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(54) **MICRO PERISTALTIC PUMP**

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(57) **ABSTRACT**

A circular arc shaped flow path (**21**) is formed as a microfluidic flow path in a sheet-like microfluidic chip (**20**). A roller (**15**) on a rotor (**10**) is pressed against the circular arc shaped flow path (**21**) in the microfluidic chip (**20**), the rotor (**10**) is rotary-driven by a driving motor **4**, and the circular arc shaped flow path (**21**) is caused to make a peristaltic motion by rotation of the rotor (**10**), to send a liquid in the flow path. On the flat surface of the rotor (**10**), a plurality of rollers (**15**) are held so as to be pressed in contact with the circular arc shaped flow path (**21**), to freely rotate on the flat surface perpendicular to a rotary shaft (**13**) of the rotor (**10**). The circular arc shaped flow path (**21**) is disposed along the rotational trajectory of the plurality of rollers (**15**).

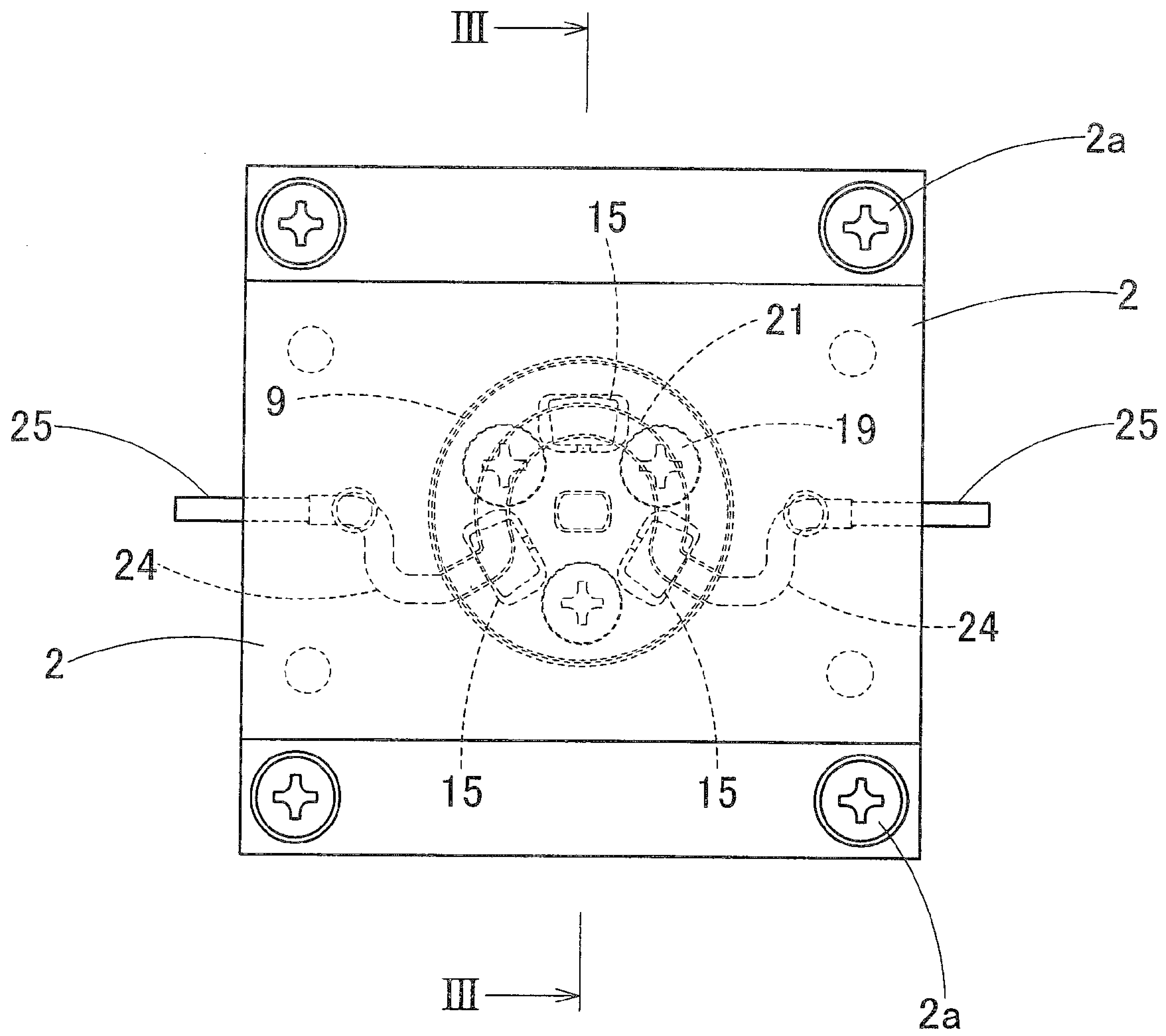

Fig . 1(a)

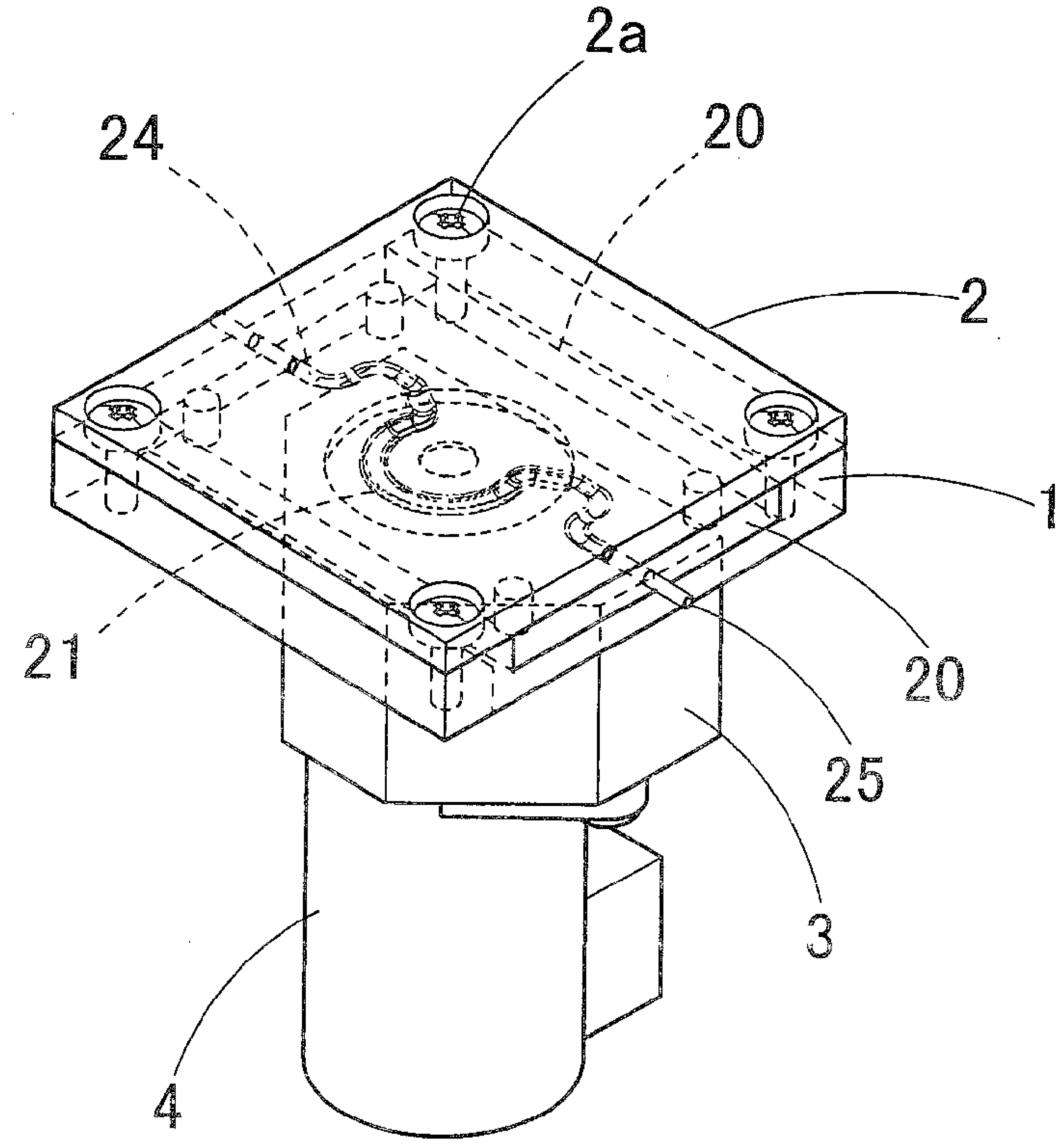

Fig . 1(b)

