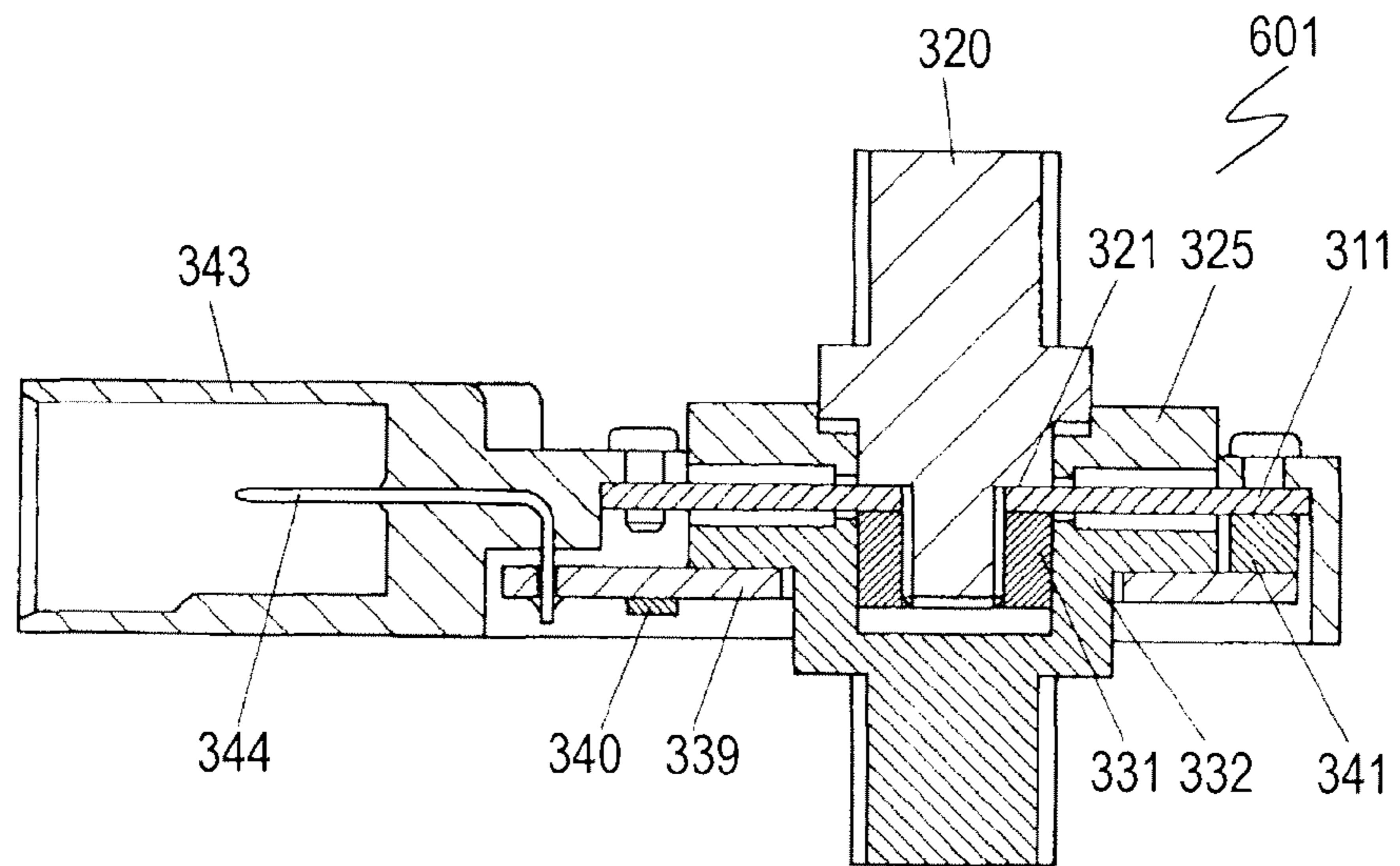


Fig. 31

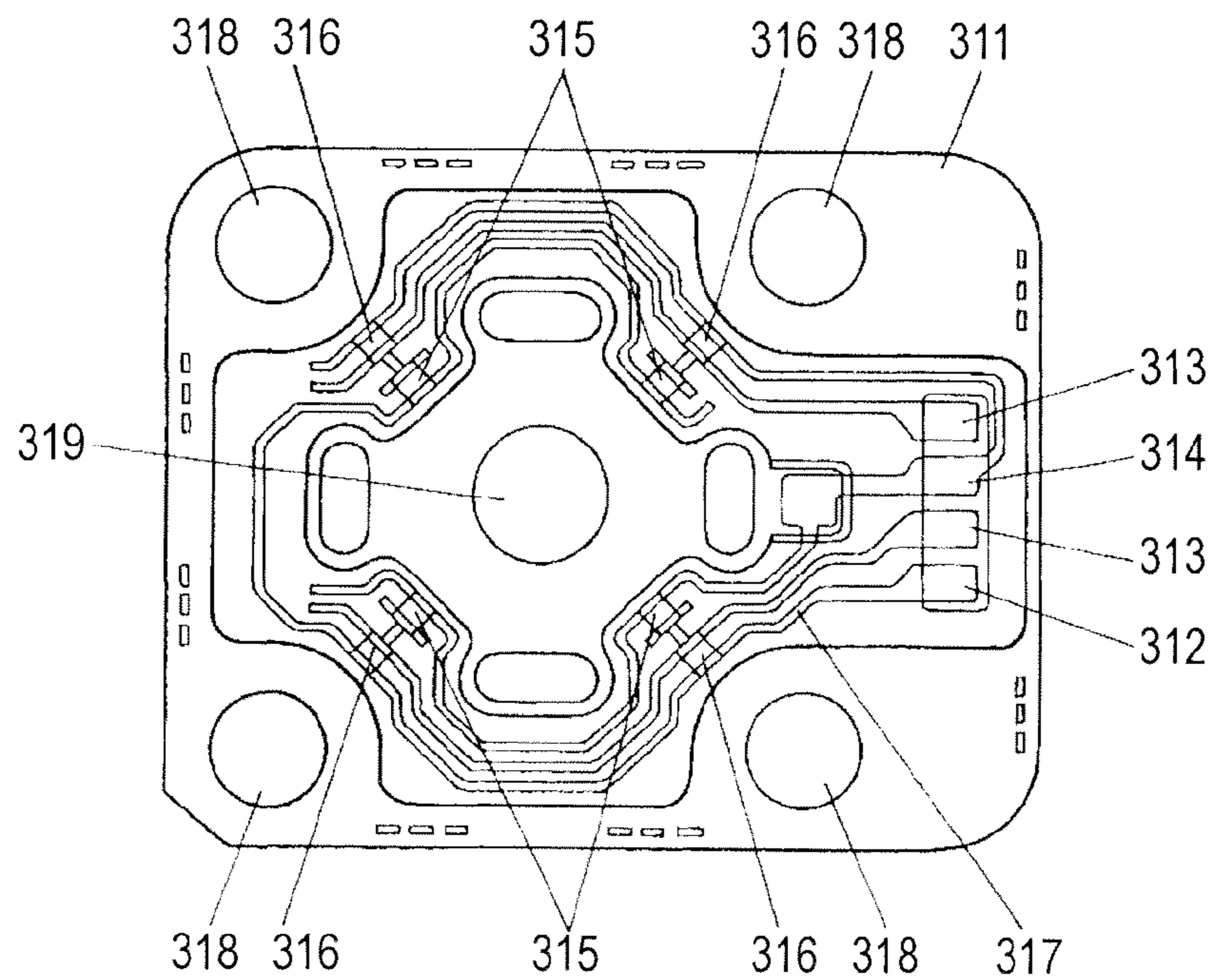


Fig. 32

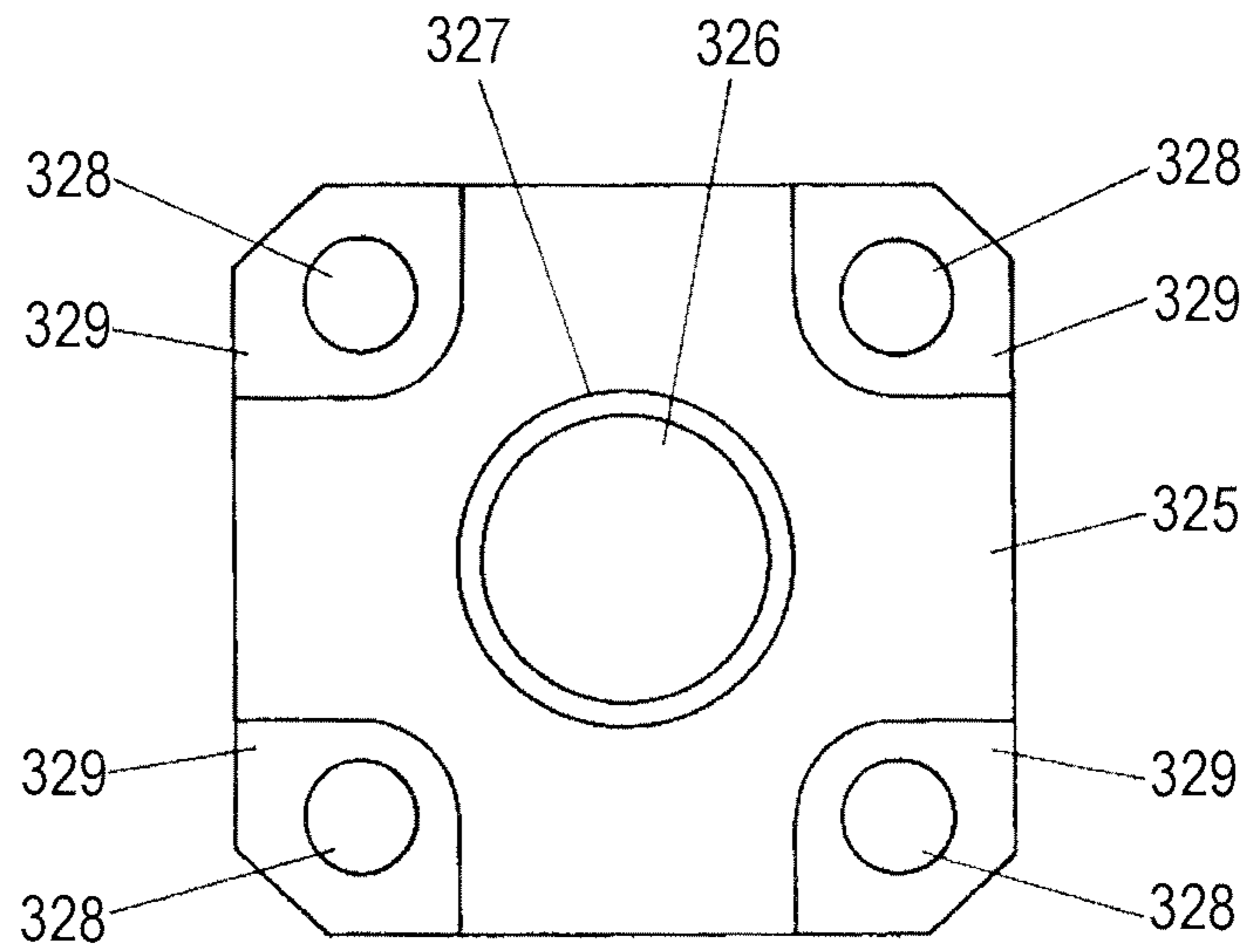
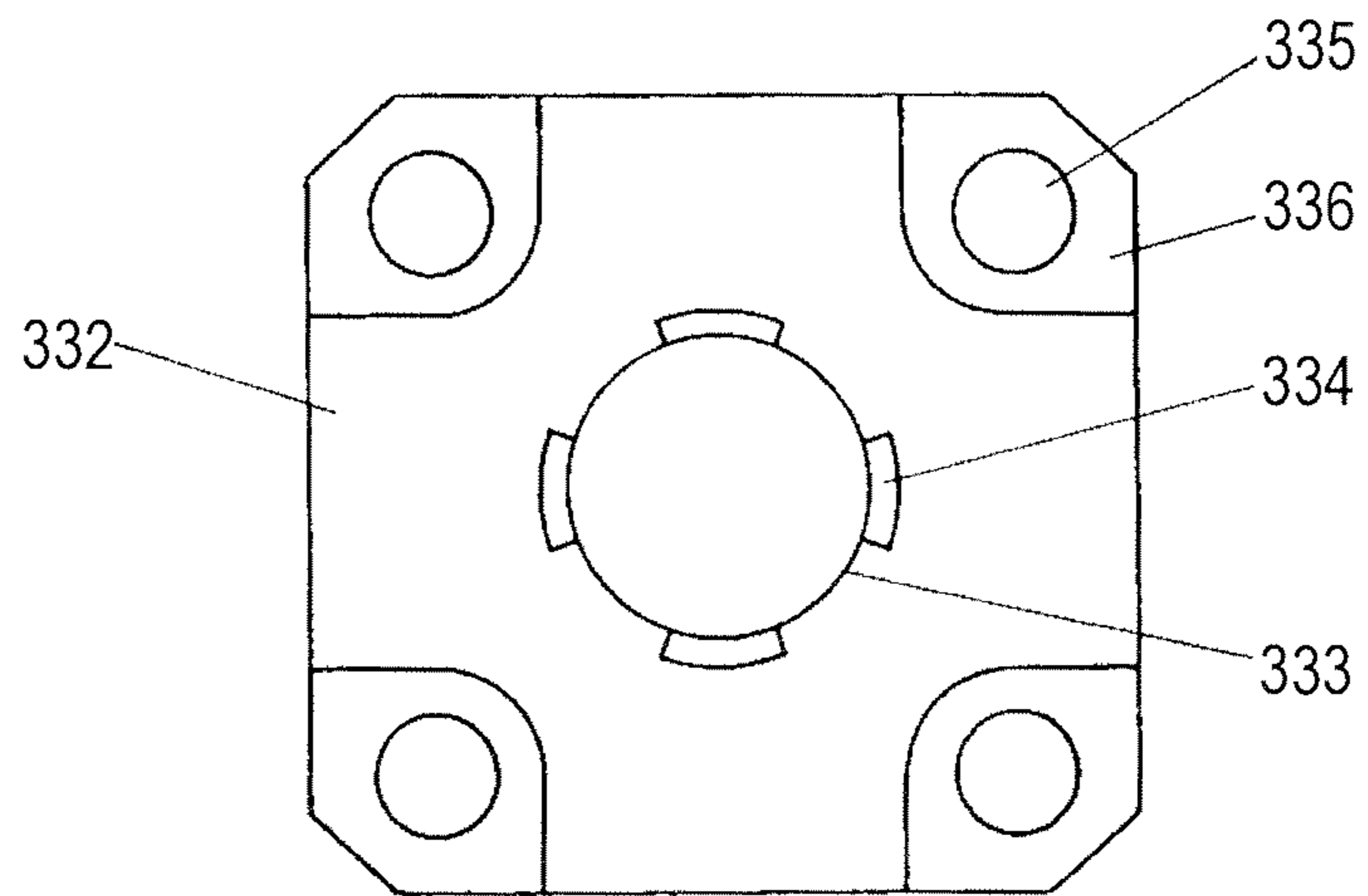


Fig. 33





## TUBULAR SENSOR WITH AN INNER PROJECTION

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.**

### RELATED APPLICATIONS

This application is a reissue application of U.S. Pat. No. 8,569,635 issued on Oct. 29, 2013 issued from U.S. patent application Ser. No. 13/120,284, filed on Mar. 22, 2011, which is the U.S. National Phase under 35 U.S.C. §371 of International Application No. PCT/JP2009/005096, tiled on Oct. 2, 2009, which in turn claims the benefit of Japanese Application No. 2008-262525, filed on Oct. 9, 2008, Japanese Application No. 2008-262526, filed on Oct. 9, 2008 and Japanese Application No. 2009-205471, filed on Sep. 7, 2009, the disclosures of which Applications are incorporated by reference herein.

### TECHNICAL FIELD

The present invention relates to a weight sensor for measuring a load applied to an object, such as a vehicle seat.

### BACKGROUND ART

FIG. 25 is a perspective view of conventional weight sensor 501 disclosed in Patent Literature 1. FIG. 26 is a view of deformable body 101 of weight sensor 501. FIG. 27 is a circuit diagram of weight sensor 501.

Deformable body 101 includes an outer side surface having a circular-cylindrical shape extending along center axis 501A. The outer side surface of deformable body 101 includes a pair of transversely extending strain resistor elements 102, a pair of longitudinally extending strain resistor elements 103, power supply electrode 104, ground (GND) electrode 105, and output electrodes 106. The outer side surface of deformable body 101 further includes circuit pattern 107 for electrically connecting these components, thereby forming a bridge circuit shown in FIG. 27.

The following is a description of the operation of conventional weight sensor 501.

FIG. 28 is a side sectional view of object 502 to which weight sensor 501 is attached. Weight sensor 501 is held between parts of mounting member 108 along center axis 501A. When a load is applied to pressing member 109, and hence a compressive force is applied to deformable body 101 in the axial direction, the resistances of the pair of longitudinally extending strain resistor elements 103 decrease, and the resistances of the pair of transversely extending strain resistor elements 102 increase. These strain resistor elements 103 and 102 extending longitudinally and transversely form the bridge circuit together with power