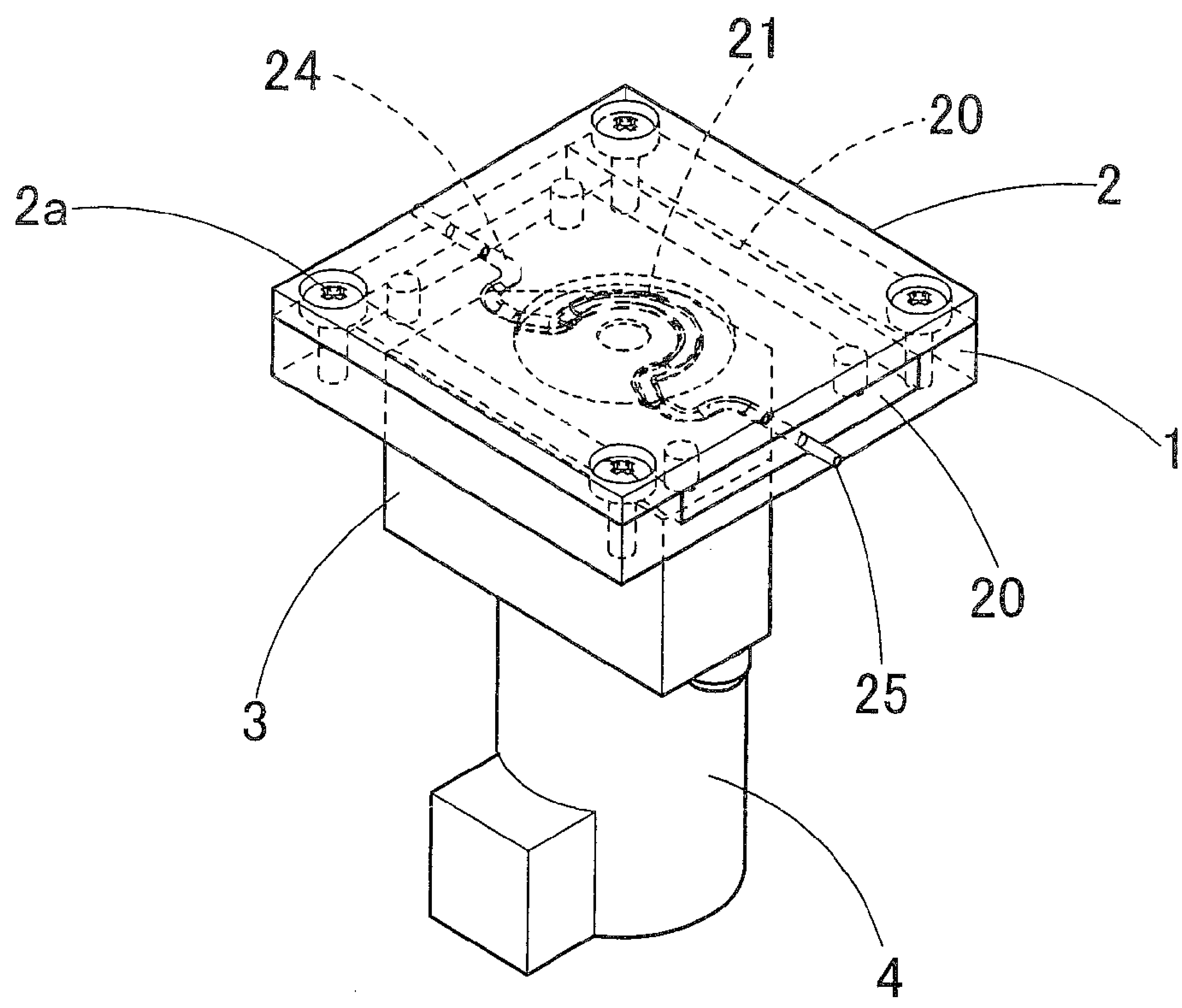

Fig . 2

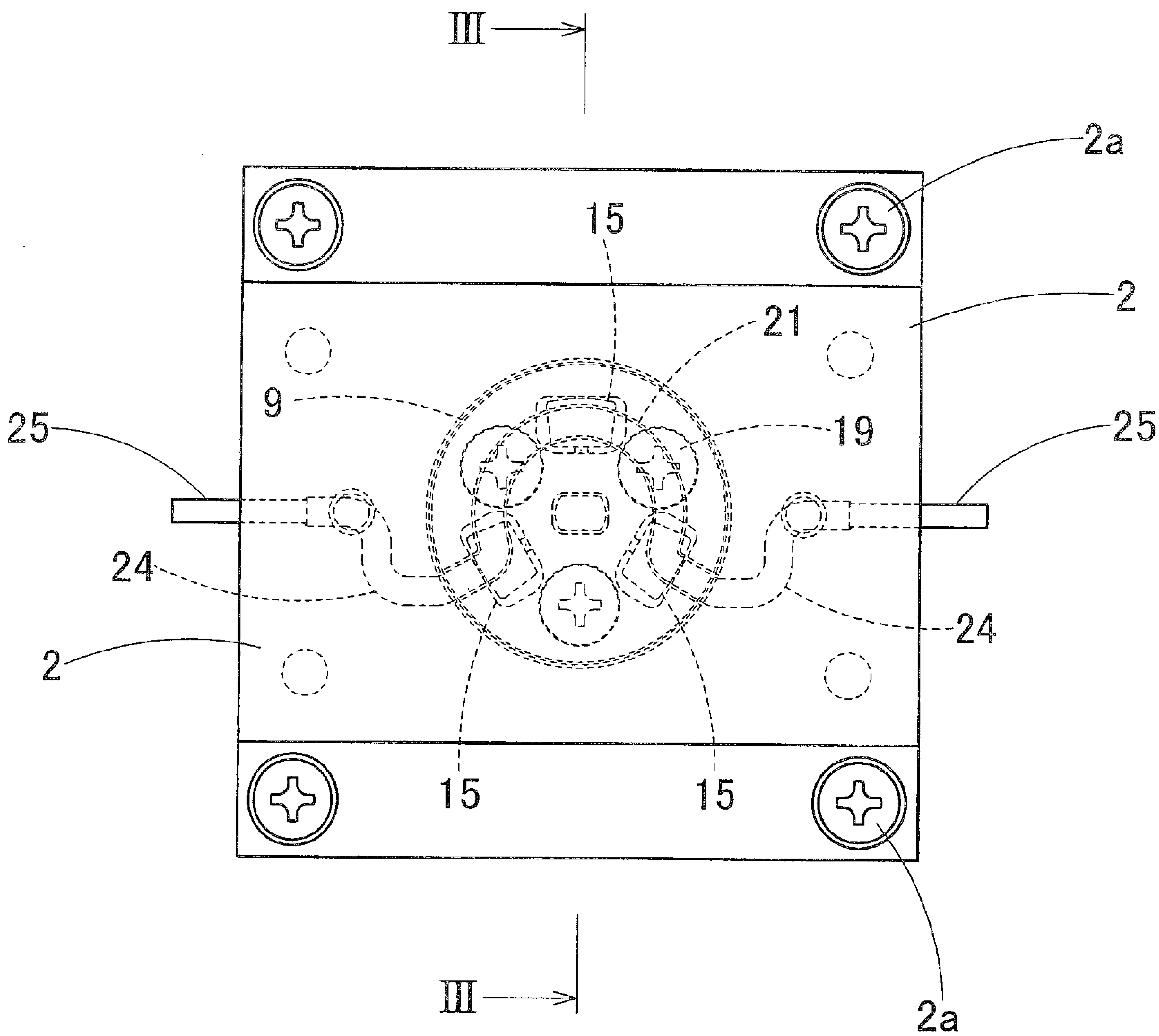

Fig . 3

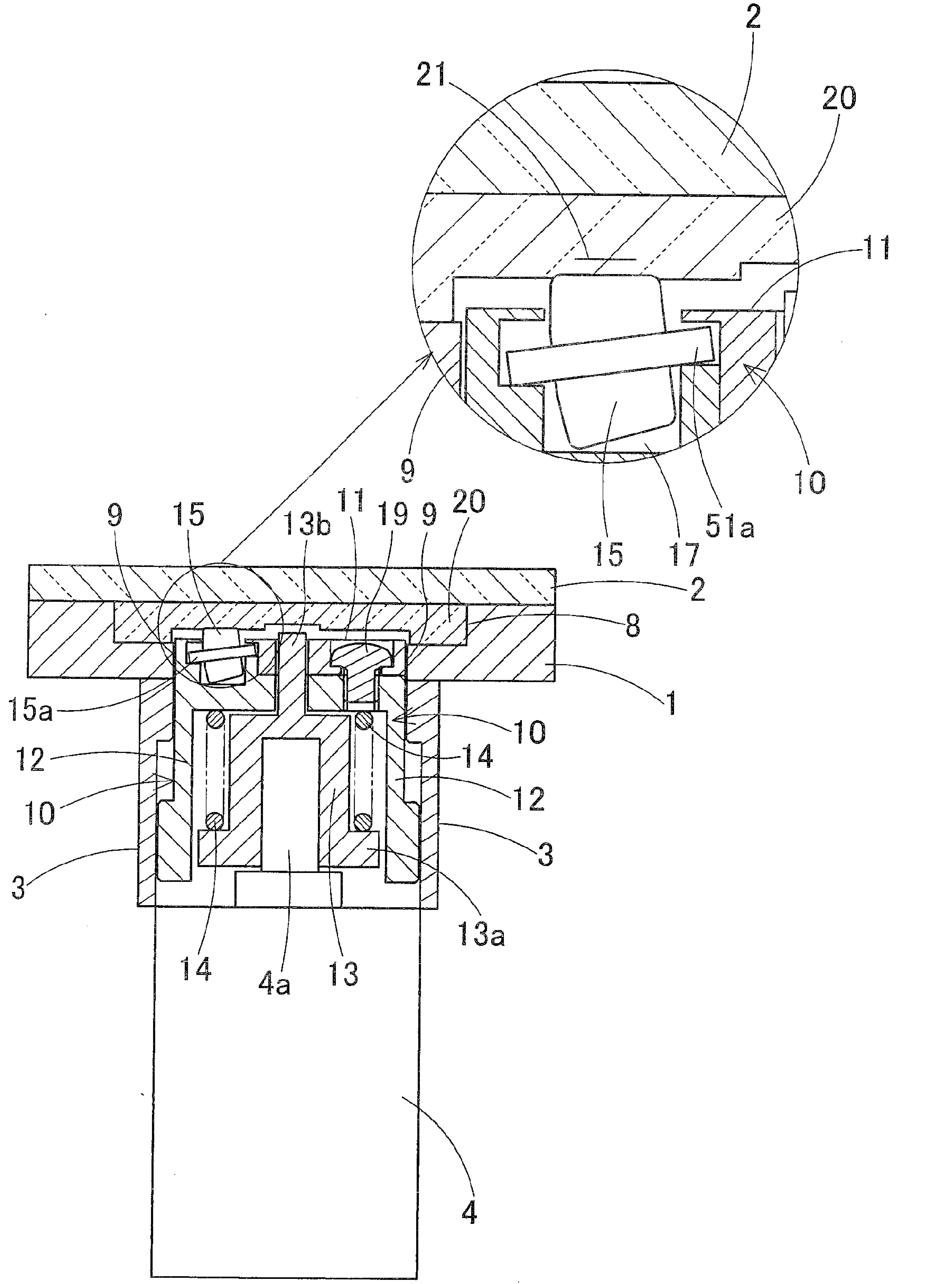
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Fig. 4

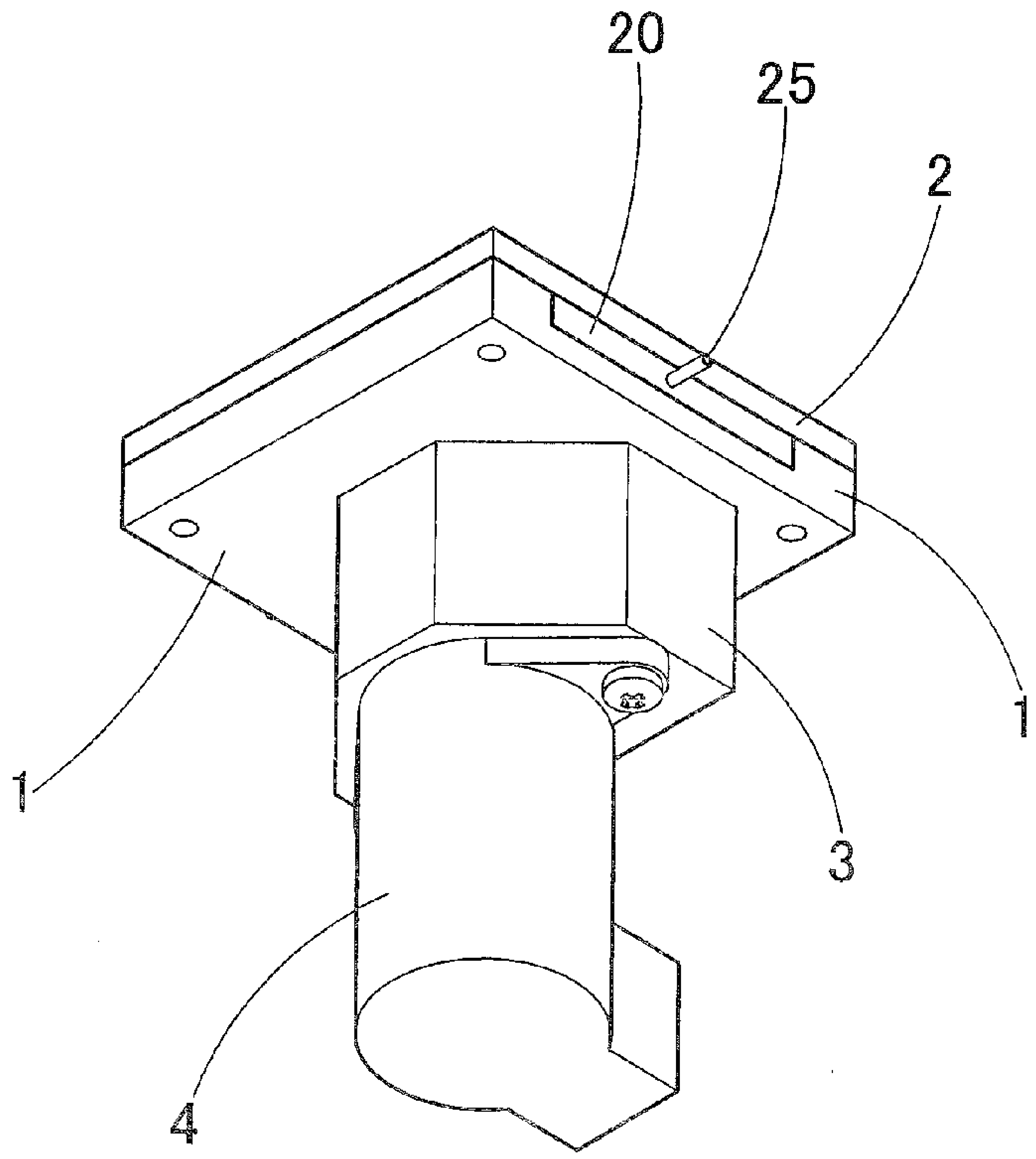


Fig. 5

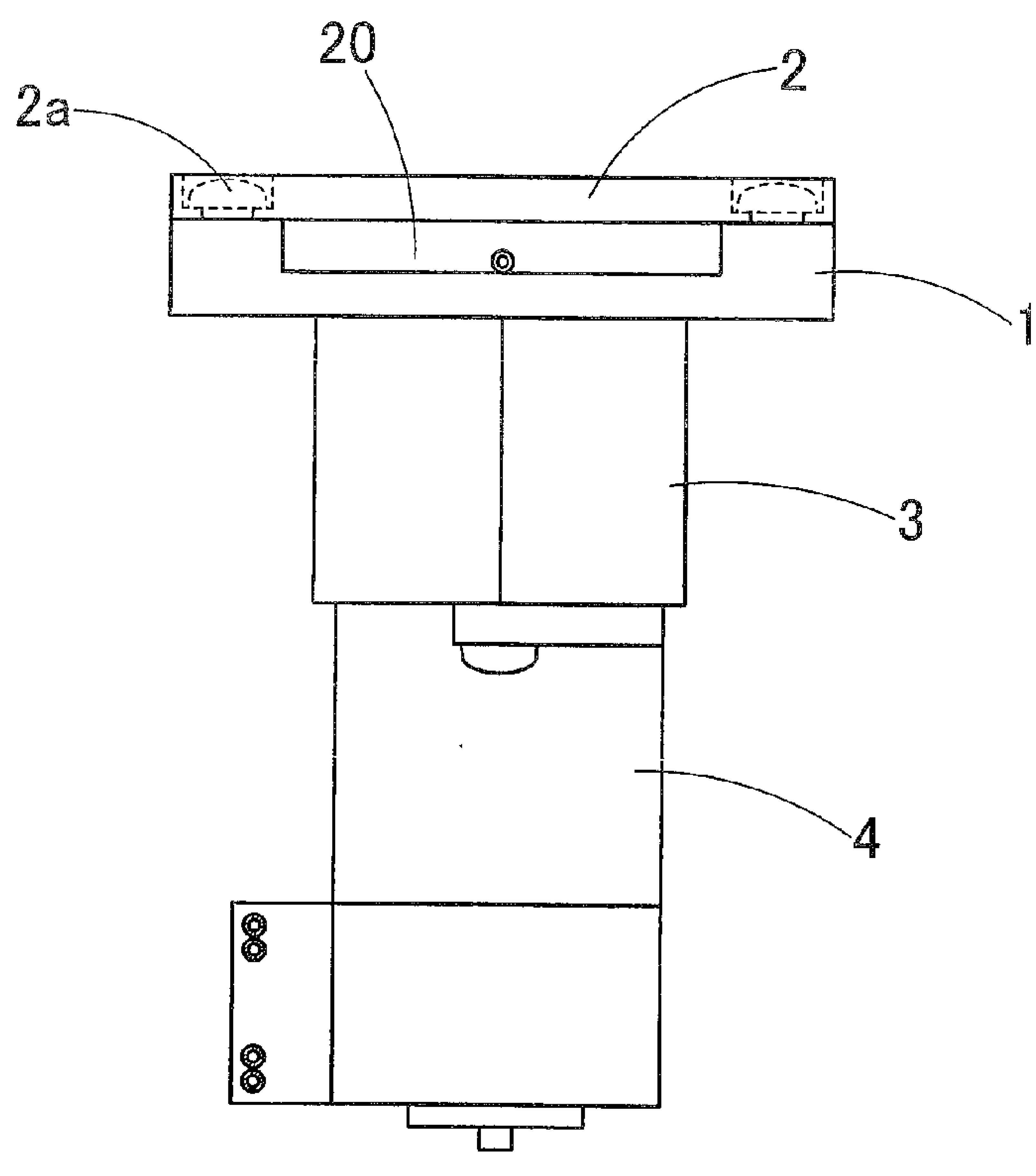


Fig. 6

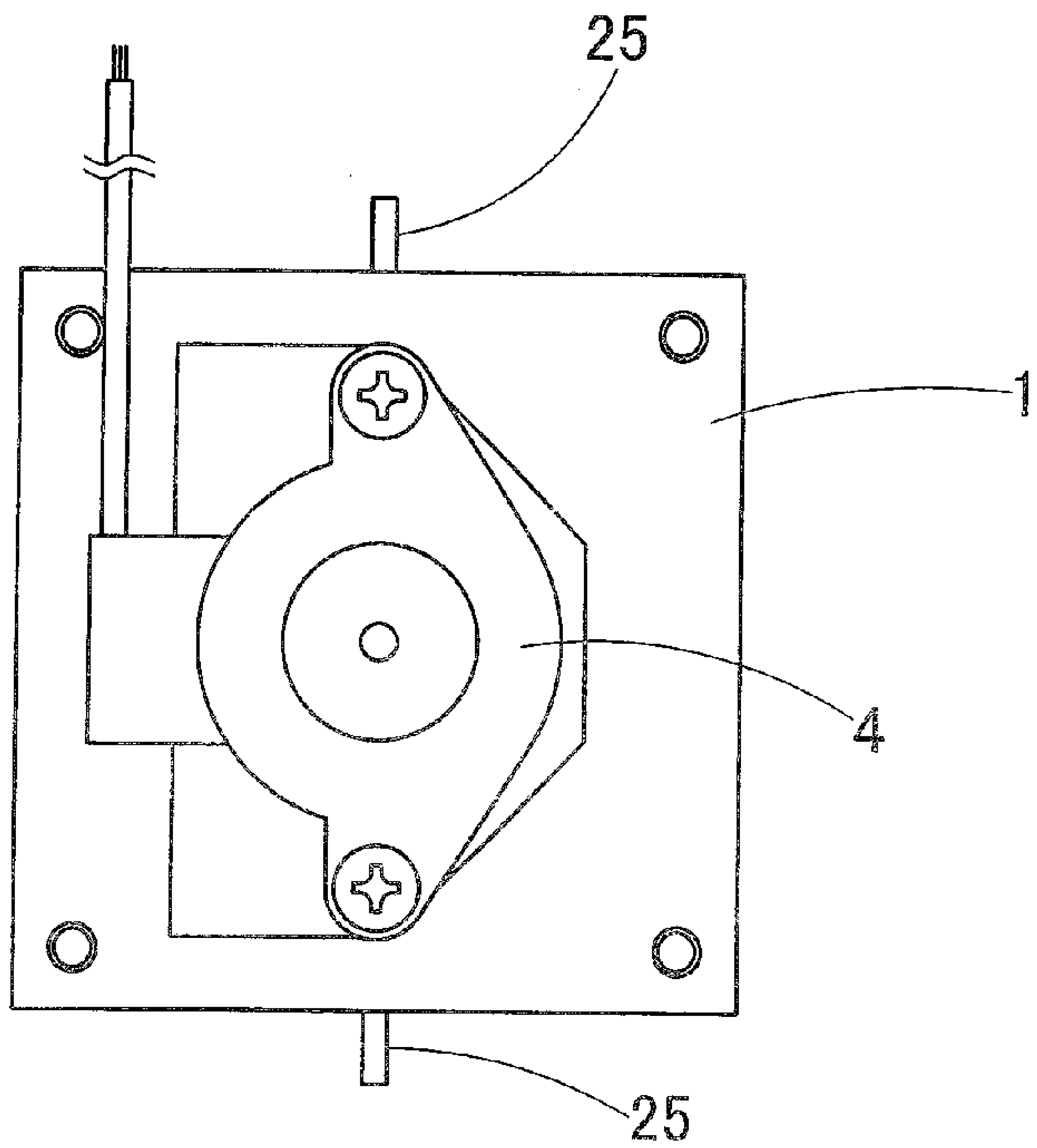


Fig. 7

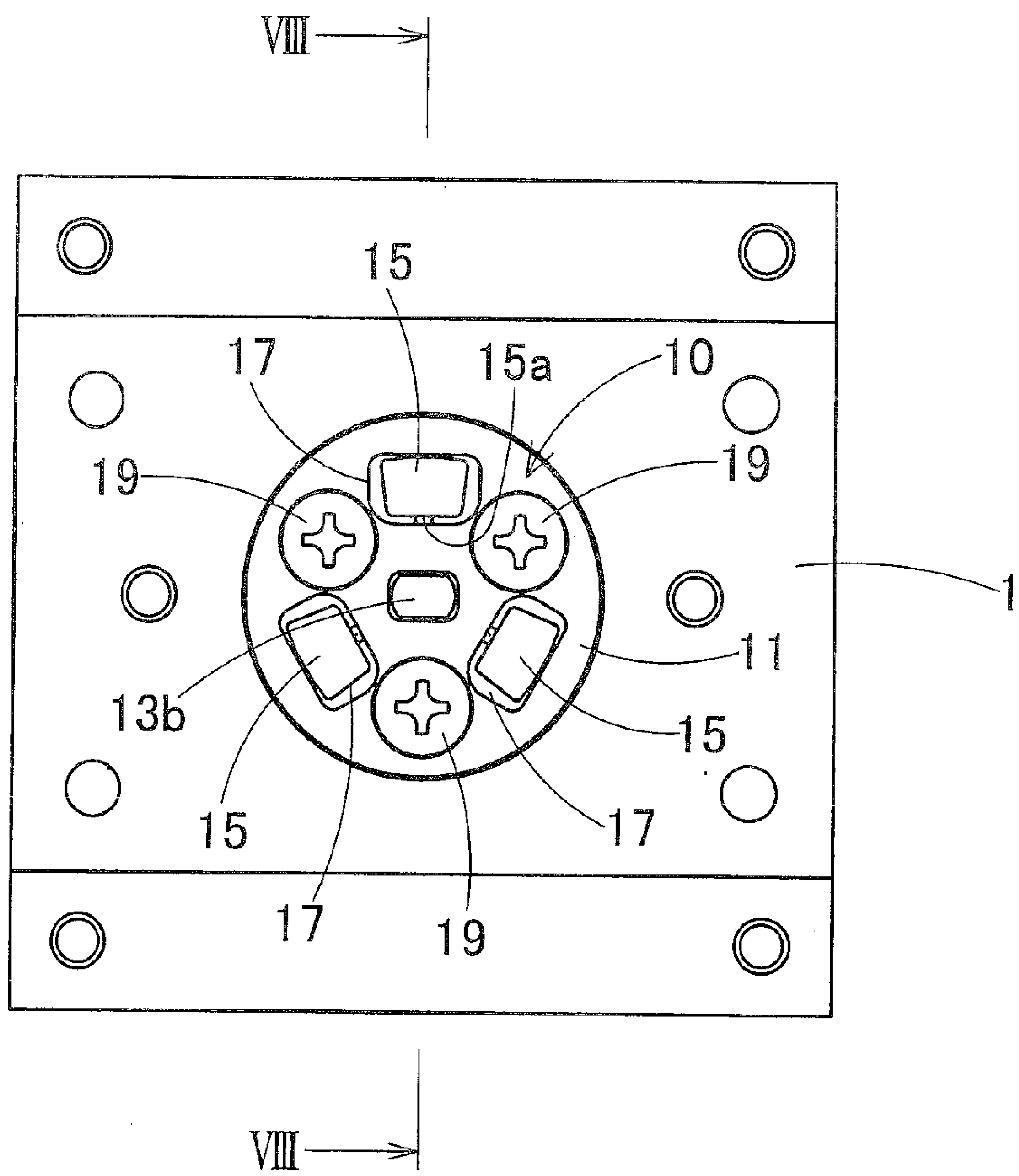


Fig . 8

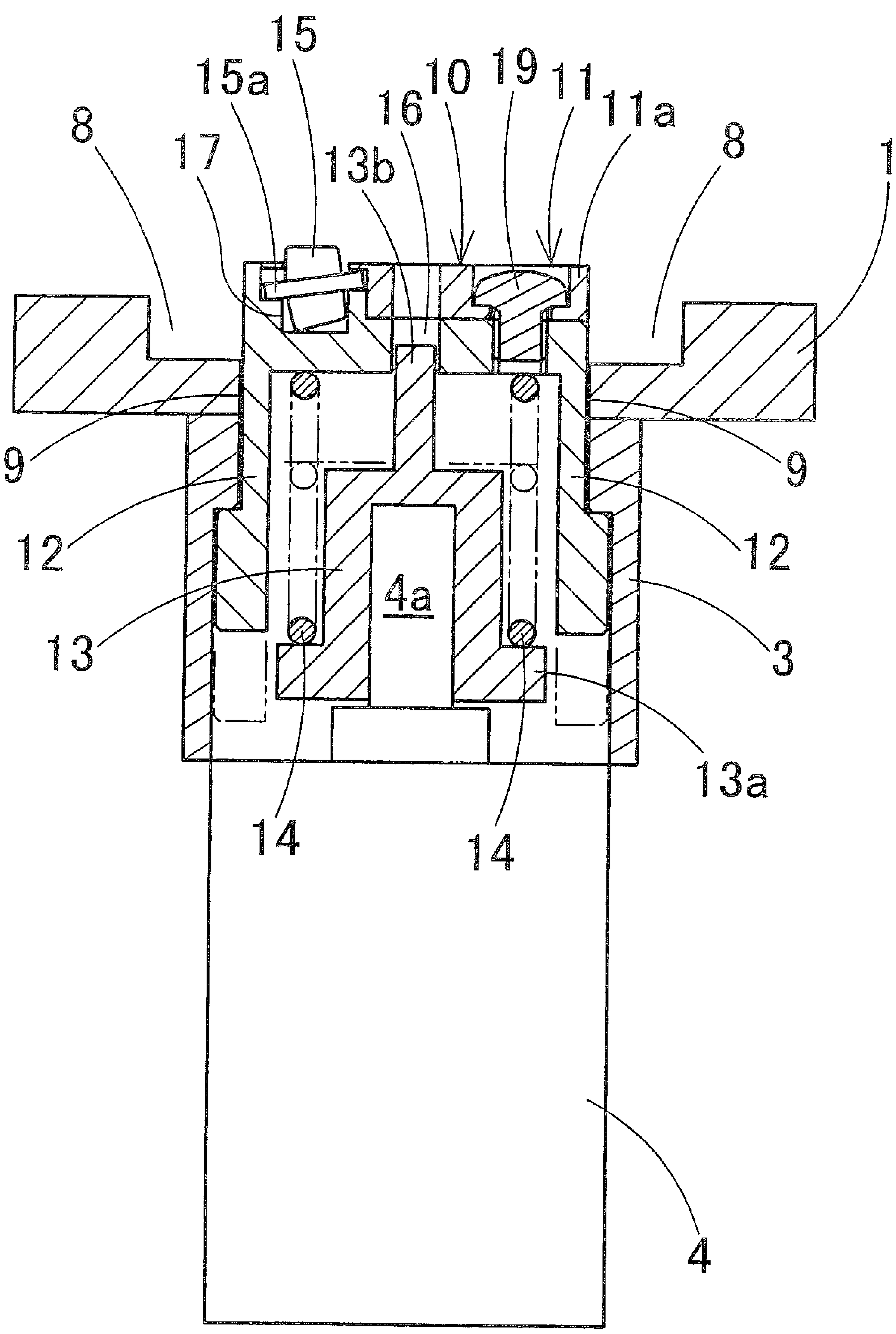


Fig . 9(a)

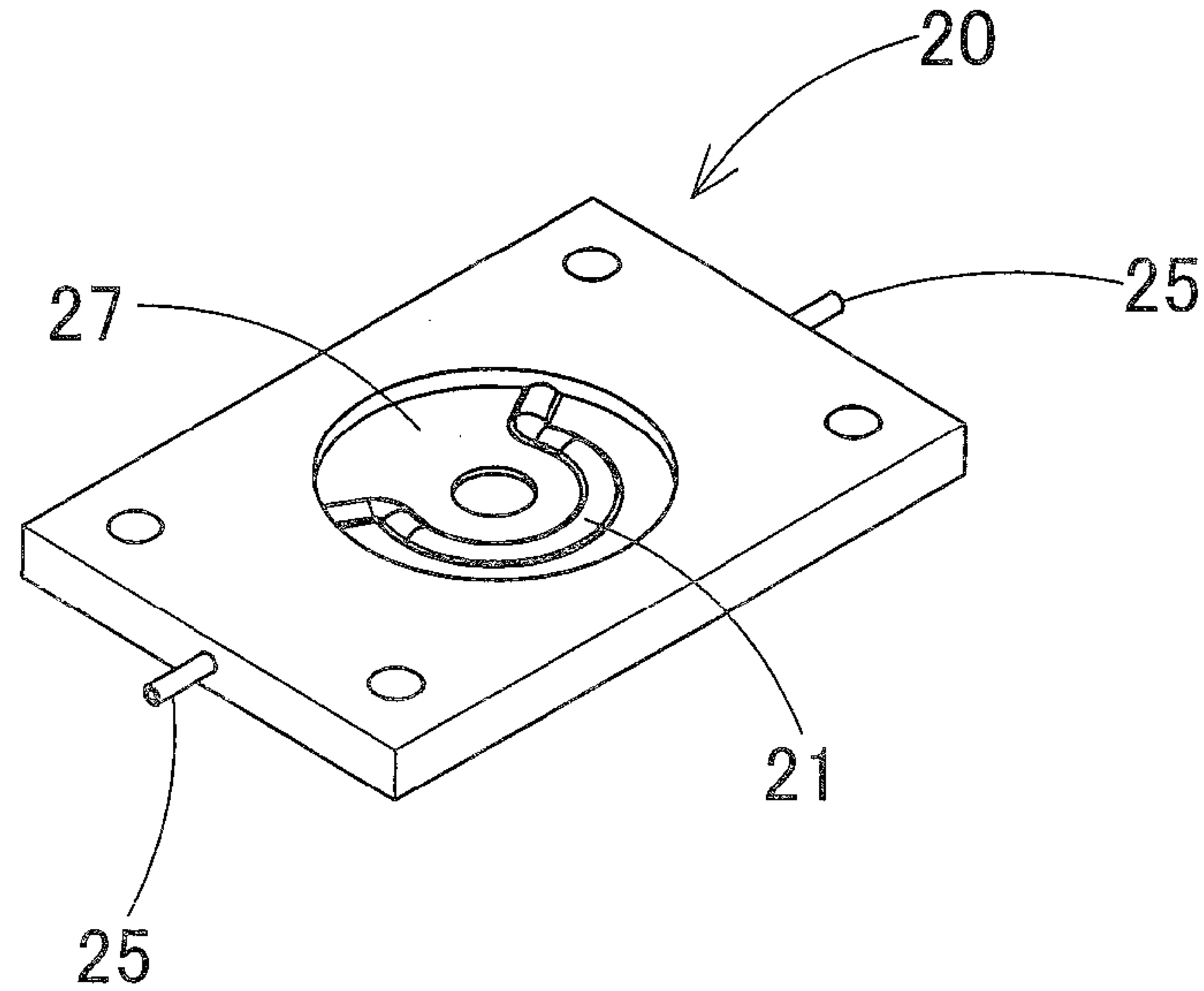


Fig . 9(b)

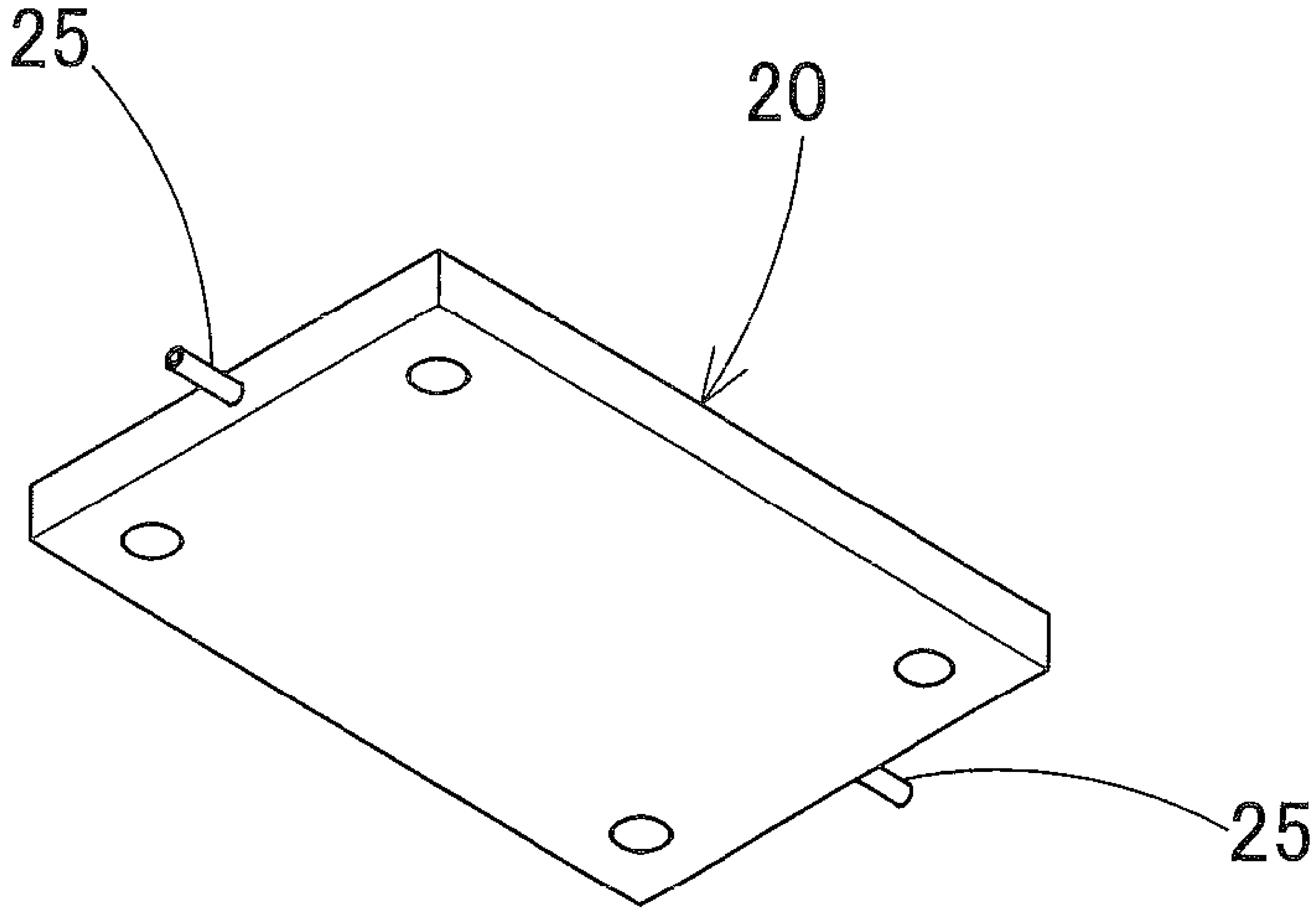


Fig . 10(a)