supply electrode 104, GND electrode 105, output electrodes 106, and circuit pattern 107. Therefore, output electrodes 106 output their output signals according to the compressive force applied to deformable body 101. The output signal is output to an external circuit through lead wires which are electrically connected to power supply electrode 104, GND electrode 105, and output electrodes 106. Thus, weight sensor 501 outputs the applied load as an electrical signal.

In conventional weight sensor 501, a compressive force is applied to deformable body 101 along center axis 501A of the cylindrical surface. As a result, deformable body 101 itself prevents deformation of strain resistor elements 102 and 103.

This makes the resistances of strain resistor elements 102 and 103 less likely to be changed, thereby reducing an output signal which is output from weight sensor 501 according to the compressive force.

FIGS. 29 and 30 are an exploded perspective view and a sectional side view of conventional weight sensor 601 disclosed in Patent Literature 2, respectively. FIG. 31 is a bottom view of insulating board 311 of weight sensor 601.

Insulating board 311 has substantially a square shape, and is made of stainless steel containing about 0.1 wt % of nickel.

As shown in FIG. 31, power supply electrode 312, a pair of output electrodes 313, GND electrode 314, four compressive-side strain resistor elements 315, four tensile-side strain resistor elements 316, and circuit pattern 317 are provided a lower surface of insulating board 311. Power supply electrode 312, output electrodes 313, GND electrode 314, and circuit pattern 317 are made of silver. Power supply electrode 312, the pair of output electrodes 313, GND electrode 314, four compressive-side strain resistor elements 315, and four tensile-side strain resistor elements 316 are electrically connected via

circuit pattern 317 so as to form a bridge circuit together. Fixing holes 318 extending between upper and lower surfaces of insulating board 311 are provided near four corners of insulating board 311. Detection hole 319 extending between the upper and lower surfaces of insulating board 311 is provided in a center of insulating board 311. Weight sensor 601 further includes pressing member 320 made of stainless steel containing about 4 wt % of nickel. Pressing member 320 includes contact part 321 and external thread 322. Contact part 321 presses around the upper end of detection hole 319 of insulating board 311. External thread 322 is formed in an outer side surface of pressing member 320.