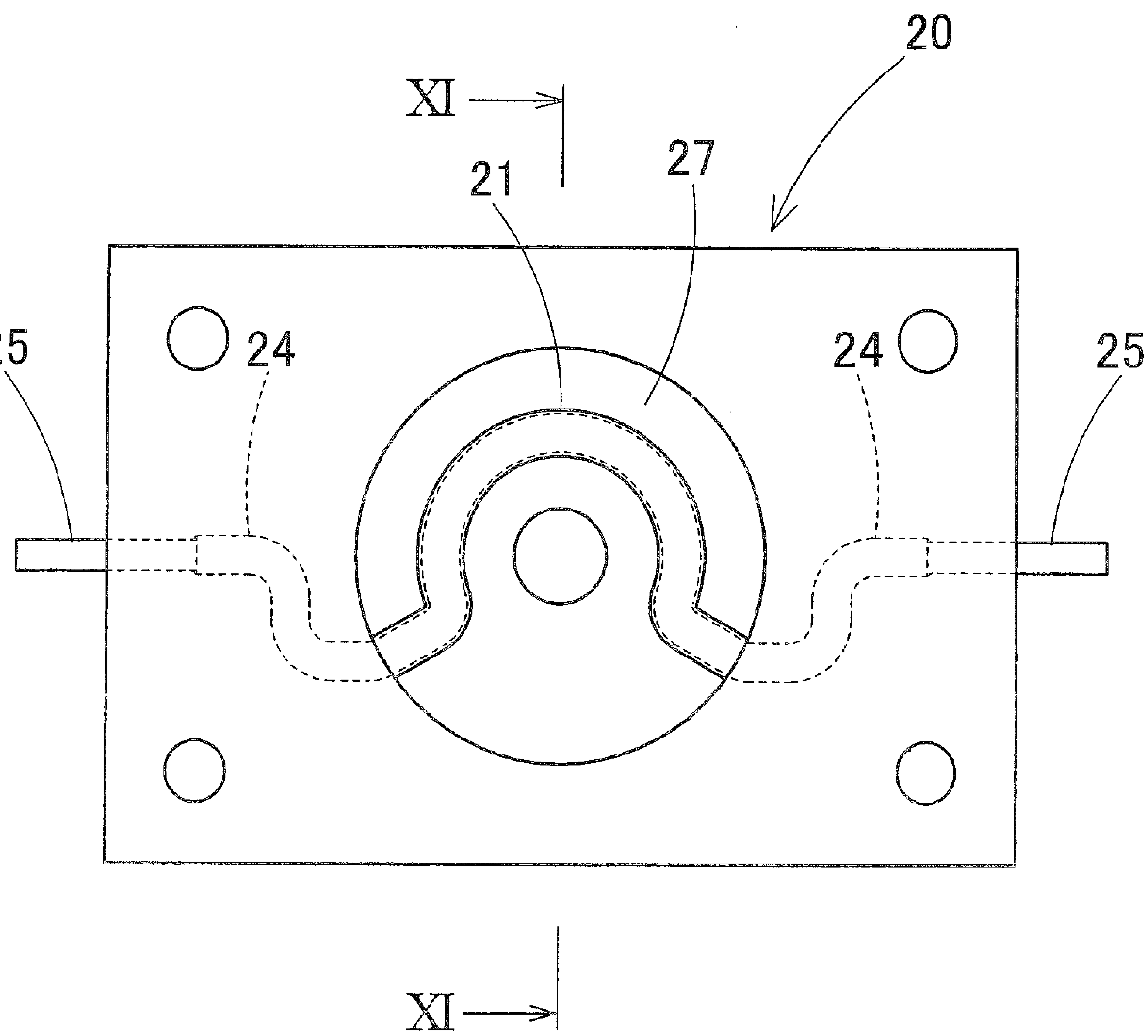
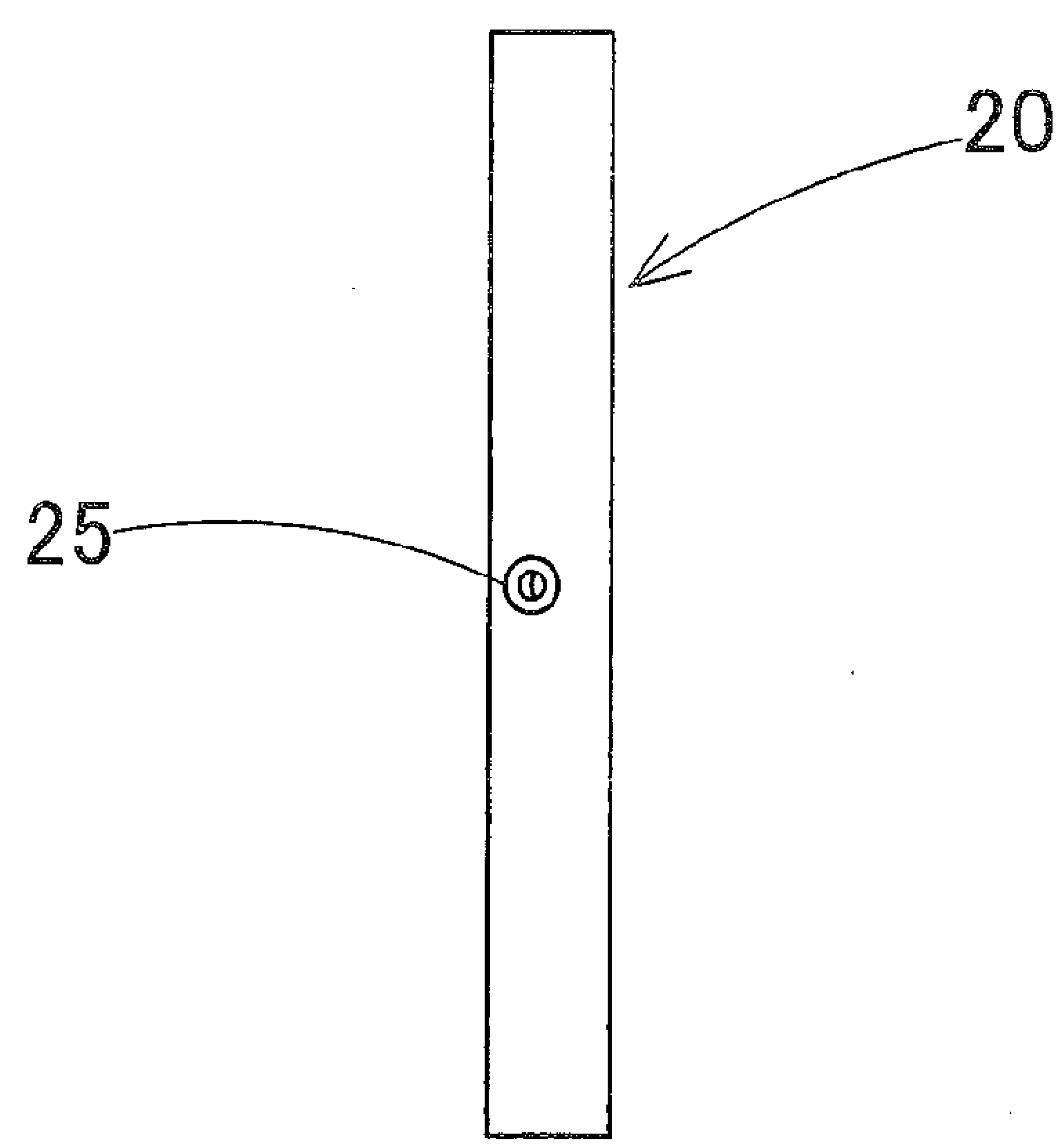


Fig . 10(b)



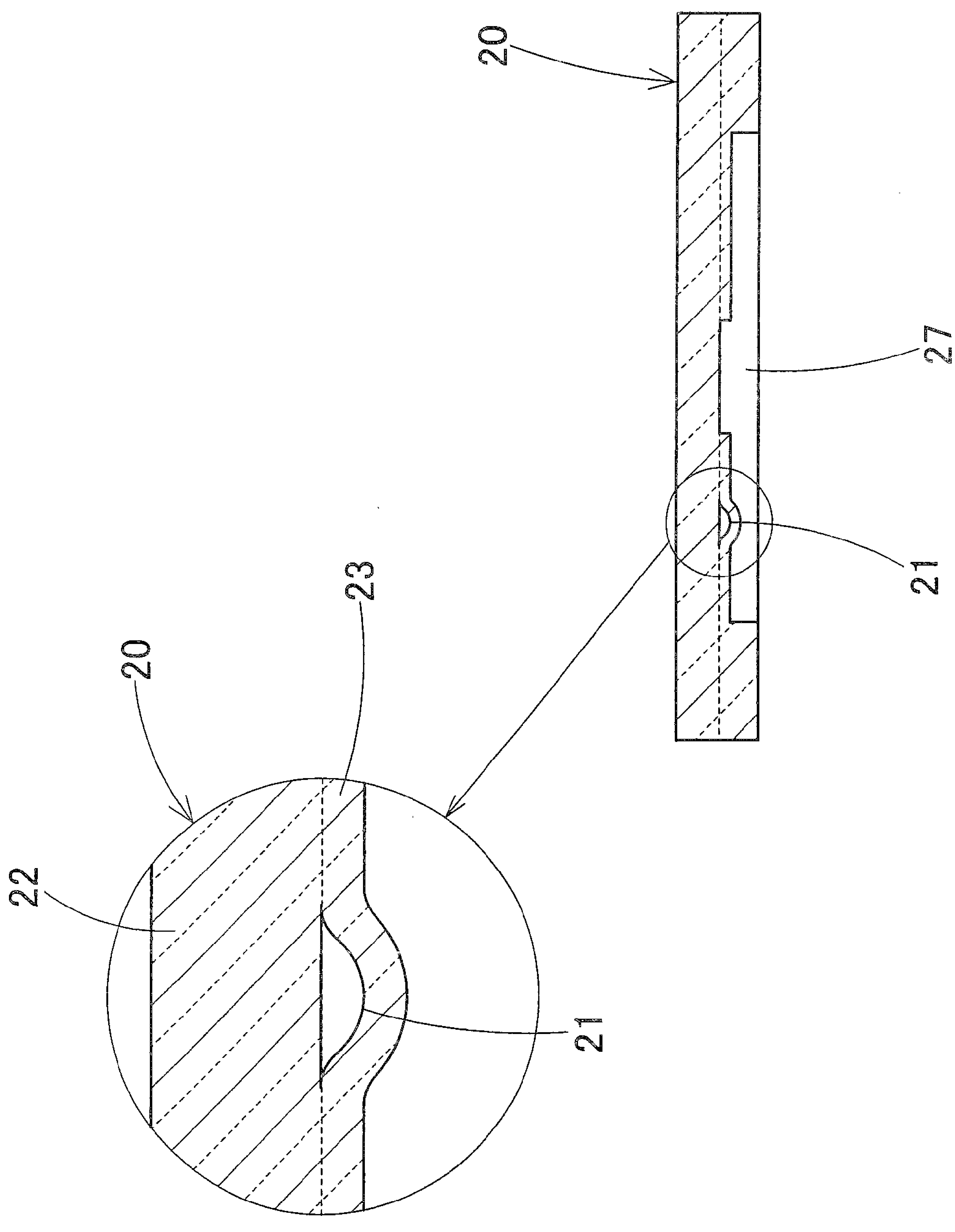


Fig. 11

Fig . 12(a)

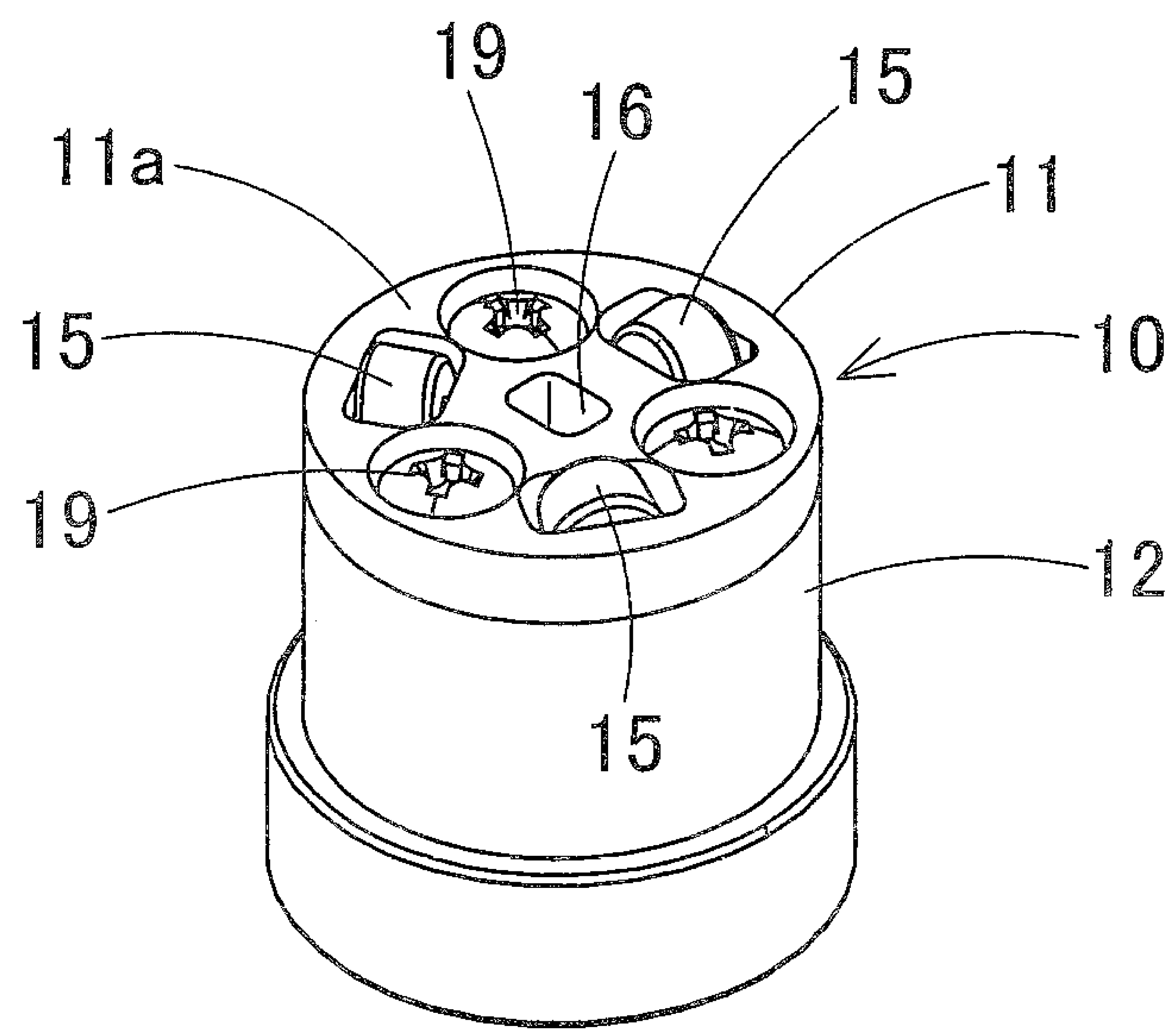


Fig . 12(b)