Anti-rotation projection 323 is provided on an outer side surface of pressing member 320 at the center in a longitudinal direction of pressing part 320. External thread 324 for mounting is provided in the upper part of an outer side surface of pressing member 320. Weight sensor 601 further includes mounting member 325 which is made of metal. Insertion hole 326 into which pressing member 320 is inserted is provided substantially in a center of mounting member 325.

FIG. 32 is a bottom view of mounting member 325. Stopper 327 is formed provided on a lower surface of mounting member 325 around insertion hole 326 stopper 327 by cutting or forging.

Fixing holes 328 extending between upper and lower surfaces of mounting member 325 is provided near four corners of mounting member 325. Sandwiching contact parts 329 are provided on the lower surface of mounting member 325 around fixing holes 328, and project from the lower surface so as to be flush with each other. Hexagonal locking part 330 is provided on the upper surface of mounting member 325, and has a step around insertion hole 326. Anti-rotation projection 323 of pressing member 320 is locked into locking part 330. External thread 322 of pressing member 320 passes through insertion hole 326 of mounting member 325 and is inserted into detection hole 319 of insulating board 311. External thread 322 extending downward is screwed with fixing member 331, which is a nut, so that pressing member 320 can be fixed to mounting member 325.

FIG. 33 is a top view of mounting member 332 made of metal. Stopper hole 333 is provided substantially in the upper surface of mounting member 332 at its center and extends downward from the upper surface. Stopper hole 333 accom-

modates the lower part of external thread **322** of pressing member **320**. Four stoppers **334** are formed on the upper surface of mounting member **332** around stopper hole **333** by forging. Strain resistor elements **315** and **316** on insulating board **311** face the area on mounting member **332** excluding four stoppers **334**.

Fixing holes **335** extending between the upper and lower surfaces of mounting member **332** is provided near the four corners of mounting member **332**. Sandwiching contact parts **336** are provided on mounting member **332** around four fixing holes **335**, and project from the upper surface so as to be flush with each other. Weight sensor **601** further includes fixing members **337**, four screws, passing through four fixing holes **328** of mounting member **325**, four fixing holes **318** of insulating board **311**, and four fixing holes **335** of mounting member **332**. Fixing members **337** are screwed with nuts **338** so as to sandwich insulating board **311** between sandwiching contact parts **329** of mounting member **325** and sandwiching contact parts **336** of mounting member **332**. The area around detection hole **319** of insulating board **311** can be displaced with respect to mounting members **325** and **332** in the vertical direction.

Weight sensor **601** further includes circuit board **339** having integrated circuit (IC) **340** mounted on a lower surface thereof. IC **340** is electrically connected to power supply electrode **312**, output electrodes **313**, and GND electrode **314** on insulating board **311** via conductive member **341**, which is made of gold wire and silicon rubber.

Weight sensor **601** further includes case **342** which includes connector part **343** projecting outward. Six connector terminals **344** electrically connected to IC **340** are provided in connector part **343**.

An operation of conventional weight sensor **601** will be described below.

When a load is applied to pressing member **320** from above, the load causes distortion on the surface of insulating board **311**. The distortion causes four compressive-side strain resistor elements **315** on the lower surface of insulating board **311** to receive a compressive stress, and four tensile-side strain resistor elements **316** to receive a tensile stress. These stresses change the resistances of compressive-side strain resistor elements **315** and tensile-side strain resistor elements **316**. Strain resistor elements **315** and **316** together form a bridge circuit. Therefore, the changes in the resistances of strain resistor elements **315** and **316** are output to an external computer from output electrodes **313**. The computer calculates the load applied to insulating board **311** based on the changes in the resistances.

When an excessively large load is applied to pressing member **320** from above, stoppers **334** of mounting member **332** contact insulating board **311**, thereby preventing plastic deformation of insulating board **311**. Similarly, when an excessively large tensile load is applied to pressing member **320**, stopper **327** of mounting member **325** contacts insulating board **311**, thereby preventing plastic deformation of insulating board **311**.

Stoppers **327** and **334** are formed by cutting or forging, and raise manufacturing cost, accordingly causing conventional weight sensor **601** to be expensive.

#### Citation List

##### Patent Literatures

Patent Literature 1: Japanese Patent Laid-Open Publication No. 06-207866

Patent Literature 2: Japanese Patent Laid-Open Publication No. 2005-106800

#### SUMMARY OF THE INVENTION

A weight sensor includes a deformable body, a first strain resistor provided on an outer side surface of the deformable body, and a pressing member applying a load to the deformable body. The deformable body includes a tubular portion having a tubular shape extending along a center axis and surrounding the center axis, and a projection projecting from an inner surface of the tubular portion. The pressing member moves along the center axis so as to apply a moment to the tubular portion.

The resistances of the strain resistors change greatly, allowing the weight sensor to measure a load with high sensitivity.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side sectional view of a weight sensor according to Exemplary Embodiment 1 of the present invention.

FIG. 2 is a side view of the weight sensor according to Embodiment 1.

FIG. 3A is a perspective view of a deformable body of the weight sensor according to Embodiment 1.

FIG. 3B is a sectional view of the deformable body shown in FIG. 3A.

FIG. 3C is a developed view of a tubular portion of the deformable body of the weight sensor according to Embodiment 1.

FIG. 4 is a circuit diagram of the weight sensor according to Embodiment 1.

FIG. 5 is an enlarged side sectional view of the weight sensor according to Embodiment 1.

FIG. 6 is a side view of the weight sensor according to Embodiment 1.

FIG. 7 is a side sectional view of the weight sensor according to Embodiment 1.

FIG. 8 is a side view of the weight sensor according to Embodiment 1.

FIG. 9 is a side sectional view of a weight sensor according to Exemplary Embodiment 2 of the present invention.

FIG. 10 is a side view of the weight sensor according to Embodiment 2.

FIG. 11A is a perspective view of a deformable body of the weight sensor according to Embodiment 2.

FIG. 11B is a sectional view of the deformable body shown in FIG. 11A.

FIG. 11C is a developed view of a tubular portion of the deformable body of the weight sensor according to Embodiment 2.

FIG. 12 is a circuit diagram of the weight sensor according to Embodiment 2.

FIG. 13 is a side sectional view of the weight sensor according to Embodiment 2.

FIG. 14 is a side sectional view of the weight sensor according to Embodiment 2.

FIG. 15 is a side view of the weight sensor according to Embodiment 2.

FIG. 16 is a side sectional view of the weight sensor according to Embodiment 2.

FIG. 17 is a side view of the weight sensor according to Embodiment 2.

FIG. 18 is a side sectional view of a weight sensor according to Exemplary Embodiment 3 of the present invention.

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FIG. 19 is a side sectional view of the weight sensor according to Embodiment 3.

FIG. 20A is a perspective view of a deformable body of the weight sensor according to Embodiment 3.

FIG. 20B is a bottom perspective view of the deformable body shown in FIG. 20A.

FIG. 20C is a sectional view of the deformable body shown in FIG. 20A.

FIG. 20D is a developed view of a tubular portion of the deformable body of the weight sensor according to Embodiment 3.

FIG. 21 is a circuit diagram of the weight sensor according to Embodiment 3.

FIG. 22 is a top view of a mounting member of the weight sensor according to Embodiment 3.

FIG. 23 is a perspective view of the mounting member of the weight sensor according to Embodiment 3.

FIG. 24 is a side sectional view of the weight sensor according to Embodiment 3.

FIG. 25 is a perspective view of a conventional weight sensor.

FIG. 26 is a developed view of a deformable body of the conventional weight sensor.

FIG. 27 is a circuit diagram of the conventional weight sensor.

FIG. 28 is a side sectional view of the conventional weight sensor.

FIG. 29 is an exploded perspective view of another conventional weight sensor.

FIG. 30 is a side sectional view of the conventional weight sensor shown in FIG. 29.

FIG. 31 is a bottom view of an insulating board of the conventional weight sensor shown in FIG. 29.

FIG. 32 is a bottom view of a mounting member of the conventional weight sensor shown in FIG. 29.

FIG. 33 is a top view of another mounting member of the conventional weight sensor shown in FIG. 29.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

##### Exemplary Embodiment 1

FIGS. 1 and 2 are a side sectional view and a side view of weight sensor 1001 according to a first exemplary embodiment of the present invention, respectively. FIG. 3A is a perspective view of deformable body 111 of weight sensor 1001. FIG. 3B is a sectional view of deformable body 111. FIG. 3C is a developed view of tubular portion 111Y of deformable body 111. FIG. 4 is a circuit diagram of weight sensor 1001.

Weight sensor 1001 includes lower mounting part 123 made of metal and having hole 125 therein. Lower mounting part 123 supports lower end 111B of deformable body 111 via elastic body 124 made of a rubber sheet.

Weight sensor 1001 further includes upper mounting part 126 made of metal and having hole 129 and caulking hole 130 therein. Upper mounting part 126 supports upper end 111A of deformable body 111 via elastic body 128 made of a rubber sheet. Lower mounting part 123 and upper mounting part 126 together constitute support member 132. Weight sensor 1001 further includes resin case 133 which has caulking portion 134. Caulking portion 134 is inserted into caulking hole 130 of upper mounting part 126, and then the tip of caulking portion 134 is caulked so as to fix support member 132 to case 133. Case 133 accommodates circuit board 135 made of polyimide.

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As shown in FIGS. 3A and 3B, deformable body 111 includes tubular portion 111Y which has a tubular shape (a circular-tubular shape according to Embodiment 1) extending along center axis 111C and surrounding center axis 111C. Tubular portion 111Y has therein through-hole 111J extending along center axis 111C. In Embodiment 1, deformable body 111 is disposed such that center axis 111C extends in a vertical direction. Tubular portion 111Y has upper end 111A and lower end 111B which are opposite to each other along center axis 111C. Tubular portion 111Y further has outer side surface 111D and inner side surface 111E opposite to outer side surface 111D. Outer side surface 111D faces an outside of the tubular shape. Inner surface 111E faces center axis 111C. Deformable body 111 further includes projection 122 projecting from inner surface 111E of tubular portion 111Y toward center axis 111C. Deformable body 111 is made of a plate made of rigid but deformable material, and its surface (at least outer side surface 111D) is insulating. In Embodiment 1, deformable body 111 includes a plate made of metal, such as ferrite stainless steel, and a glass layer provided on the surface (outer side surface 111D) of the metal plate. Power supply electrodes 112 and 113, output electrodes 114 and 115, and ground (GND) electrode 116 which are disposed close to each other and made of Ag are provided on outer side surface 111D. Intermediate circumference 111F at which tubular portion 111Y crosses a surface perpendicular to center axis 111C between upper and lower ends 111A and 111B is defined in tubular portion 111Y. In Embodiment 1, ends 111A and 111B are perpendicular to center axis 111C, and intermediate circumference 111F is positioned at the middle between ends 111A and 111B. Intermediate circumference 111F divides outer side surface 111D of tubular portion 111Y into upper outer side surface 111G and lower outer side surface 111H. In other words, upper outer side surface 111G is located between intermediate circumference 111F and upper end 111A. Lower outer side surface 111H is located between intermediate circumference 111F and lower end 111B.

Projection 122 projects toward center axis 111C from peripheral intermediate portion 111F of inner surface 111E of tubular portion 111Y.

Lower-side strain resistors 117 and 119 are provided on lower outer side surface 111H. Lower-side strain resistor 117 has ends 117C and 117D, and includes strain resistor elements 117A and 117B connected in series between ends 117C and 117D. Strain resistor elements 117A and 117B have resistances changing depending on the geometric distortion generated by a stress applied to the elements. Therefore, the resistance between ends 117C and 117D of lower-side strain resistor 117 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 117A and 117B, that is, strain resistor 117. Lower-side strain resistor 119 has ends 119C and 119D, and includes strain resistor elements 119A and 119B connected in series between ends 119C and 119D. Strain resistor elements 119A and 119B have resistances changing depending on the geometric distortion generated by a stress applied to the elements.

Therefore, the resistance between ends 119C and 119D of lower-side strain resistor 119 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 119A and 119B, that is, strain resistor 119. End 117D of lower-side strain resistor 117 is electrically connected to power supply electrode 112 via circuit pattern 8, and end 117C is connected to output electrode 114 via circuit pattern 118. End 119C of lower-side strain resistor 119 is electrically connected to output electrode 115 via circuit pat-

tern 118, and end 119D is electrically connected to GND electrode 116 via circuit pattern 118.

Upper-side strain resistors 120 and 121 are provided on upper outer side surface 111G. Upper-side strain resistor 120 has ends 120C and 120D, and includes strain resistor elements 120A and 120B connected in series between ends 120C and 120D. Strain resistor elements 120A and 120B have resistances changing depending on the geometric distortion generated by a stress applied to the elements. Therefore, the resistance between ends 120C and 120D of upper-side strain resistor 120 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 120A and 120B, that is, strain resistor 120. Upper-side strain resistor element 121 has ends 121C and 121D, and includes strain resistor elements 121A and 121B connected in series between ends 121C and 121D. Strain resistor elements 121A and 121B have resistances changing depending on the geometric distortion generated by a stress applied to the elements. Therefore, the resistance between ends 121C and 121D of upper-side strain resistor 121 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 121A and 121B, that is, strain resistor 121. End 120D of upper-side strain resistor 120 is electrically connected to GND electrode 116 via circuit pattern 118, and end 120C is connected to output electrode 114 via circuit pattern 118. End 121D of upper-side strain resistor 121 is electrically connected to power supply electrode 113 via circuit pattern 118, and end 121C is electrically connected to output electrode 115 via circuit pattern 118. Lower-side strain resistors 117 and 119 and upper-side strain resistors 120 and 121 together constitute a bridge circuit.

Strain resistor elements 117A and 117B and strain resistor elements 119 and 119B are arranged alternately in a circumferential direction of outer side surface 111D of deformable body 111 perpendicular to center axis 111C. In other words, strain resistor element 117A is located between strain resistor elements 119A and 119B, and strain resistor element 119A is located between strain resistor elements 117A and 117B in the circumferential direction of outer side surface 111D. Strain resistor element 117B is located between strain resistor elements 119A and 119B, and strain resistor element 119B is located between strain resistor elements 117A and 117B in the circumferential direction of outer side surface 111D.

Strain resistor elements 120A and 120B and strain resistors 121A and 121B are arranged alternately in the circumferential direction of outer side surface 111D of deformable body 111 perpendicular to center axis 111C. In other words, strain resistor element 120A is located between strain resistor elements 121A and 121B, and strain resistor element 121A is located between strain resistor elements 120A and 120B in the circumferential direction of outer side surface 111D. Strain resistor element 120B is located between strain resistor elements 121A and 121B, and strain resistor element 121B is located between strain resistor elements 120A and 120B in the circumferential direction of outer side surface 111D. As shown in FIG. 3C, strain resistor elements 120A, 120B, 121A, and 121B are located above strain resistor elements 117A, 117B, 119A, and 119B, respectively, that is, in the direction parallel to center axis 111C.

Circuit board 135 shown in FIG. 1 is electrically connected to power supply electrodes 112 and 113, output electrodes 114 and 115, and GND electrode 116 which are formed on outer side surface 111D of deformable body 111. Processing circuit 136 implemented by an integrated circuit (IC) is mounted onto circuit board 135. Processing circuit 136 processes signals output from output electrodes 114 and 115 of the bridge circuit which is composed of lower-side strain

resistors 117 and 119, upper-side strain resistors 120 and 121, and circuit pattern 118 formed on deformable body 111. Case 133 includes connector part 138 having connector terminals 137. Connector terminals 137 electrically connected to circuit board 135 output signals outside.

A method for manufacturing weight sensor 1001 of Embodiment 1 will be described below.

First, a glass paste is printed on the upper surface of a metal plate, such as a stainless steel plate, and then, sintered for about ten minutes at a temperature ranging from 550° C. to 850° C. so as to form deformable body 111.

Next, a silver paste is printed on outer side surface 111D of deformable body 111, and then sintered for about ten minutes at a temperature ranging from 550° C. to 850° C. so as to form power supply electrodes 112 and 113, output electrodes 114 and 115, GND electrode 116, and circuit pattern 118 on outer side surface 111D of deformable body 111.

Next, a metal glaze paste is printed on outer side surface 111D of deformable body 111, dried for about ten minutes at a temperature ranging from 150° C. to 250° C., and then sintered for about ten minutes at about 850° C. so as to form strain resistor elements 117A, 117B, 119A, 119B, 120A, 120B, 121A, and 121B, thereby forming lower-side strain resistors 117 and 119 and upper-side strain resistors 120 and 121.

Next, elastic body 124 is bonded to upper surface 123A of lower mounting part 123, and deformable body 111 is placed on upper surface 124A of elastic body 124.

Then, elastic body 128 is placed on upper end 111A of deformable body 111, and upper mounting part 126 is bonded to upper surface 128A of elastic body 128.

An operation of weight sensor 1001 according to Embodiment 1 will be described below. FIG. 5 is an enlarged side sectional view of weight sensor 1001 for illustrating deformable body 111 and pressing member 141. FIG. 6 is a side view of deformable body 111.

First, bolt 139 with collar 139A is inserted from the lower side of lower mounting part 123 of support member 132 into hole 125 of lower mounting part 123, through-hole 111J of deformable body 111, and hole 129 of upper mounting part 126.

Next, bolt 139 is screwed with nut 140 at a position where lower surface 140B of nut 140 contacts upper surface 122A of projection 122 of deformable body 111. Bolt 139 and nut 140 together constitute pressing member 141. In this situation, as shown in FIGS. 5 and 6, pressing member 141 contacts projection 122 of deformable body 111, but no load is applied to deformable body 111.

Predetermined voltages (5V according to Embodiment 1) are applied to power supply electrodes 112 and 113, and GND electrode 116 is grounded.