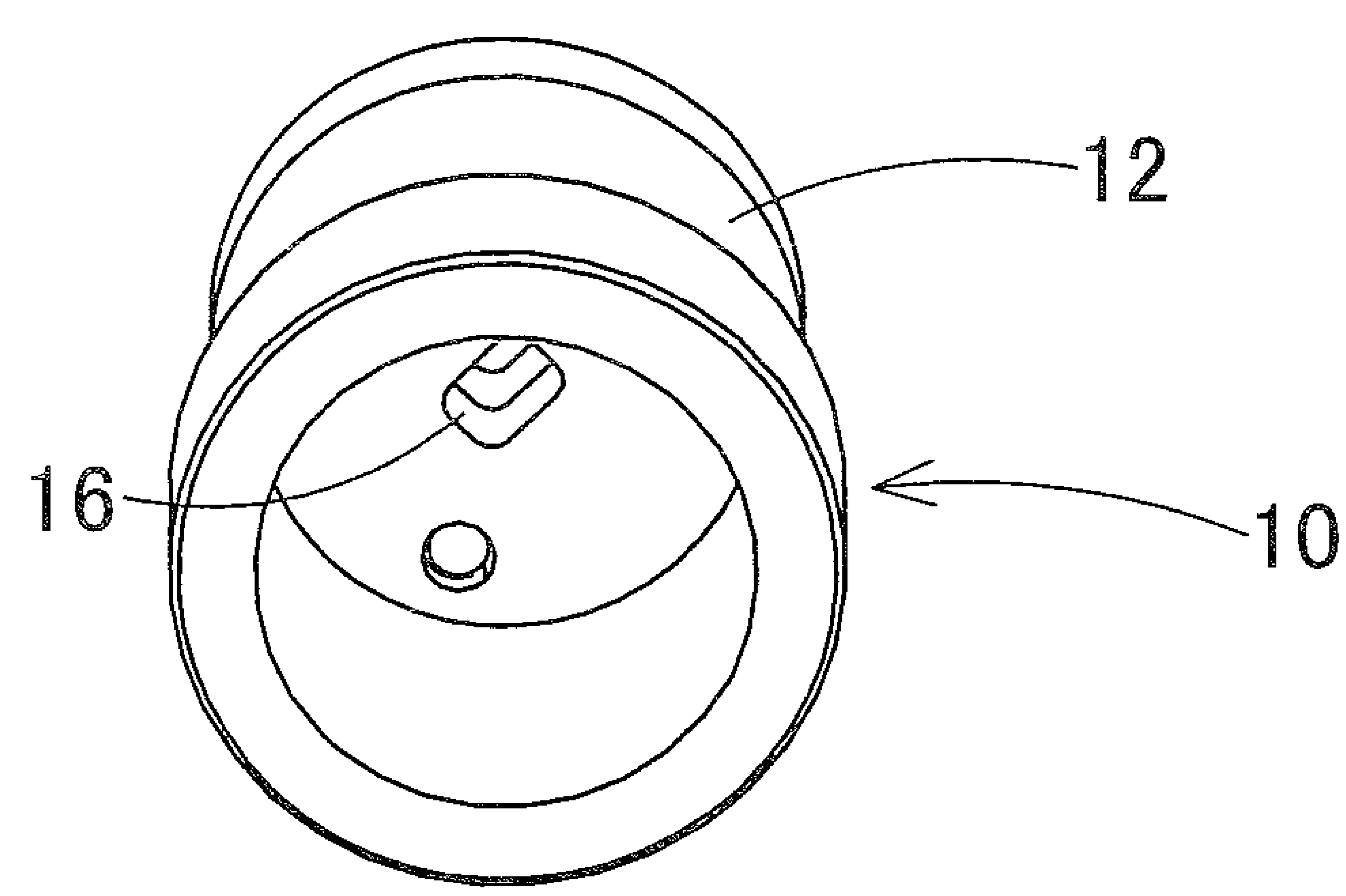


Fig . 13

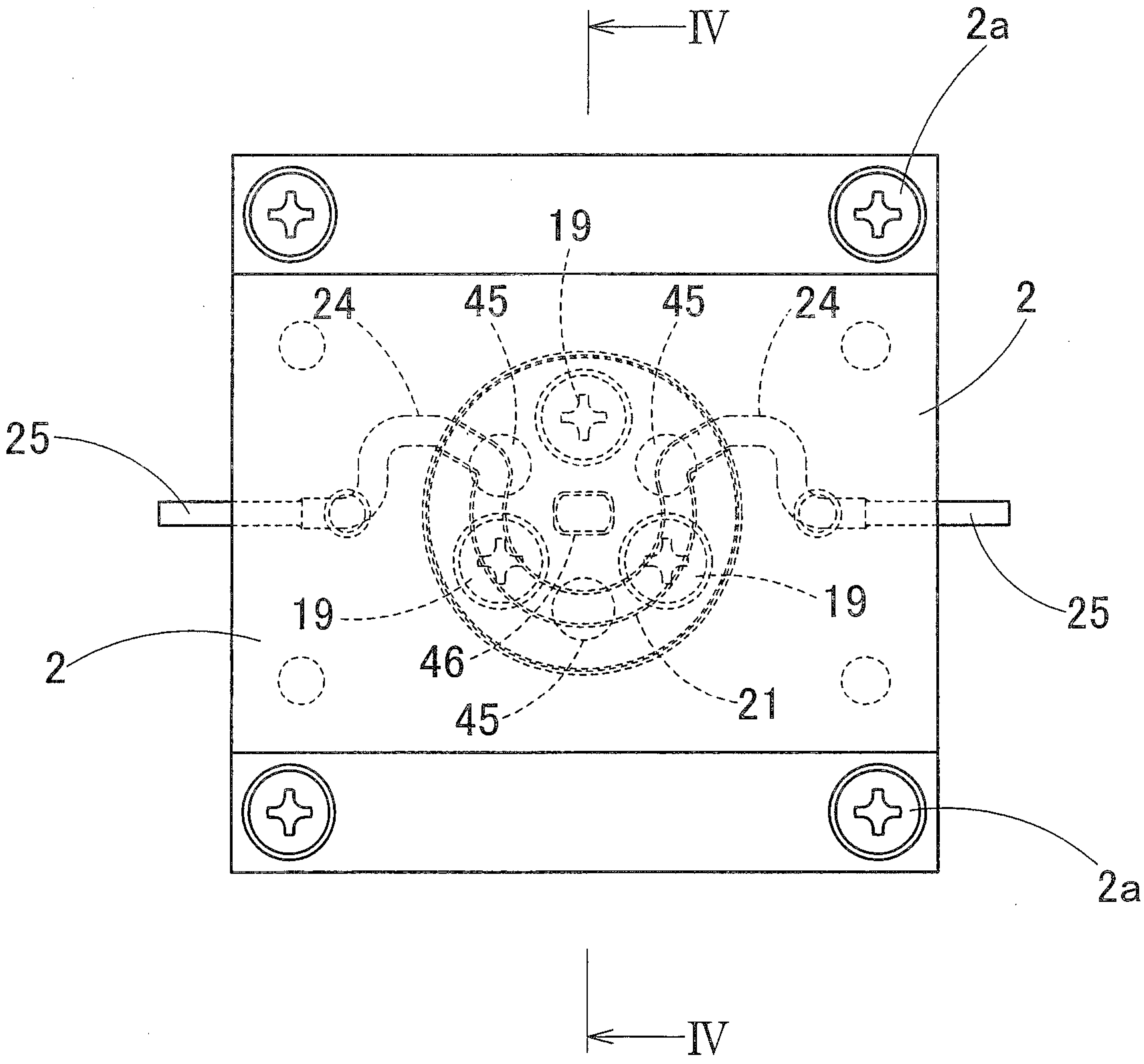


Fig . 14

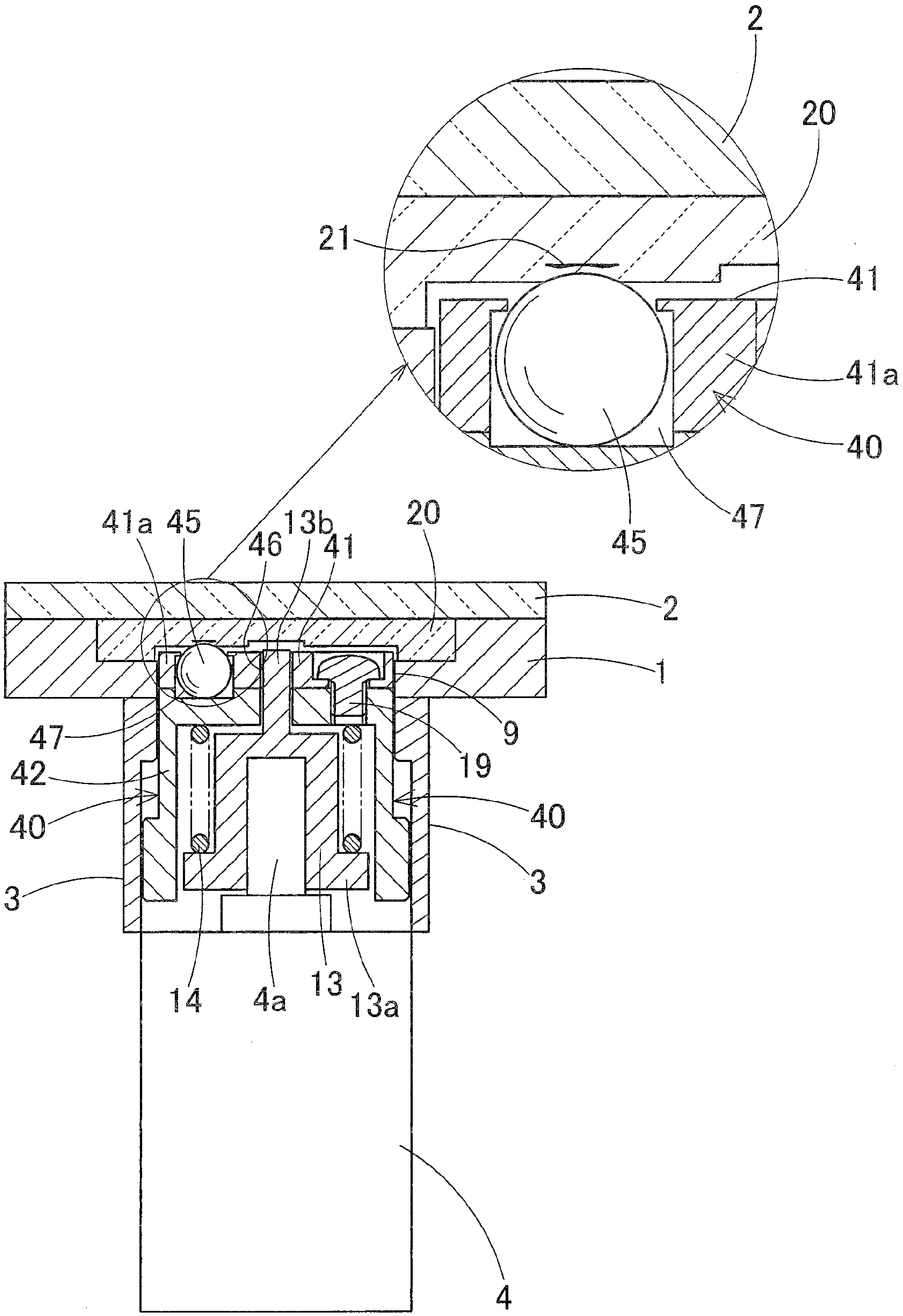

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Fig . 15

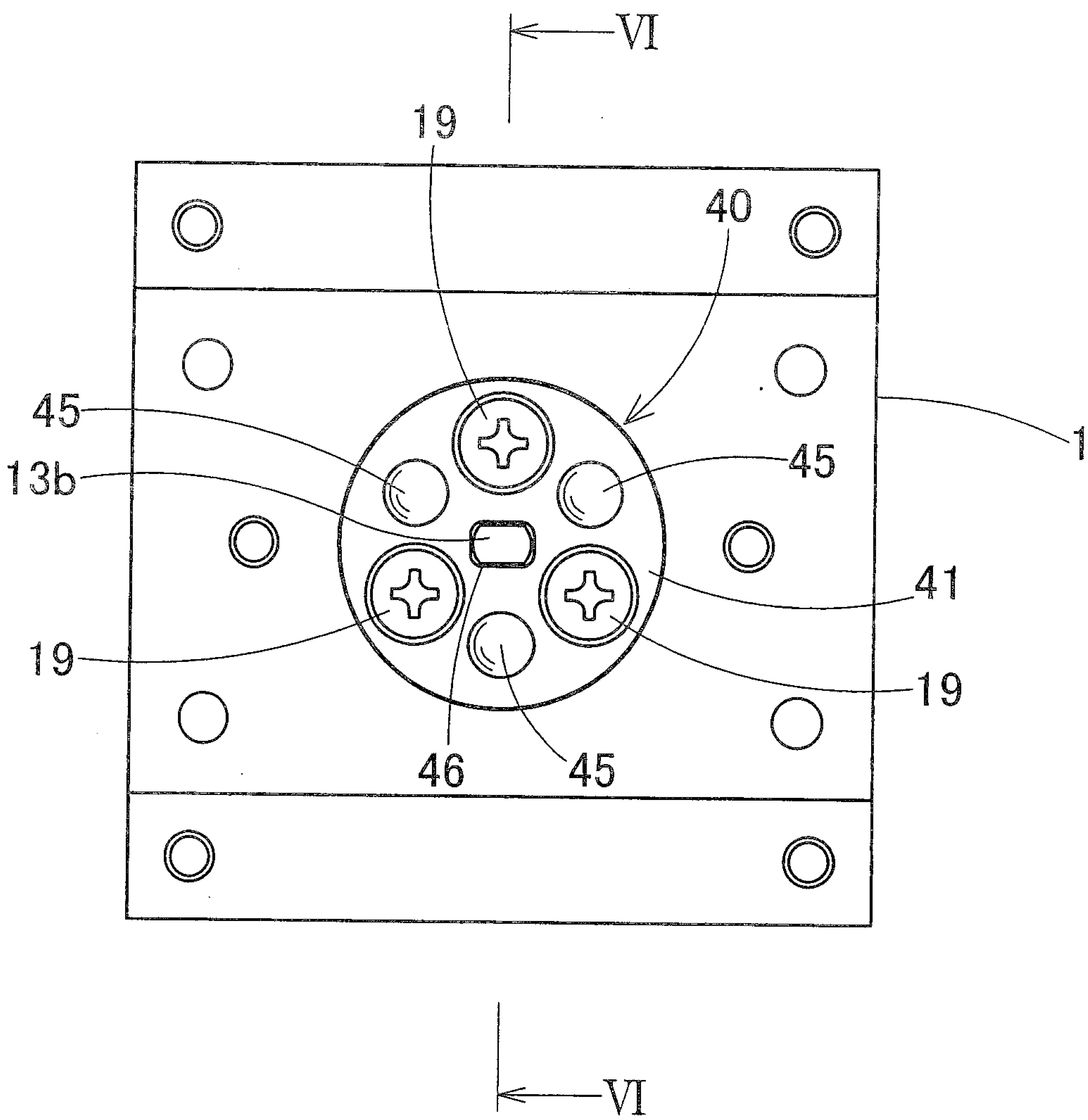


Fig . 16

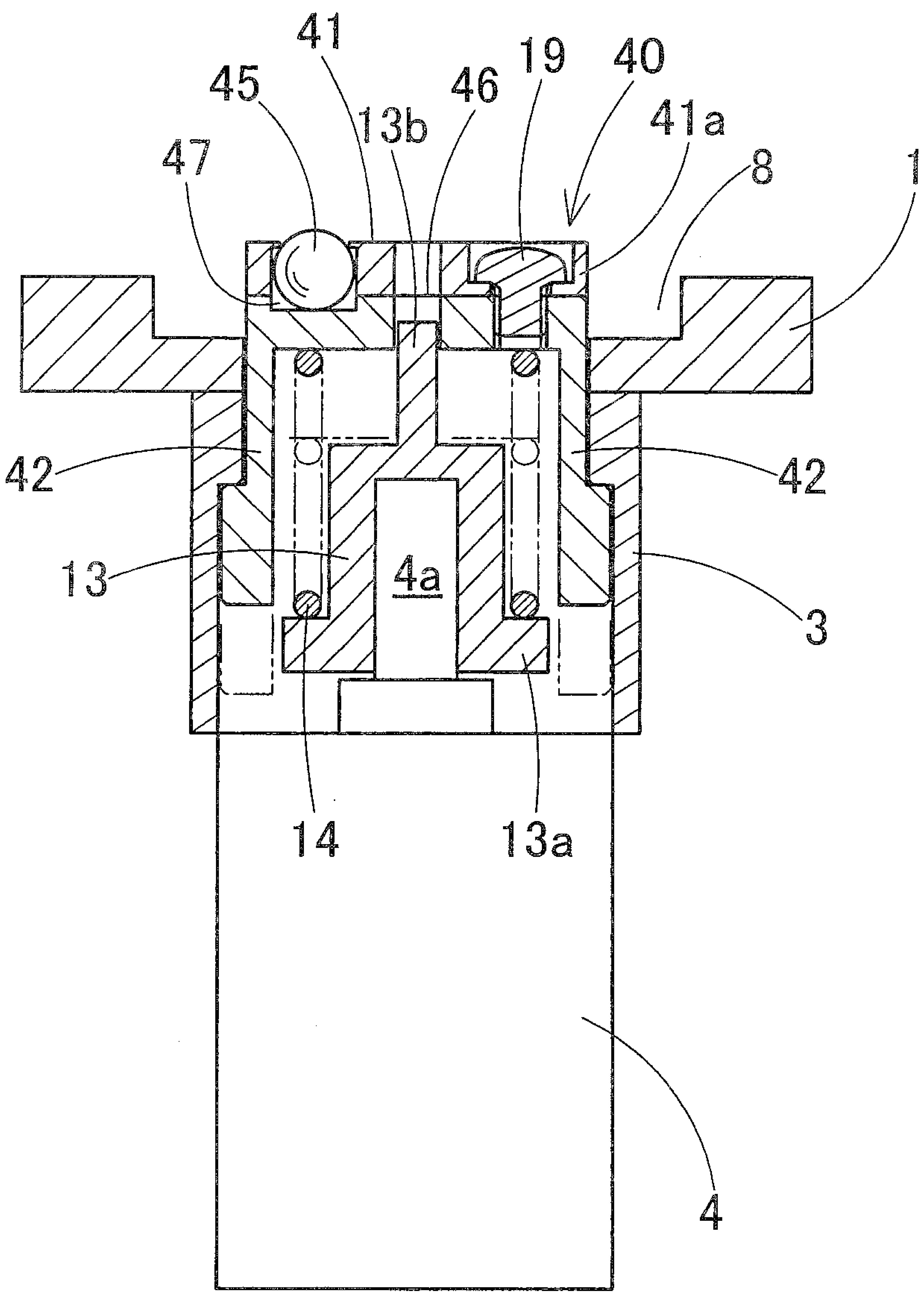


Fig . 17(a)

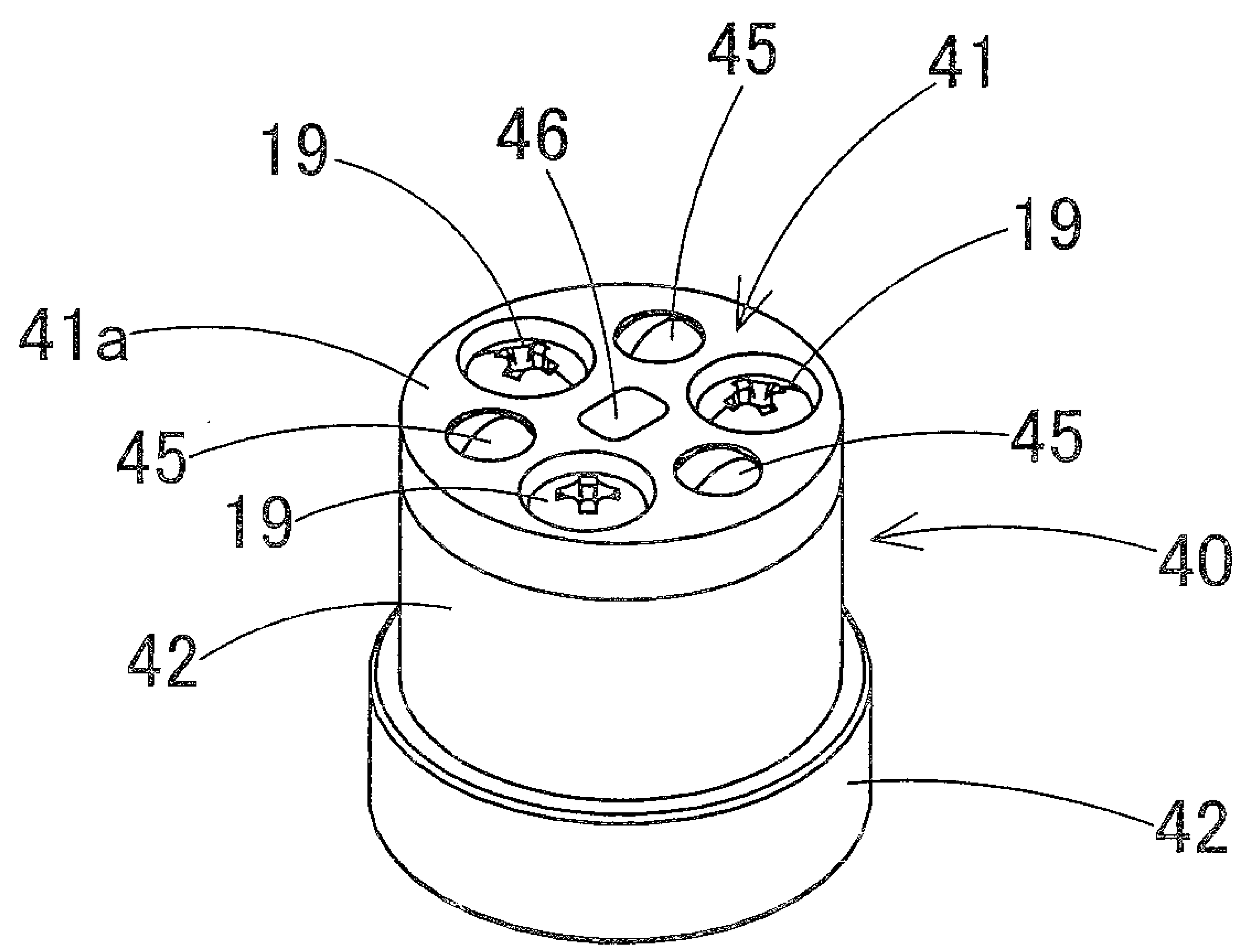
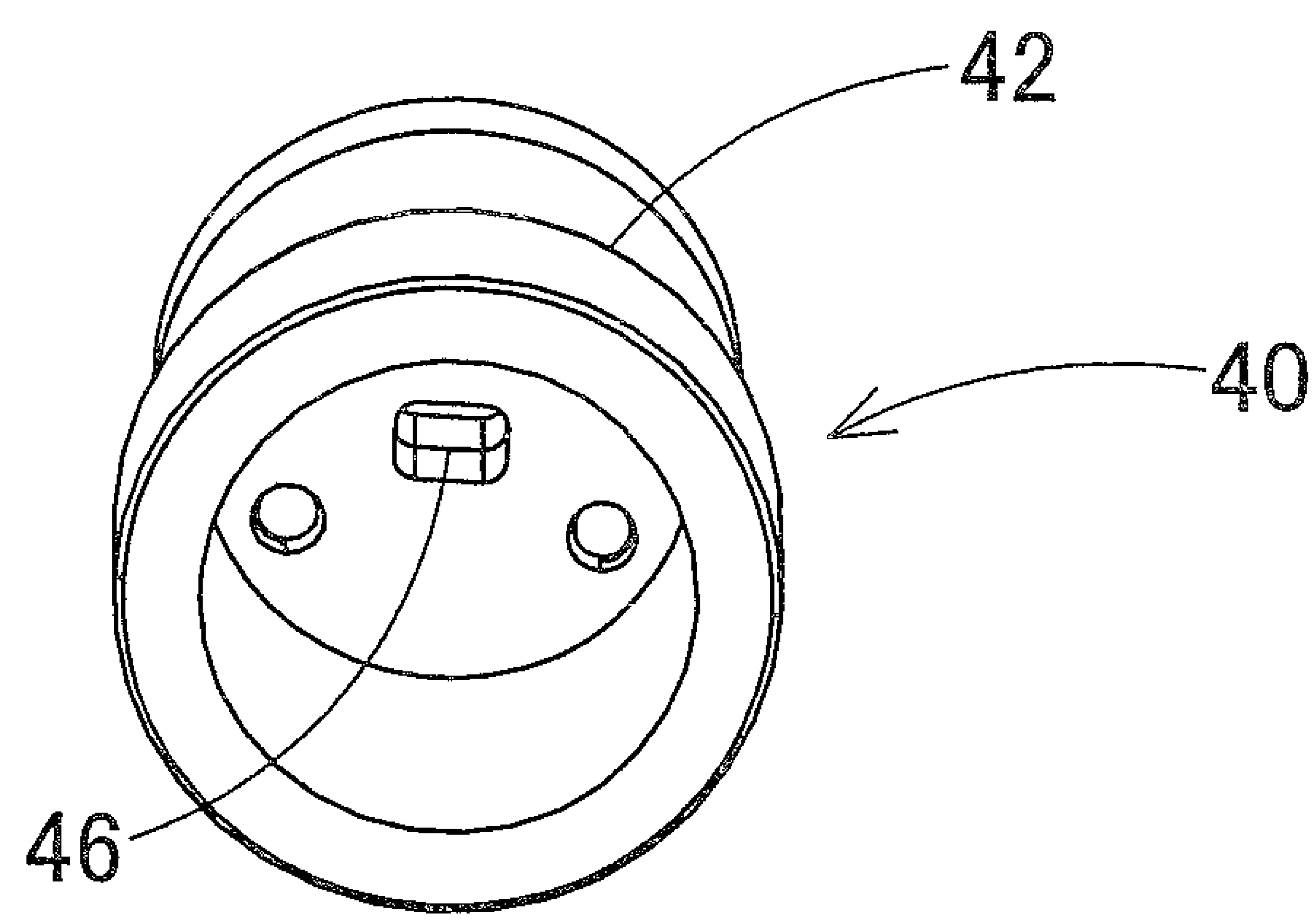


Fig . 17(b)



MICRO PERISTALTIC PUMP

TECHNICAL FIELD

[0001] The present invention relates to a micro peristaltic pump which is used at the time of flowing micro-fluid such as a culture solution or various types of reagents into a microfluidic flow path, to perform cell culturing, reagent screening, chemical analysis, and the like, and in particular, to a micro peristaltic pump which is capable of reducing rotational load on its rotor.

BACKGROUND ART

[0002] Conventionally, a peristaltic pump (peristalsis pump) in which a plurality of rollers are rotatably-pivotally supported on a circular rotor, and the outer circumferential surfaces of the respective rollers on the rotor are pressed against a tube, to send a liquid in the tube while rotating the rotor, has been known by the following Patent Document 1 and the like.

CITATION LIST

Patent Literature

[0003] Patent Document 1: Japanese Translation of International Application (Kohyo) No. 2007-523284

SUMMARY OF INVENTION

Technical Problem

[0004] However, this type of conventional peristaltic pump is configured such that a circular rotor which is rotary-driven by a motor rotatably-pivotally supports a plurality of rollers on its outer circumferential portion, and the spindles of the respective rollers are disposed in a direction orthogonal to the rotary shaft of the rotor, and during rotation of the rotor, the outer circumferential surfaces of the respective rollers are pushed against a tube (flexible conduit tube), and the rollers on the rotor are sequentially pressed against the tube to rotationally move, to send a liquid.

[0005] Therefore, there has been the problem that, because the reactive force of loading with which the tube is pressed by the respective rollers is applied perpendicularly to the rotary shaft of the motor, the rotational load of the motor is increased, and particularly in a micro peristaltic pump which is used at the time of flowing micro-fluid such as a culture solution or various types of reagents into a microfluidic flow path, to perform cell culturing, reagent screening, chemical analysis, and the like, the motor grows in size, which makes it difficult to downsize the entire pump.

[0006] Further, in this type of peristaltic pump, usually, it is impossible to easily detach the portion of the tube from a pump casing including the rotor. Therefore, there has been the problem that it is impossible to easily place a microchip having a microfluidic flow path in contact with the roller portions of the rotor, to mount it so as to be detachable at the time of performing cell culturing, reagent screening, chemical analysis, and the like, and it is impossible to simply make a used microchip disposable by each culturing or screening.

[0007] The present invention is to solve the above-described problems, and an object of the present invention is to provide a micro peristaltic pump in which the rotational load of its rotor is reduced, to be able to reduce driving force for rotary-driving, and it is possible to easily attach and detach a microchip in which a flow path is formed.