FIG. 7 is an enlarged side sectional view of weight sensor 1001 having pressing member 141 apply a load to deformable body 111. FIG. 8 is a side view of outer side surface 111D of deformable body 111 having a load is applied to deformable body 111. When applied with a load along center axis 111C from above, pressing member 141 presses upper surface 122A of projection 122 of deformable body 111 downward. As a result, pressing member 141 applies a shear load parallel to center axis 111C to tubular portion 111Y via projection 122. More specifically, pressing member 141 presses deformable body 111 in parallel to center axis 111C so that tubular portion 111Y and projection 122 are urged and displaced in directions relatively opposite to each other. The shear load applies a moment to outer side surface 111D of tubular deformable body 111 linked to projection 122. The moment decreases radius R111A of upper end 111A of deformable

body 111, and increases radius R111B of lower end 111B as shown in FIG. 8. The moment displaces upper end 111A and lower end 111B of tubular portion 111Y in directions relatively opposite to each other in a radial direction about center axis 111C. The decrease in radius R111A of upper end 111A of tubular portion 111Y contracts upper outer side surface 111G of outer side surface 111D. The increase in radius R111B of lower end 111B of tubular portion 111Y of deformable body 111 expands lower outer side surface 111H of outer side surface 111D. This decreases the resistances of upper-side strain resistors 120 and 121 (strain resistor elements 120A, 120B, 121A, and 121B) formed on upper outer side surface 111G of outer side surface 111D, and increases the resistances of lower-side strain resistors 117 and 119 (strain resistor elements 117A, 117B, 119A, and 119B) formed on lower outer side surface 111H of outer side surface 111D. This changes the voltage between output electrodes 114 and 115 of the bridge circuit which is composed of strain resistors 117, 119, 120, and 121 shown in FIG. 4. The voltage is processed by processing circuit 136 so as to measure the load applied to deformable body 111.

As described above, in weight sensor 1001 of Embodiment 1, pressing member 141 for pressing projection 122 of deformable body 111 moves along center axis 111C of deformable body 111, thereby applying a moment to deformable body 111. This moment easily causes outer side surface 111D of deformable body 111 to deform. As a result, the resistances of strain resistors 117, 119, 120, and 121 formed on outer side surface 111D are easily changed so as to greatly change the voltage between output electrodes 114 and 115 of the bridge circuit. This increases the sensitivity of a signal to be output from weight sensor 1001.

Support member 132 is composed of upper mounting part 126 and lower mounting part 123. Elastic body 128 provided between upper mounting part 126 and deformable body 111 facilitates the change in radius R111A of upper end 111A of tubular portion 111Y of deformable body 111. This causes upper outer side surface 111G of outer side surface 111D of deformable body 111 (tubular portion 111Y) to easily deform, accordingly increasing the sensitivity of the signal output from weight sensor 1001.

Elastic body 124 provided between lower mounting part 123 and deformable body 111 facilitates the change in radius R111B of lower end 111B of tubular portion 111Y of deformable body 111. This causes lower outer side surface 111H of outer side surface 111D of deformable body 111 (tubular portion 111Y) to easily deform, thereby increasing the sensitivity of the signal output from weight sensor 1001.

Exemplary Embodiment 2

FIGS. 9 and 10 are a side sectional view and a side view of weight sensor 1002 according to Exemplary Embodiment 2 of the present invention, respectively. FIG. 11A is a perspective view of deformable body 211 of weight sensor 1002. FIG. 11B is a sectional view of deformable body 211. FIG. 11C is a developed view of tubular portion 211Y of deformable body 211. FIG. 12 is a circuit diagram of weight sensor 1002.

Lower pressing portion 225 made of metal has hole 227 therein. Lower pressing portion 225 supports lower end 211B of tubular portion 211Y of deformable body 211 via elastic body 226 made of a rubber sheet. Upper pressing portion 228 made of metal has hole 230 and a caulking hole therein. Upper pressing portion 228 contacts and supports upper end 211A of tubular portion 211Y of deformable body 211. Lower pressing portion 225 and upper pressing portion 228 together constitute pressing member 232. Case 233 made of resin has a caulking portion. The caulking portion is inserted into the caulking hole of upper pressing portion 228, and then, the tip

of the caulking portion is caulked so as to fix pressing member 232 to case 233. Case 233 accommodates circuit board 235 made of polyimide. Recess 225C provided in lower pressing portion 225 opens at upper surface 225A, and has bottom 225D.

As shown in FIGS. 11A and 11B, deformable body 211 includes tubular portion 211Y having a tubular shape (a circular cylindrical shape according to Embodiment 2) extending along and around center axis 211C. Tubular portion 211Y has through-hole 211J therein extending along center axis 211C. In Embodiment 2, deformable body 211 is disposed so that center axis 211C extends in a vertical direction. Tubular portion 211Y has upper end 211A and lower end 211B opposite to each other along center axis 211C. Tubular portion 211Y further has outer side surface 211D on the outside of the cylindrical shape, and inner surface 211E which is opposite to outer side surface 211D and faces center axis 211C. Deformable body 211 includes projection 222 projecting from inner surface 211E of tubular portion 211Y toward center axis 211C. Deformable body 211 is made of a plate made of a hard but deformable material, and has a surface which has an insulating property, at least outer side surface 211D has an insulating property. According to Embodiment 2, deformable body 211 includes a metal plate, such as a ferrite stainless steel plate, and a glass layer formed on a surface (outer side surface 211D) of the metal plate. Power supply electrodes 212 and 213, output electrodes 214 and 215, and ground (GND) electrode 216, are provided on outer side surface 211D, are disposed close to each other, and made of Ag. In tubular portion 211Y, the position which is between upper and lower ends 211A and 211B and at which tubular portion 211Y crosses a surface perpendicular to center axis 211C is defined as intermediate circumference 211F. According to Embodiment 2, ends 211A and 211B are perpendicular to center axis 211C, and intermediate circumference 211F is the middle between ends 211A and 211B. Intermediate circumference 211F divides outer side surface 211D of tubular portion 211Y into upper outer side surface 211G and lower outer side surface 211H. In other words, upper outer side surface 211G is located between intermediate circumference 211F and upper end 211A. Lower outer side surface 211H is located between intermediate circumference 211F and lower end 211B.

Projection 222 projects toward center axis 211C from inner surface 211E of intermediate circumference 211F of tubular portion 211Y

Lower-side strain resistors 217 and 219 are provided on lower outer side surface 211H. Lower-side strain resistor 217 has ends 217C and 217D, and is composed of strain resistor elements 217A and 217B connected in series between ends 217C and 217D. Strain resistor elements 217A and 217B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 217C and 217D of lower-side strain resistor 217 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 217A and 217B, that is, strain resistor 217. Lower-side strain resistor 219 has ends 219C and 219D, and is composed of strain resistor elements 219A and 219B connected in series between ends 219C and 219D. Strain resistor elements 219A and 219B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 219C and 219D of lower-side strain resistor 219 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 219A and 219B, that is, strain resistor 219. End 217D of lower-side strain resistor 217

is electrically connected to power supply electrode **212** via circuit pattern **218**, and end **217C** is connected to output electrode **214** via circuit pattern **218**. End **219C** of lower-side strain resistor **219** is electrically connected to output electrode **215** via circuit pattern **218**, and end **219D** is electrically connected to GND electrode **216** via circuit pattern **218**.

Upper-side strain resistors **220** and **221** are provided on upper outer side surface **211G**. Upper-side strain resistor **220** has ends **220C** and **220D**, and is composed of strain resistor elements **220A** and **220B** connected in series between ends **220C** and **220D**. Strain resistor elements **220A** and **220B** have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends **220C** and **220D** of upper-side strain resistor **220** changes depending on the geometric distortion generated by the stress applied to strain resistor elements **220A** and **220B**, that is, strain resistor **220**. Upper-side strain resistor **221** has ends **221C** and **221D**, and is composed of strain resistor elements **221A** and **221B** connected in series between ends **221C** and **221D**. Strain resistor elements **221A** and **221B** have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends **221C** and **221D** of upper-side strain resistor **221** changes depending on the geometric distortion generated by the stress applied to strain resistor elements **221A** and **221B**, that is, strain resistor **221**. End **220D** of upper-side strain resistor **220** is electrically connected to GND electrode **216** via circuit pattern **218**, and end **220C** is connected to output electrode **214** via circuit pattern **218**. End **221D** of upper-side strain resistor **221** is electrically connected to power supply electrode **213** via circuit pattern **218**, and end **221C** is electrically connected to output electrode **215** via circuit pattern **218**. Lower-side strain resistors **217** and **219** and upper-side strain resistors **220** and **221** together constitute a bridge circuit.

Strain resistor elements **217A** and **217B** and resistor elements **219A** and **219B** are arranged alternately in a circumferential direction of outer side surface **211D** of deformable body **211** perpendicular to center axis **211C**.

In other words, strain resistor element **217A** is located between strain resistor elements **219A** and **219B**, and strain resistor element **219A** is located between strain resistor elements **217A** and **217B** on outer side surface **211D** in the circumferential direction. Strain resistor element **217B** is located between strain resistor elements **219A** and **219B**, and strain resistor element **219B** is located between strain resistor elements **217A** and **217B** on outer side surface **211D** in the circumferential direction.

Strain resistor elements **220A** and **220B** and resistor elements **221A** and **221B** are arranged alternately in the circumferential direction of outer side surface **211D** of deformable body **211** perpendicular to center axis **211C**.

In other words, strain resistor element **220A** is located between strain resistor elements **221A** and **221B**, and strain resistor element **221A** is located between strain resistor elements **220A** and **220B** in the circumferential direction of outer side surface **211D**. Strain resistor element **220B** is located between strain resistor elements **221A** and **221B**, and strain resistor element **221B** is located between strain resistor elements **220A** and **220B** in the circumferential direction of outer side surface **211D**. As shown in FIG. 11C, strain resistor elements **220A**, **220B**, **221A**, and **221B** are located above strain resistor elements **217A**, **217B**, **219A**, and **219B**, respectively, that is, in a direction parallel to center axis **211C**.

Deformable body **211** further includes retained portion **223** provided at tip **222C** of projection **222**. Retained portion **223** has a larger width in a direction of center axis **211C** than

projection **222**. Retained portion **223** and projection **222** together constitute fixing part **224**.