Solution to Problem

[0008] In order to achieve the above-described object, a micro peristaltic pump of the present invention in which a circular arc shaped flow path is formed as a microfluidic flow path in a sheet-like microfluidic chip, a rotor is pressed against the circular arc shaped flow path in the microfluidic chip, the rotor is rotary-driven by rotary driving means, and the circular arc shaped flow path is caused to make a peristaltic motion by rotation of the rotor, to send a liquid in the flow path, and in the micro peristaltic pump,

[0009] a plurality of free-rotating bodies are held so as to be pressed in contact with the circular arc shaped flow path on the flat surface, to freely rotate on a flat surface perpendicular to a rotary shaft of the rotor,

[0010] the circular arc shaped flow path in the microfluidic chip swells out of a flat surface of the microfluidic chip to be formed into a circular arc shape such that its cross section becomes a substantially mountain shape, and is disposed along a rotational trajectory of the plurality of free-rotating bodies,

[0011] a solid member is attached from a side opposite to the free-rotating bodies, so as to cover the circular arc shaped flow path, and

[0012] at the time of rotary-driving of the rotor by the rotary driving means, the free-rotating bodies on the rotor rotate while pressing their outer circumferential surfaces against the circular arc shaped flow path on the flat surface, to send a liquid in the circular arc shaped flow path.

[0013] In accordance with the micro peristaltic pump of the present invention, because the circular arc shaped flow path in the microfluidic chip swells out of a flat surface of the microfluidic chip to be formed into a circular arc shape such that its cross section becomes a substantially mountain shape, the loading with which the outer circumferential surfaces of the respective free-rotating bodies on the rotor press and crush the circular arc shaped flow path becomes extremely low. That is, as compared with, for example, a case of rotary-driving so as to press and crush a flexible tube having a circular cross section, which is used fora conventional peristaltic pump by a rotor, because the circular arc shaped flow path of a mountain shape in cross section is a mountain shape on the side pressed by the rotor, and is a flat surface on the non-pressed side, it is possible to make the loading for pressing and crushing the circular arc shaped flow path extremely low.

[0014] Moreover, because the loading for crushing the circular arc shaped flow path is applied in parallel to the rotary shaft for driving, the influence of this pressing-loading on the rotational load of the rotary driving means becomes extremely low, which makes it possible to greatly reduce the rotational load of the rotor.

[0015] Moreover, because the pressing-loading with which the outer circumferential surfaces of the free-rotating bodies press the circular arc shaped flow path is kept by the solid member covering the circular arc shaped flow path from the opposite side, even with low pressing-loading, it is possible to press to move the circular arc shaped flow path so as to make a peristaltic motion while efficiently crushing the circular arc shaped flow path.

[0016] Thereby, in the case where a driving motor is used as the rotary driving means for example, the rotational load of the rotor is greatly reduced, which makes it possible to use a compact motor as the driving motor. Therefore, it is possible to further downsize the entire shape of the micro peristaltic pump.

[0017] Here, a rotary shaft of the driving motor is, as the rotary driving means, linked to the rotor in a direction perpendicular to the flat surface of the rotor, the driving motor is attached to a base, the rotor is installed so as to be rotatable in an opening portion provided in the base, and the microfluidic chip is housed in a chip housing portion provided in the base, thereby it is possible to fix the solid member to the base so as to cover the microfluidic chip.

[0018] Further, here, it is preferable that a spring holding portion is fit into an output shaft of the driving motor, a spring is mounted between the spring holding portion and the rotor, and the free-rotating bodies on the rotor are pushed against the circular arc shaped flow path in the microfluidic chip, to be biased by the spring. In accordance with this, with a simple configuration, it is possible to easily mount the circular arc shaped flow path in the microfluidic chip to the free-rotating bodies on the rotor so as to push those against it with appropriate loading.

[0019] Further, here, the present invention may be configured such that a plurality of rollers are rotatably-pivotally supported as the free-rotating bodies so as to be capable of pressing outer circumferential surfaces of the rollers against the circular arc shaped flow path on the flat surface perpendicular to the rotary shaft of the rotor, and be exposed from the flat surface of the rotor.

[0020] Further, here, the present invention may be configured such that a plurality of balls are rotatably-pivotally held as the free-rotating bodies so as to be capable of pressing outer circumferential surfaces of the balls against the circular arc shaped flow path on the flat surface perpendicular to the rotary shaft of the rotor, and be exposed from the flat surface of the rotor.

[0021] Further, here, the circular arc shaped flow path in the microfluidic chip may be formed such that two polymeric elastic sheets are superposed, and the two polymeric elastic sheets are bonded to one another so as to cause one of the polymeric elastic sheets on a side with which the free-rotating bodies come into contact, to bow at a portion of the flow path and swell out to be a mountain shape. In accordance with this, it is possible to highly accurately and easily manufacture a microfluidic chip having a circular arc shaped flow path for a peristaltic pump. Further, because the portion of the polymeric elastic sheet of the circular arc shaped flow path swelling out to be a mountain shape may be formed to be thinner, the pressing and crushing loading onto the circular arc shaped flow path becomes extremely low, which makes it possible to further reduce the rotational load of the rotor.

[0022] Further, here, the present invention may be configured such that the roller on the rotor is formed into a substantially circular truncated cone shape such that circumferential velocities at an inner circumferential side and an outer circumferential side of the roller are the same during rotation, and a spindle of the roller is pivotally supported in a sloped manner such that the outer circumferential surface of the roller is parallel to the surface of the circular arc shaped flow path in the microfluidic chip. In accordance with this, the circumferential velocities at the inner circumferential side and the outer circumferential side of the outer circumferential surface of the roller are made the same, so as to smoothly rotate the roller, which makes it possible to lighten the rotational load thereof.

[0023] Further, here, three free-rotating bodies may be installed at intervals of approximately 120 degrees on the rotor, and the circular arc shaped flow path in the microfluidic chip may be formed within an angular range of approximately 240 degrees. In accordance with this, because the two free-rotating bodies always securely press the circular arc shaped flow path in the microfluidic chip during rotation of the rotor, it is possible to improve the seal performance of the pump.

[0024] Further, here, the present invention may be configured such that the solid member is fixed to the base with a retainer, and when the solid member is detached, the microfluidic chip is exposed so as to be detachable. In accordance with this, after a liquid is made to flow into the circular arc shaped flow path in the microfluidic chip, to perform cell culturing, reagent screening, chemical analysis, and the like, it is possible to easily detach the microfluidic chip, to be disposable by merely detaching the solid member, and it is possible to easily set a new microfluidic chip.

[0025] Further, here, the present invention may be configured such that the ball of the rotor is rotatably housed in a retention hole provided in the flat surface of the rotor, and a part of the ball slightly protrudes from the flat surface of the rotor during rotation, and the outer circumferential surface of the ball is pressed in contact with the surface of the circular arc shaped flow path in the microfluidic chip. In accordance with this, the surface of the circular arc shaped flow path in the microfluidic chip is pressed by the outer circumferential surface of the ball slightly protruding out of the flat surface of the rotor, which makes it possible to satisfactorily perform peristaltic pumping.

[0026] Further, here, as the solid member, a transparent plate-like solid cover body may be attached from a side opposite to the free-rotating bodies, so as to cover the circular arc shaped flow path. in accordance with this, it is possible to observe a state of the circular arc shaped flow path through the transparent cover body from the outside.

Advantageous Effects of Invention

[0027] In accordance with the micro peristaltic pump of the present invention, the rotational load of its rotor is reduced, which makes it possible to reduce driving force of rotary driving means for rotary-driving, it is possible to easily attach and detach the microfluidic chip in which a circular arc shaped flow path is formed, and it is possible to easily use the microfluidic chip to be disposable.

BRIEF DESCRIPTION OF DRAWINGS

[0028] FIGS. **1**(*a*) and **1**(*b*) are perspective views of a micro peristaltic pump according to a first embodiment of the present invention.

[0029] FIG. **2** is a plan view of the micro peristaltic pump.

[0030] FIG. **3** is a cross sectional view taken along the line III-III of FIG. **2**.

[0031] FIG. **4** is a perspective view of the micro peristaltic pump when viewed from below.

[0032] FIG. **5** is a left side view of the micro peristaltic pump.

[0033] FIG. **6** is a bottom view of the micro peristaltic pump.

[0034] FIG. **7** is a plan view in a state in which a cover body and a microfluidic chip are detached.

[0035] FIG. **8** is a cross sectional view taken along the line VIII-VIII of FIG. **7**.

[0036] FIGS. **9**(*a*) and **9**(*b*) are perspective views of a micro microfluidic chip.

[0037] FIG. **10**(*a*) is a plan view of the micro microfluidic chip, and FIG. **10**(*b*) is a side view of the micro microfluidic chip.

[0038] FIG. **11** is a cross sectional view taken along the line XI-XI of FIG. **10**.

[0039] FIGS. **12**(*a*) and **12**(*b*) are perspective views of a rotor.

[0040] FIG. **13** is a plan view of a micro peristaltic pump according to a second embodiment.

[0041] FIG. **14** is a cross sectional view taken along the line IV-IV of FIG. **13**.

[0042] FIG. **15** is a plan view of the same pump in a state in which a cover body and a microfluidic chip are detached.

[0043] FIG. **16** is a cross sectional view taken along the line VI-VI of FIG. **15**.

[0044] FIGS. **17**(*a*) and **17**(*b*) are perspective views of a rotor.

DESCRIPTION OF EMBODIMENTS

[0045] Hereinafter, an embodiment of the present invention will be described with reference to the drawings. FIGS. **1** to **12** show a micro peristaltic pump according to a first embodiment, and this micro peristaltic pump shows an example of a micro peristaltic pump which is configured such that three rollers **15** are pivotally supported on a rotor **10** in order to send a liquid at a micro flow rate in a flow path formed in a microfluidic chip.

[0046] This micro peristaltic pump is, in outline, configured such that a circular arc shaped flow path **21** is formed as a microfluidic flow path in a sheet-like microfluidic chip **20**, and the rollers **15** on the rotor **10** are pressed against the circular arc shaped flow path **21** in the microfluidic chip **20**, the rotor **10** is rotary-driven by a driving motor **4** as rotary driving means, and the circular arc shaped flow path **21** is caused to make a peristaltic motion by rotation of the rotor **10**, to send a liquid in the flow path. As shown in FIGS. **1**, **3**, **4**, and **5**, the driving motor **4** is attached upward to an attaching portion **3** provided on the lower portion of a base **1**.

[0047] The base **1** is configured such that a plate-like portion is formed integrally with the upper portion of the attaching portion **3**, and a substantially square chip housing portion **8** is formed in the plate-like portion in order to function as a holder which houses the microfluidic chip **20**. The attaching portion **3** is provided downward in an extended condition on the lower side of the plate-like portion, and the driving motor **4** is attached upward to the attaching portion **3**. An opening portion is formed so as to open downward in the attaching portion **3**, and an output shaft side of the driving motor **4** is inserted into the opening portion from below, to be fixed. A substantially rectangular chip housing portion **8** is formed, as a sheet-like space, so as to open into the upper side, in the top surface of the plate-like portion of the base **1**. A circular opening portion **9** is formed in the center of the chip housing portion **8**, and an upper portion of the rotor **10** shown in FIG. **12** is inserted into the circular opening portion **9** from below.

[0048] As shown in FIG. **3**, an output shaft **4***a* of the driving motor **4** is provided upward, and a spring holding portion **13** is fixed to the output shaft **4***a* so as to cover it from above. The rotor **10** having a turned-down cup shape (FIG. **12**) is attached onto the spring holding portion **13** from above so as to cover it via a coil spring **14**. The coil spring **14** is mounted between its flange portion **13***a* and the rotor **10** onto the outer circumference of the spring holding portion **13**.

[0049] The rotor **10** is biased upward with respect to the spring holding portion **13**, that is, the output shaft **4***a* of the driving motor **4** by this coil spring **14**. A shaft-like tip end portion **13***b* serving as a rotary shaft of the rotor **10** is provided in an extended condition at the upper portion of the spring holding portion **13**, and the tip end portion **13***b* of the spring holding portion **13** is, as the rotary shaft, fitted into an odd-shaped hole provided in the center of the rotor **10**, to be coupled to the rotor **10**.

[0050] The spring holding portion **13** is coupled to the output shaft **4***a* by fitting the output shaft **4***a* of the driving motor **4** into its central shaft hole, to transmit the rotary-driving force of the driving motor **4** to the rotor **10** via the spring holding portion **13**, thereby the rotor **10** rotates at low speed. As the driving motor **4**, for example, an extremely compact DC motor or stepping motor which has a built-in reduction machine is used, and its output shaft **4***a* is rotary-driven at low speed.

[0051] The coil spring **14** mounted to the spring holding portion **13** is a spring having extremely low spring force, and when the rotor **10** is pushed from above, the rotor **10** is pushed up slightly by the weak spring force from the spring force of the coil spring **14**, to provide upward loading to the rotor **10**.

[0052] In addition, the rotor **10** may be biased upward by using a plate spring in place of the coil spring. Further, a handle-type manual rotating mechanism may be used in place of the driving motor **4**, and in this case, the spring holding portion **13** is to be manually rotary-driven by the handle.

[0053] The rotor **10** is, as shown in FIGS. **8** and **12**, formed such that a circular flat surface portion **11** is provided on the upper portion of a cylindrical portion **12**, and three retention holes **17** are formed in the flat surface portion **11**, and the above-described rollers **15** serving as free-rotating bodies are rotatably-pivotally supported in the respective retention holes **17**. A cover portion **11***a* is attached to the flat surface portion **11** with three attaching screws **19** so as to cover the three rollers **15**, and the respective rollers **15** in the retention holes **17** are rotatably-pivotally supported with spindles **15***a*, to be attached. The three retention holes **17** provided in the flat surface portion **11** are formed at angular intervals of 120 degrees, and the rollers **15** are rotatably-pivotally supported with the spindles **15***a* radially installed in the respective retention holes **17**. Holes with diameters smaller than those of the retention holes **17** are formed in the cover portion **11***a*, and as shown in FIG. **8**, the upper portions of the respective rollers **15** are exposed so as to slightly protrude from these holes.

[0054] Because the three rollers **15** are disposed at angular intervals of approximately 120 degrees on the rotor **10**, and the three rollers **15** at intervals of 120 degrees touch the circular arc shaped flow path **21** formed within an angular range of approximately 240 degrees at the microfluidic chip **20**, to rotate, it is in a state in which the two rollers **15** always press and crush the circular arc shaped flow path **21** during rotation, thereby it is possible to improve the seal performance of the pump.

[0055] The spindles **15***a* of the rollers **15** are radially disposed in planar view as shown in FIG. **7**, and are held in a sloped manner so as to be lower on their outer circumferential portions and higher on their inner circumferential portions as shown in FIG. **8**. Further, the roller **15** is formed into a circular truncated cone shape, and its outer circumferential surface is formed in a sloped manner so as to be thinner on the inner circumferential portion, and thicker on the outer circumferential portion as in FIG. **8**. Thereby, the three rollers **15** are installed so as to keep its upper outer circumferential surface horizontal to the flat surface of the flat surface portion **11** on the flat surface portion **11** of the rotor **10** as shown in FIGS. **3** and **8**.