Circuit board **235** shown in FIG. 9 is electrically connected to power supply electrodes **212** and **213**, output electrodes **214** and **215**, and GND electrode **216** which are formed on outer side surface **211D** of deformable body **211**. Circuit board **235** includes processing circuit **236** implemented by an integrated circuit (IC). Processing circuit **236** processes signals output from output electrodes **214** and **215** of the bridge circuit which is composed of lower-side strain resistors **217** and **219**, upper-side strain resistors **220** and **221**, and circuit pattern **218** formed on deformable body **211**. Case **233** includes connector part **238** having connector terminals **237**. Connector terminals **237** electrically connected to circuit board **235** output signals outside.

A method for manufacturing weight sensor **1002** according to Embodiment 2 will be described below.

Deformable body **211** is manufactured using the same materials and methods as deformable body **111** and strain resistors **117**, **119**, **120**, and **121** according to Embodiment 1. Deformable body **211** includes strain resistors **217**, **219**, **220**, and **221**; power supply electrodes **212** and **213**; output electrodes **214** and **215**; GND electrode **216**; and circuit pattern **218** which are provided on outer side surface **211D**.

Next, elastic body **226** is bonded to bottom **225D** of recess **225C** which opens at upper surface **225A** of lower pressing portion **225**. Then, tubular portion **211Y** of deformable body **211** is placed on upper surface **226A** of elastic body **226**.

Next, upper pressing portion **228** is bonded to upper end **211A** of tubular portion **211Y** of deformable body **211**, and upper pressing portion **228** is bonded to upper surface **225A** of lower pressing portion **225**.

An operation of weight sensor **1002** according to Embodiment 2 will be described below. FIG. 13 is a side sectional view of weight sensor **1002**. FIG. 14 is an enlarged side sectional view of weight sensor **1002** for illustrating deformable body **211** and pressing member **232**. FIG. 15 is a side view of deformable body **211**.

As shown in FIG. 13, collar **241** is attached to an outer periphery of bolt **239** on upper surface **240A** of support plate **240** into which bolt **239** is previously installed. Deformable body **211** is placed so that lower surface **233B** of retained portion **223** contacts upper surface **241A** of collar **241**. Then, collar **242** is placed on upper surface **223A** of retained portion **223**. Then, nut **243** is screwed onto bolt **239** so that retained portion **223** is sandwiched between collars **241** and **242**. Bolt **239**, support plate **240**, collars **241** and **242**, and nut **243** together constitute fixing member **244** for fixing deformable body **211**. In this situation, as shown in FIGS. 14 and 15, pressing member **232** contacts tubular portion **211Y** of deformable body **211**, but no load is applied to deformable body **211**.

Predetermined voltages (5V according to Embodiment 2) are applied to power supply electrodes **212** and **213**, and GND electrode **216** is grounded.

FIG. 16 is an enlarged side sectional view of weight sensor **1002** while pressing member **232** applies a load to deformable body **211**. When applied with a load along center axis **211C** from above, pressing member **232** presses upper end **211A** of tubular portion **211Y** downward, and applies a shear load parallel to center axis **211C** to tubular portion **211Y** of deformable body **211**. More specifically, pressing member **232** presses deformable body **211** in parallel with center axis **211C** so that tubular portion **211Y** and projection **222** are urged and displaced in directions relatively opposite to each other. This shear load applies a moment to outer side surface **211D** of tubular portion **211Y** linked to projection **222**. The

moment increases radius R211A of upper end 211A of deformable body 211 as shown in FIG. 17. The moment displaces upper end 211A and lower end 211B of tubular portion 211Y in directions relatively opposite to each other in a radial direction about center axis 211C. The increase in radius R211A of upper end 211A of tubular portion 211Y of deformable body 211 expands upper outer side surface 211G of outer side surface 211D. This results in an increase in the resistances of upper-side strain resistors 220 and 221 (strain resistor elements 220A, 220B, 221A, and 221B) provided on upper outer side surface 211G of outer side surface 211D. This changes the voltage between output electrodes 214 and 215 of the bridge circuit which is composed of strain resistors 217, 219, 220, and 221 shown in FIG. 12. The voltage is processed by processing circuit 236 so as to measure the load applied to deformable body 211.

As described above, in weight sensor 1002 of Embodiment 2, pressing member 232 for pressing projection 222 of deformable body 211 moves along center axis 211C of deformable body 211, thereby applying a moment to deformable body 211. This causes outer side surface 211D of deformable body 211 to easily deform. As a result, the resistances of strain resistors 217 and 219 provided on outer side surface 211D are easily changed so as to greatly change the voltage between output electrodes 214 and 215 of the bridge circuit. This increases the sensitivity of a signal to be output from weight sensor 1002.

#### Exemplary Embodiment 3

FIGS. 18 and 19 are side sectional views of weight sensor 1003 according to Exemplary Embodiment 3 of the present invention. FIGS. 20A and 20B are a perspective view and a bottom perspective view of deformable body 351 of weight sensor 1003, respectively. FIG. 20C is a sectional view of deformable body 351. FIG. 20D is a developed view of tubular portion 351Y of deformable body 351.

As shown in FIGS. 20A to 20C, deformable body 351 includes tubular portion 351Y having a tubular shape (a circular cylindrical shape according to Embodiment 3) extending along and around center axis 351C. According to Embodiment 3, deformable body 351 is disposed so that center axis 351C extends in a vertical direction. Tubular portion 351Y has upper end 351A and lower end 351B which are opposite to each other along center axis 351C. Tubular portion 351Y has outer side surface 351D on the outside of the cylindrical shape, and inner surface 351E which is opposite to outer side surface 351D and which faces center axis 351C. Deformable body 351 further includes projection 362 projecting from inner surface 351E of tubular portion 351Y toward center axis 351C. Deformable body 351 is made of a plate made of a hard but deformable material, and a surface having an insulating property. At least outer side surface 351D has an insulating property. According to Embodiment 3, deformable body 351 is made of a metal plate, such as a ferrite stainless steel plate, and a glass layer formed on a surface (outer side surface 351D) of the metal plate. Power supply electrodes 352 and 353, output electrodes 354 and 355, and ground (GND) electrode 356 provided on outer side surface 351D are disposed close to each other and are made of Ag. In tubular portion 351Y, the position which is between upper and lower ends 351A and 351B and at which tubular portion 351Y crosses a surface perpendicular to center axis 351C is defined as intermediate circumference 351F. According to Embodiment 3, ends 351A and 351B are perpendicular to center axis 351C, and intermediate circumference 351F is closer to end 351B than to end 351A. Intermediate circumference 351F divides outer side surface 351D of tubular portion 351Y into upper outer side surface 351G and lower outer side surface 351H. In

other words, upper outer side surface 351G is located between intermediate circumference 351F and upper end 351A. Lower outer side surface 351H is located between intermediate circumference 351F and lower end 351B.

Projection 362 projects toward center axis 351C from inner surface 351E of intermediate circumference 351F of tubular portion 351Y

Lower-side strain resistors 357 and 359 are provided on lower outer side surface 351H. Lower-side strain resistor 357 has ends 357C and 357D, and is composed of strain resistor elements 357A and 357B connected in series between ends 357C and 357D. Strain resistor elements 357A and 357B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 357C and 357D of lower-side strain resistor 357 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 357A and 357B, that is, strain resistor 357. Lower-side strain resistor 359 has ends 359C and 359D, and is composed of strain resistor elements 359A and 359B connected in series between ends 359C and 359D. Strain resistor elements 359A and 359B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 359C and 359D of lower-side strain resistor 359 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 359A and 359B, that is, strain resistor 359. End 357D of lower-side strain resistor 357 is electrically connected to power supply electrode 352 via circuit pattern 358, and end 357C is connected to output electrode 354 via circuit pattern 358. End 359C of lower-side strain resistor 359 is electrically connected to output electrode 355 via circuit pattern 358, and end 359D is electrically connected to GND electrode 356 via circuit pattern 358.

Upper-side strain resistors 360 and 361 are provided on upper outer side surface 351G. Upper-side strain resistor 360 has ends 360C and 360D, and is composed of strain resistor elements 360A and 360B connected in series between ends 360C and 360D. Strain resistor elements 360A and 360B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 360C and 360D of upper-side strain resistor 360 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 360A and 360B, that is, strain resistor 360. Upper-side strain resistor 361 has ends 361C and 361D, and is composed of strain resistor elements 361A and 361B connected in series between ends 361C and 361D. Strain resistor elements 361A and 361B have resistances changing depending on the geometric distortion generated by a stress applied to the resistor elements. Therefore, the resistance between ends 361C and 361D of upper-side strain resistor 361 changes depending on the geometric distortion generated by the stress applied to strain resistor elements 361A and 361B, that is, strain resistor 361. End 360D of upper-side strain resistor 360 is electrically connected to GND electrode 356 via circuit pattern 358, and end 360C is connected to output electrode 354 via circuit pattern 358. End 361D of upper-side strain resistor 361 is electrically connected to power supply electrode 353 via circuit pattern 358, and end 361C is electrically connected to output electrode 355 via circuit pattern 358. Lower-side strain resistors 357 and 359 and upper-side strain resistors 360 and 361 together constitute a bridge circuit.

Strain resistor elements 357A and 357B and strain resistor elements 359A and 359B are arranged alternately in a circumferential direction of outer side surface 351D of deformable body 351 perpendicular to center axis 351C. In other

words, strain resistor element **357A** is located between strain resistor elements **359A** and **359B**, and strain resistor element **359A** is located between strain resistor elements **357A** and **357B** in the circumferential direction of outer side surface **351D**. Strain resistor element **357B** is located between strain resistor elements **359A** and **359B**, and strain resistor element **359B** is located between strain resistor elements **357A** and **357B** in the circumferential direction of outer side surface **351D**.

Strain resistor elements **360A** and **360B** and strain resistor elements **361A** and **361B** are arranged alternately in the circumferential direction of outer side surface **351D** of deformable body **351** perpendicular to center axis **351C**. In other words, strain resistor element **360A** is located between strain resistor elements **361A** and **361B**, and strain resistor element **361A** is located between strain resistor elements **360A** and **360B** in the circumferential direction of outer side surface **351D**. Strain resistor element **360B** is located between strain resistor elements **361A** and **361B**, and strain resistor element **361B** is located between strain resistor elements **360A** and **360B** in the circumferential direction of outer side surface **351D**. As shown in FIG. **20D**, strain resistor elements **360A**, **360B**, **361A**, and **361B** are located above strain resistor elements **357A**, **357B**, **359A**, and **359B**, respectively, that is, in a direction parallel to center axis **351C**.

Deformable body **351** further includes retained portion **363** provided at tip **362C** of projection **362**. Retained portion **363** has a larger width in the direction of center axis **351C** than projection **362**, and projects downward from projection **362** toward lower end **351B**. Retained portion **363** and projection **362** together constitute fixing part **364**.

Deformable body **351** has a retained portion provided on inner surface **351E** at upper end **351A** of tubular portion **351Y**. Weight sensor **1003** includes pressing member **365** made of metal which is fixed to upper end **351A** of tubular portion **351Y**, that is, to fixing part **364A**. Screw **366** is provided on outer side surface of pressing member **365**. Case **367** made of resin accommodates circuit board **368** made of polyimide.

Circuit board **368** shown in FIG. **19** is electrically connected to power supply electrodes **352** and **353**, output electrodes **354** and **355**, and GND electrode **356** which are provided on outer side surface **351D** of deformable body **351**. Processing circuit **369** implemented by an integrated circuit (IC) is mounted onto circuit board **368**. Processing circuit **369** processes signals output from output electrodes **354** and **355** of the bridge circuit which is composed of lower-side strain resistors **357** and **359**, upper-side strain resistors **360** and **361**, and circuit pattern **358** formed on deformable body **351**. Case **367** includes connector part **371** having connector terminals **370**. Connector terminals **370** are electrically connected to circuit board **368** output signals outside.

FIG. **22** is a top view of mounting member **372** of weight sensor **1003**. Mounting member **372** has fixing hole **373** therein. Retained portion **363** of deformable body **351**, that is, outer side surface **363D** of lower end **363B** of fixing part **364** is fixed in fixing hole **373**. Mounting member **372** has stopper groove **374** therein having a circular shape surrounding fixing hole **373**. When an excessive pressing load is applied to pressing member **365** and causes tubular portion **351Y** to move downward, the inner bottom surface of stopper groove **374** contacts lower end **351B** of tubular portion **351Y**.

More specifically, lower end **351B** of tubular portion **351Y** contacts mounting member **372**, thereby preventing tubular portion **351Y** from being displaced downward with respect to mounting member **372**. This eliminates the need to provide a stopper to mounting member **372** by a mechanical process-

ing, such as cutting or forging, thereby eliminating the process of mechanically processing the stopper.

Since the inner bottom surface of stopper groove **374** can contact lower end **351B** of tubular portion **351Y**, the thickness of weight sensor **1003** can be smaller by the amount corresponding to the depth of stopper groove **374**.

FIG. **23** is a perspective view of mounting member **376** of weight sensor **1003**. Mounting member **372** has two mounting holes **375** therein. Mounting member **376** is fixedly welded at both ends to mounting member **372**. Mounting member **376** has two mounting holes **377** therein corresponding to two mounting holes **375** of mounting member **372**.

Through-hole **378** is provided substantially in a center of mounting member **376** for passing pressing member **365** therethrough. The center of mounting member **376** protrudes a direction to upper end **351A** of tubular portion **351Y**.

When an excessive tensile load is applied to pressing member **365** and causes tubular portion **351Y** to move upward, upper end **351A** of tubular portion **351Y** contacts mounting member **376** so as to prevent tubular portion **351Y** from being displaced upward with respect to mounting member **376**. This eliminates the need to provide a stopper to mounting member **376** by mechanical processing, such as cutting or forging, thereby eliminating the process of mechanically processing the stopper.

A method for manufacturing weight sensor **1003** of Embodiment 3 will be described below.

Deformable body **351** is manufactured using the same materials and methods as deformable body **111** and strain resistors **117**, **119**, **120**, and **121** of Embodiment 1. Deformable body **351** includes strain resistors **357**, **359**, **360**, and **361**; power supply electrodes **352** and **353**; output electrodes **354** and **355**; GND electrode **356**; and circuit pattern **358** on outer side surface **351D**.

Next, circuit board **368** is placed on case **367** in which connector terminals **370** are previously embedded and molded by insert molding. Then, processing circuit **369** is mounted on circuit board **368**, thereby being electrically connected to connector terminals **370**.

Next, pressing member **365** is fixedly welded to fixing part **364A** of upper end **351A** of tubular portion **351Y**.

Next, fixing part **364** of retained portion **363** of deformable body **351** is inserted into fixing hole **373** of mounting member **372**, and fixedly welded to the fixing hole.

Then, both ends of mounting member **376** are placed at both ends of the upper surface of mounting member **372**, and fixedly welded thereto.

An operation of weight sensor **1003** will be described below. FIG. **24** is a side sectional view of weight sensor **1003**.

Weight sensor **1003** is placed on the upper surface of sheet rail **379** such that bolts **380** passes through mounting holes **375** of mounting member **372** and mounting holes **377** of mounting member **376**. Then, nuts **381** are screwed onto bolts **380** so as to fix weight sensor **1003** to sheet rail **379**. Then, coupler **382** linked to a vehicle seat is attached to pressing member **365** via bolt **383**.

In this situation, when a passenger sits on the seat, a load is applied to coupler **382** from above, and consequently, a shear load is applied to tubular portion **351Y**. The shear load applies a moment to outer side surface **351D** of tubular portion **351Y**. The moment expands upper outer side surface **351G** of outer side surface **351D** of tubular portion **351Y**. This results in an increase in the resistances of upper-side strain resistors **360** and **361** (strain resistor elements **360A**, **360B**, **361A**, and **361B**). The moment also contracts lower outer side surface **351H** of outer side surface **351D**, thereby reducing the resistances of lower-side strain resistors **357** and **359** (strain resis-



tor elements 357A, 357B, 359A, and 359B). This changes the voltage between output electrodes 354 and 355 of the bridge circuit which is composed of strain resistors 357, 359, 360, and 361 shown in FIG. 21. The voltage is processed by processing circuit 369 so as to measure the load applied to deformable body 351.

When a lifting load is applied to coupler 382, upper outer side surface 351G of outer side surface 351D of tubular portion 351Y is contracted so as to reduce the resistances of upper-side strain resistors 360 and 361. Simultaneously, lower outer side surface 351H of outer side surface 351D is expanded so as to increase the resistances of lower-side strain resistors 357 and 359. This changes the voltage between output electrodes 354 and 355 of the bridge circuit which is composed of strain resistors 357, 359, 360, and 361 shown in FIG. 21. The voltage is processed by processing circuit 369 so as to measure the load applied to deformable body 351.

As described above, mounting member 372 fixes deformable body 351. Deformable body 351 includes retained portion 363 provided at tip 362C of projection 362. Retained portion 363 of deformable body 351 is fixed to mounting member 372. Mounting member 372 has an upper surface facing lower end 351B of tubular portion 351Y. When no load is applied to pressing member 365, the upper surface of mounting member 372 is located away from upper end 351A of tubular portion 351Y. Upon an excessive load being applied to pressing member 365, the upper surface of mounting member 372 contacts lower end 351B of tubular portion 351Y so as to prevent tubular portion 351Y from being displaced downward. Mounting member 376 is joined to mounting member 372 and has a lower surface faces upper end 351A of tubular portion 351Y. When no load is applied to pressing member 365, the lower surface of mounting member 376 is located away from upper end 351A of tubular portion 351Y. When an excessive load is applied to pressing member 365, the lower surface of mounting member 372 contacts upper end 351A of tubular portion 351Y so as to prevent tubular portion 351Y from being displaced upward. The upper surface of mounting member 372 has stopper groove 374 therein having an inner bottom surface contacting lower end 351B of tubular portion 351Y when an excessive load is applied to pressing member 365.

When coupler 382 applies an excessive pressing load to pressing member 365 from above, lower end 351B of tubular portion 351Y contacts the inner bottom surface of stopper groove 374, thereby preventing plastic deformation of tubular portion 351Y.

When coupler 382 applies an excessive tensile load to pressing member 365 to displace pressing member 365 upward, upper end 351A of tubular portion 351Y contacts the lower surface of mounting member 376, thereby preventing plastic deformation of tubular portion 351Y.

Embodiments 1 to 3, terms, such as “above”, “lower”, “upward”, and “downward”, indicating directions indicate relative directions depending from components, such as the deformable body, of the weight sensors, and do not indicate absolute directions, such as a vertical direction.

#### INDUSTRIAL APPLICABILITY

This weight sensor has resistances of strain resistors change so greatly to measure a load with high sensitivity and is useful especially to measure a load applied to a vehicle seat.

#### Reference Marks in the Drawings

111 deformable body  
111A upper end

111B lower end  
111C center axis  
111D outer side surface  
111E inner surface  
111F intermediate circumference  
111G upper outer side surface  
111H lower outer side surface  
111Y tubular portion  
117 strain resistor (second strain resistor)  
120 strain resistor (first strain resistor)  
122 projection  
124 elastic body (second elastic body)  
128 elastic body (first elastic body)  
132 support member  
141 pressing member  
211 deformable body  
211A upper end  
211B lower end  
211C center axis  
211D outer side surface  
211E inner surface  
211F intermediate circumference  
211G upper outer side surface  
211H lower outer side surface  
211J through-hole  
211Y tubular portion  
217 strain resistor (second strain resistor)  
220 strain resistor (first strain resistor)  
222 projection  
223 retained portion  
232 pressing member  
244 fixing member  
351 deformable body  
351A upper end  
351B lower end  
351Y tubular portion  
362 projection  
363 retained portion  
372 mounting member (first mounting member)  
374 stopper groove  
376 mounting member (second mounting member)  
1001 weight sensor  
1002 weight sensor  
1003 weight sensor

The invention claimed is:

1. A [weight] sensor comprising:  
a deformable body including

a tubular portion having a tubular shape extending along a center axis and surrounding the center axis, the tubular portion having an outer side surface and an inner surface, the outer side surface facing in a direction away from the center axis, the inner surface facing the center axis, and  
a projection projecting from the inner surface of the tubular portion;

a first strain resistor provided on the outer side surface of the deformable body; and

a pressing member [moving] *that moves* along the center axis [so as to apply] *and applies* a load to the deformable body so as to apply a moment to the tubular portion of the deformable body, *wherein:*

*the pressing member presses the deformable body to urge the projection and the tubular portion of the deformable body relatively in directions which are opposite to each other and which are parallel with the center axis, and*

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*the moment displaces an upper end and a lower end of the tubular portion in directions relatively opposite to each other in a radial direction about the center axis.*

2. The [weight] sensor of claim 1, wherein the pressing member presses the deformable body to urge the projection and the tubular portion of the deformable body relatively in directions which are opposite to each other and which are parallel with the center axis.]

3. The [weight] sensor of claim 1, further comprising a support member for supporting the deformable body, [wherein the tubular portion of the deformable body has an upper end and a lower end opposite to each other along the center axis,]

wherein the support member supports the upper end and the lower end of the deformable body, and wherein the pressing member presses the projection so as to apply the moment to the tubular portion.

4. The [weight] sensor of claim 3, further comprising a first elastic body provided between the support member and the upper end of the tubular portion of the deformable body.

5. The [weight] sensor of claim 4, further comprising a second elastic body provided between the support member and the lower end of the tubular portion of the deformable body.

6. The [weight] sensor of claim 1, further comprising a fixing member for fixing the deformable body, wherein the tubular portion of the deformable body has an upper end and a lower end opposite to each other along the center axis,

[wherein the tubular portion of the deformable body has an upper end and a lower end opposite to each other along the center axis,]

wherein the deformable body further includes a retained portion provided at a tip of the projection,

wherein the fixing member fixes the retained portion of [he] the deformable body, and

wherein the pressing member presses the tubular portion of the deformable body such that the moment is applied to the tubular portion of the deformable body.

7. The [weight] sensor of claim 1, further comprising a second strain resistor [formed] disposed on the outer side surface of the deformable body,

wherein an intermediate circumference at which the tubular portion crosses a surface perpendicular to the center axis between the upper end and the lower end of the tubular portion is defined,

wherein the intermediate circumference divides the outer side surface of the tubular portion into an upper outer side surface and a lower outer side surface,

wherein the first strain resistor and the second strain resistor are disposed on the upper outer side surface and the lower outer side surface, respectively, and

wherein the projection of the deformable body projects from the intermediate circumference on the inner surface of the tubular portion.

8. The [weight] sensor of claim 1, further comprising a first mounting member for fixing the deformable body, wherein the deformable body further includes a retained portion provided at a tip of the projection,

wherein the retained portion of the deformable body is fixed to the first mounting member,

[wherein the tubular portion of the deformable body has an upper end and a lower end opposite to each other along the center axis,]

wherein the first mounting member has an upper surface facing the lower end of the tubular portion,

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wherein, when no load is applied to the pressing member, the upper surface of the first mounting member is located away from the upper end of the tubular portion, and

wherein, when an excessive load is applied to the pressing member, the upper surface of the first mounting member contacts the lower end of the tubular portion so as to prevent the tubular portion from being displaced downward.

9. The [weight] sensor of claim 8, further comprising: a second mounting member joined to the first mounting member, the second mounting member having a lower surface facing the upper end of the tubular portion,

wherein, when no load is applied to the pressing member, the lower surface of the second mounting member is located away from the upper end of the tubular portion, and

wherein, when an excessive load is applied to the pressing member, the lower surface of the second mounting member contacts the upper end of the tubular portion so as to prevent the tubular portion from being displaced upward.

10. The [weight] sensor of claim 8, wherein a stopper groove is provided in the upper surface of the first mounting member, and the stopper groove has an inner bottom surface which contacts the lower end of the tubular portion when the excessive load is applied to the pressing member.

11. The [weight] sensor of claim 1, further comprising: a first mounting member for fixing the deformable body; and

a second mounting member joined to the first mounting member,

wherein the deformable body further includes a retained portion provided at a tip of the projection, wherein the retained portion of the deformable body is fixed to the first mounting member,

wherein the tubular portion of the deformable body has an upper end and a lower end opposite to each other along the center axis,

wherein the second mounting member has a lower surface facing the upper end of the tubular portion,

wherein, when no load is applied to the pressing member, the lower surface of the second mounting member is located away from the upper end of the tubular portion, and

wherein, when an excessive load is applied to the pressing member, the lower surface of the second mounting member contacts the upper end of the tubular portion so as to prevent the tubular portion from being displaced upward.

12. A sensor comprising:

a deformable body including:

a tubular portion having a tubular shape and having an outer side surface and an inner surface; and

a projection projecting from the inner side surface of the tubular portion;

a pressing member configured to apply a force to the deformable body;

a first strain resistor disposed on the deformable body and configured to detect an amount of the force; and

a second strain resistor disposed on the deformable body, wherein the pressing member presses the deformable body to urge the projection and the tubular portion of the deformable body relatively in directions which are opposite to each other and which are parallel with a center axis of the tubular portion, and

the first strain resistor is disposed on an upper portion of the deformable body with respect to the projection and

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*the second strain resistor is disposed on a lower portion of the deformable body with respect to the projection.*

13. *The sensor of claim 12, wherein the pressing member is configured to apply the force through the projection of the deformable body.*

14. *The sensor of claim 12, further comprising: a support member configured to support the deformable body, wherein:*

*the tubular portion of the deformable body has an upper end and a lower end opposite to each other,*

*the support member supports the upper end and the lower end of the deformable body, and*

*the pressing member presses the projection so as to apply a moment to the tubular portion.*

15. *The sensor of claim 14, further comprising:*

*at least one elastic body provided at least one of between the support member and the upper end of the tubular portion of the deformable body and between the support member and the lower end of the tubular portion of the deformable body.*

16. *The sensor of claim 12, further comprising: a fixing member configured to fix the deformable body, wherein:*

*the tubular portion of the deformable body has an upper end and a lower end opposite to each other,*

*the deformable body further includes a retained portion provided at a tip of the projection,*

*the fixing member fixes the retained portion of the deformable body, and*

*the pressing member presses the tubular portion of the deformable body such that a moment is applied to the tubular portion of the deformable body.*

17. *The sensor of claim 12, further comprising: a first mounting member configured to fix the deformable body, wherein:*

*the deformable body further includes a retained portion provided at a tip of the projection,*

*the retained portion of the deformable body is fixed to the first mounting member,*

*the tubular portion of the deformable body has an upper end and a lower end opposite to each other,*

*the first mounting member has an upper surface facing the lower end of the tubular portion, and*

*when no load is applied by the pressing member, the upper surface of the first mounting member is located away from the upper end of the tubular portion, and when an*

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*excessive load is applied by the pressing member, the upper surface of the first mounting member contacts the lower end of the tubular portion so as to prevent the tubular portion from being displaced downward.*

18. *The sensor of claim 17, further comprising:*

*a second mounting member connected to the first mounting member, the second mounting member having a lower surface facing the upper end of the tubular portion,*

*wherein, when no load is applied by the pressing member, the lower surface of the second mounting member is located away from the upper end of the tubular portion,*

*and when an excessive load is applied by the pressing member, the lower surface of the second mounting member contacts the upper end of the tubular portion so as to prevent the tubular portion from being displaced upward.*

19. *The sensor of claim 17, wherein:*

*a stopper groove is provided in the upper surface of the first mounting member, and*

*the stopper groove has an inner bottom surface which contacts the lower end of the tubular portion when the excessive load is applied by the pressing member.*

20. *The sensor of claim 12, further comprising:*

*a first mounting member configured to fix the deformable body; and*

*a second mounting member connected to the first mounting member, wherein:*

*the deformable body further includes a retained portion provided at a tip of the projection,*

*the retained portion of the deformable body is fixed to the first mounting member,*

*the tubular portion of the deformable body has an upper end and a lower end opposite to each other,*

*the second mounting member has a lower surface facing the upper end of the tubular portion,*

*when no load is applied by the pressing member, the lower surface of the second mounting member is located away from the upper end of the tubular portion, and when an excessive load is applied by the pressing member, the lower surface of the second mounting member contacts the upper end of the tubular portion so as to prevent the tubular portion from being displaced upward.*

\* \* \* \* \*