[0056] In this way, because the rollers **15** radially installed on the flat surface portion **11** are formed into the circular truncated cone shapes, their spindles **15***a* are pivotally supported in a sloped manner and the upper outer circumferential surfaces of the respective rollers **15** are horizontal to the flat surface portion **11**, to slightly protrude, when the three rollers **15** touch the circular arc shaped flow path **21** in the microfluidic chip **20** thereon, to rotate, the circumferential velocities of the inner circumferential portions and the outer circumferential portions are made the same. Further, a radius of the rotational trajectory of these three rollers **15** is set to be the same as the radius of the circular arc shaped flow path **21** in the microfluidic chip **20**.

[0057] On the other hand, as shown in FIG. **3**, the rectangular plate-like chip housing portion **8** is formed in the base **1** into which the rotor **10** is inserted from below, and the microfluidic chip **20** is housed in the chip housing portion **8**. At the upper portion of the base **1**, a transparent plate-like cover body **2** is fixed as a solid member onto the base **1** with fixing screws **2***a* so as to cover the top surface of the microfluidic chip **20** as shown in FIG. **1**. The cover body **2** is formed of a hard transparent synthetic resin, and it is possible to observe a state inside the microfluidic chip **20** through the cover body **2**. In addition, a simple wall surface member (solid member) having a flat part of an opaque solid structure may be used in place of the transparent plate-like cover body **2**. Further, the cover body **2** may be fixed by using a retainer such as fixation clips in place of the fixing screws **2***a* for fixing the cover body **2**.

[0058] The microfluidic chip **20** is, as shown in FIGS. **9**, **10**, and **11**, formed to be rectangular sheet-like from a polymeric elastic body which is soft transparent synthetic resin such as PDMS or silicon resin. A circular concave portion **27** is formed in the center of the main body of the microfluidic chip **20**, and the circular arc shaped flow path **21** is formed in the concave portion **27**. A radius of the circular arc shaped flow path **21** is the same as the radius of the rotational trajectory of the three rollers **15** on the rotor **10**, and a width in the transverse direction of the circular arc shaped flow path **21** is substantially the same as the length width in the axial direction of the roller **15**. The upper portion of the rotor **10** is inserted into the circular concave portion **27** from below, and the rollers **15** rotate while pressing and crushing the circular arc shaped flow path **21**. Tube-like flow paths **24** for flowing micro-fluid are formed up to the rim portions in the microfluidic chip **20** on the both sides of the circular arc shaped flow path **21**, and connecting pipes (stainless steel pipes or the like) **25** for external connection are connected to the end marginal portions of the flow paths **24**.

[0059] As shown in FIG. **11**, the circular arc shaped flow path **21** in the microfluidic chip **20** is formed on the lower side of the flat surface such that its cross section swells out to be a mountain shape downward, and the top surface of the circular arc shaped flow path **21** is a flat shape, thereby it is possible for the rollers **15** to make a rolling motion while satisfactorily crushing the circular arc shaped flow path **21** even with low pressing-loading,

[0060] The microfluidic chip **20** of such a shape may be manufactured such that, at the time of manufacture, for example, by using two polymeric elastic sheets (sheet such as a PDMS) having the same thickness, the lower sheet is superposed onto the upper sheet, and the lower sheet is molded to form the circular concave portion **27**, and the two sheets are further molded and bonded so as to form the circular arc shaped flow path **21** in the concave portion **27**. At that time, the circular arc shaped flow path **21** in the concave portion **27** is manufactured by bonding so as to cause a part of the lower thinner second elastic sheet **23** to bow into a circular arc shape such that the cross section of the flow path swells out to be a mountain shape. Thereby, as shown in FIG. **11**, the portion of the circular arc shaped flow path **21** which will be a pump portion in the microfluidic chip **20** is to be conjugated under the thicker first elastic sheet **22** so as to cause the thinner second elastic sheet **23** to bow into a circular arc shape.

[0061] In addition, a solid member may be used in place of the first elastic sheet **22**, and the second elastic sheet **23** may be conjugated onto the surface of the solid member so as to cause the second elastic sheet **23** to bow into a circular arc shape, thereby forming the circular arc shaped flow path **21**.

[0062] As a concrete example of the microfluidic chip **20**, for example, as shown in FIG. **11**, the first elastic sheet **22** with a thickness of approximately 1.1 mm and the second elastic sheet **23** are superposed and bonded, to manufacture the microfluidic chip **20**. In that case, when a depth of the concave portion **27** of the pump portion is set to approximately 0.8 mm, a thickness of the second elastic sheet **23** of the pump portion is to be approximately 0.3 mm, and the circular arc shaped flow path **21** has a thickness of the outer layer on its swelled-out side of approximately 0.1 mm, and a height width of a space in the circular arc shaped flow path **21** of approximately 0.1 mm.

[0063] In this way, because the circular concave portion **27** is formed on the lower surface of the second elastic sheet **23**, and the circular arc shaped flow path **21** is formed in the concave portion **27**, it is possible to form the circular arc shaped flow path **21** which may be crushed with extremely low pressing-loading by adjusting a depth of the concave portion **27**. That is, because it is possible to adjust the thickness of the outer layer of the circular arc shaped flow path **21** by changing the depth of the concave portion **27**, it is possible to manufacture the circular arc shaped flow path **21** so as to minimize loading at the time of pressing and crushing by the rollers **15** while keeping the durability of the circular arc shaped flow path **21** high.

[0064] In addition, in the above-described embodiment, the driving motor **4** is fixed upward from below the base **1**, the circular arc shaped flow path **21** for a peristaltic pump is provided in the lower surface of the microfluidic chip **20**

housed in the chip housing portion **8** in the base **1**, and the rollers **15** for pressing are pivotally supported on the top surface of the rotor **10** which is rotary-driven by the driving motor **4**. However, the present invention may be configured such that those members are installed in the upside-down positions and forms, and the rollers on the lower surface of the rotor which are installed on the upper side of the circular arc shaped flow path are pressed against the circular arc shaped flow path formed in the top surface of the microfluidic chip **20**, and the rotor is rotary-driven by the driving motor which is installed so as to set its output shaft downward.

[0065] Further, the shape of the microfluidic chip **20** housed in the chip housing portion **8** is rectangular as shown in FIGS. **9**. However, the shape of the microfluidic chip **20** may be square or triangular. Further, the microfluidic chip **20** may be configured such that the respective chip members are formed as chip modules, and as a chip module which uses those chip modules in combination

[0066] Next, the using mode and the operation of the micro peristaltic pump of the above-described configuration will be described. This micro peristaltic pump is used at the time of flowing micro-fluid such as a culture solution or various types of reagents into the flow path of the microfluidic chip **20**, to perform cell culturing, reagent screening, chemical analysis, and the like.

[0067] The microfluidic chip **20** to be used is housed such that the fixing screws **2***a* on the pump top surface are taken off to detach the cover body **2**, and as shown in FIG. **8**, the chip housing portion **8** in the base **1** is opened, and the circular arc shaped flow path **21** in the microfluidic chip **20** is set on the downside at a predetermined position inside the chip housing portion **8**. In this way, because it is possible to simply and easily set the microfluidic chip **20** by merely detaching the cover body **2**, in the case where the microfluidic chip is replaced in each culturing or analysis, it is possible to extremely easily replace the chip, and easily use the microfluidic chip to be disposable.

[0068] When the microfluidic chip **20** is set in the chip housing portion **8**, the cover body **2** is attached to a predetermined position, and the cover body **2** is fixed with the fixing screws **2***a*, the circular arc shaped flow path **21** in the concave portion **27** of the microfluidic chip **20** touches the three rollers **15** on the rotor **10**, to be pressed, and the rotor **10** compresses the coil spring **14** to be slightly pushed down. Although the pressing-loading applied to the rollers **15** at this time is extremely low, because the outer layer of the circular arc shaped flow path **21** swelling out to be a mountain shape is extremely thin, and the non-pressed side of the circular arc shaped flow path **21** is a flat shape, as shown in FIG. **3**, the outer layer of the circular arc shaped flow path **21** touched by the rollers **15** are easily crushed with the low loading.

[0069] In this state, the rotor **10** rotates in a clockwise direction in FIG. **2**, and the three rollers **15** freely rotate while pressing and crushing the circular arc shaped flow path **21**, and the rollers **15** make rolling motions along the circular arc shaped flow path **21**. At this time, the loading with which the rollers **15** press the circular arc shaped flow path **21** is applied in parallel to the output shaft **4***a* of the driving motor **4**. Therefore, a percentage at which the rotational load of the output shaft **4***a* and the spring holding portion **13** is increased by the pressing-loading by the rollers **15** is extremely low.

[0070] Accordingly, it is possible even for the extremely compact and low output driving motor **4** to rotary-drive the rotor **10**, to send a liquid in the flow path **24**. The circular arc shaped flow path **21** makes a peristaltic motion by the rotary-driving of the rotor **10** by the driving motor **4**, and the liquid in the flow path **24** in the microfluidic chip is sent from the left to the right in FIG. **2**.

[0071] In this way, in the above-described micro peristaltic pump, the three rollers **15** are held on the flat surface of the rotor **10** so as to be pressed in contact with the circular arc shaped flow path **21** in the microfluidic chip **20**, to freely rotate on the flap surface perpendicular to the rotary shaft of the rotor **10**, the circular arc shaped flow path **21** is disposed along the rotational trajectory of the respective rollers **15**, and the output shaft **4***a* of the driving motor **4** is coupled to the central portion of the rotor **10** in a direction perpendicular to the flat surface of the rotor **10**.

[0072] At the time of rotary-driving of the rotor **10** by the driving motor **4**, the rollers **15** on the rotor **10** rotate so as to press and crush the flow path of a cross sectional shape swelling out to be a mountain shape to rotate while pressing its outer circumferential surface against the circular arc shaped flow path **21** in the microfluidic chip **20** in parallel to the rotary shaft of the rotor **10**, to send the liquid in the circular arc shaped flow path **21**. Therefore, the rotor **10** is rotary-driven with the extremely low rotary load. Therefore, it is possible to use a low-output and compact motor as the driving motor **4**, and it is possible to considerably downsize the micro peristaltic pump.

[0073] FIGS. **13** to **17** show a micro peristaltic pump according to a second embodiment. This micro peristaltic pump is configured such that balls **45** are rotatably provided in place of the above-described rollers onto the flat surface portion of its rotor **40**. In addition, the portions which are the same as those of the micro peristaltic pump according to the first embodiment are denoted by the same reference numerals, and detailed descriptions thereof will be omitted.

[0074] The rotor **40** of this micro peristaltic pump is, as shown in FIGS. **14** to **17**, formed so as to provide a circular flat surface portion **41** on the upper portion of a cylindrical portion **42**. The spring holding portion **13** is inserted upward into the cylindrical portion **42** via the coil spring **14** from below, and the tip end portion **13***b* of the spring holding portion **13** is, as a rotary shaft, fitted into a shaft hole **46** of the rotor **40**. Three retention holes **47** are formed in the flat surface portion **41** of the rotor **40**, and the balls (stainless steel balls) **45** are rotatably installed in the respective retention holes **47**.

[0075] A cover portion **41***a* is attached to the top surface of the flat surface portion **41** with three attaching screws **19** so as to cover the balls **45**. The three balls **45** are rotatably held in the retention holes **47**. In planar view of the rotor **40**, the three balls **45** are radially disposed at intervals of 120 degrees centering on the rotary shaft of the rotor **40** (the tip end portion **13***b* of the spring holding portion **13**). Holes with smaller diameters are formed at the positions corresponding to the three retention holes **47** in the cover portion **41***a* covering the upper portion of the rotor **40**, and as shown in FIG. **14**, the upper portions of the respective balls **45** are exposed so as to slightly protrude from these holes.

[0076] Further, because the three retention holes **47** are formed in the same way in the cover portion **41***a* of the flat surface portion **41** of the rotor **40**, as shown in FIG. **14**, the balls **45** housed in the respective retention holes **47** slightly protrude their upper outer circumferential surfaces from the top of the flat surface portion **41** of the rotor **40**, and the upper outer circumferential surfaces of the three balls **45** are located in parallel to the flat surface of the flat surface portion **41**.

[0077] In this way, the three balls **45** installed radially on the flat surface portion **41** are disposed at angular intervals of 120 degrees, and their upper outer circumferential surfaces slightly protrude in parallel to the flat surface portion **41**. Further, a radius of the rotational trajectory of these three balls **45** during rotation of the rotor **40** is the same as the radius of the circular arc shaped flow path **21** in the microfluidic chip **20**. Therefore, in a state in which the upper portion of the rotor **40** is inserted into the opening portion **9** of the base **1**, and the microfluidic chip **20** is housed in the chip housing portion **8** of the base **1**, as shown in FIG. **14**, the upper outer circumferential surfaces of the three balls **45** on the top surface of the rotor **40** touch the circular arc shaped flow path **21** in the microfluidic chip **20**, to be capable of crushing the circular arc shaped flow path **21** with extremely low pressing-loading.

[0078] In the micro peristaltic pump of the above-described configuration, at the time of use, in the same way in the above description, the fixing screws **2***a* on the pump top surface are taken off to detach the cover body **2**, the chip housing portion **8** in the base **1** is opened, and the microfluidic chip **20** is housed so as to set the circular arc shaped flow path **21** on the downside at a predetermined position inside the chip housing portion **8**.

[0079] When the microfluidic chip **20** is set in the chip housing portion **8**, the cover body **2** is attached to a predetermined position, and the cover body **2** is fixed with the fixing screws **2***a*, as shown in FIG. **14**, the circular arc shaped flow path **21** in the concave portion **27** of the microfluidic chip **20** touches the upper outer circumferential portions of the three balls **45** on the rotor **40**, to be pressed, and the rotor **40** compresses the coil spring **14** to be slightly pushed down. Although the pressing-loading applied to the balls **45** at this time is extremely low, because the outer layer of the circular arc shaped flow path **21** swelling out to be a mountain shape is extremely thin, and the non-pressed side of the circular arc shaped flow path **21** is a flat shape, as shown in FIG. **14**, the outer layer of the circular arc shaped flow path **21** touched by the balls **45** is easily crushed with low pressing-loading.

[0080] In this state, the rotor **40** rotates in a clockwise direction in FIG. **13**, and the three balls **45** freely rotate while pressing and crushing the circular arc shaped flow path **21**, and the balls **45** make rolling motion along the circular arc shaped flow path **21**. At this time, the loading with which the balls **45** press the circular arc shaped flow path **21** is applied in parallel to the output shaft **4***a* of the driving motor **4**. Therefore, a percentage at which the rotational load of the output shaft **4***a* and the spring holding portion **13** is increased by the pressing-loading of the balls **45** is extremely low.

[0081] Accordingly, it is possible even for the extremely compact and low output driving motor **4** to rotary-drive the rotor **40**, to send a liquid in the flow path **24**. The circular arc shaped flow path **21** makes a peristaltic motion by the rotary-driving of the rotor **40** by the driving motor **4**, and the liquid in the flow path **24** in the microfluidic chip is sent from the left to the right in FIG. **13**.

[0082] In this way, in the above-described micro peristaltic pump, the three balls **45** are held on the flat surface of the rotor **40** so as to be pressed in contact with the circular arc shaped flow path **21** in the microfluidic chip **20**, to freely rotate on the flap surface perpendicular to the rotary shaft of the rotor **40**, the circular arc shaped flow path **21** is disposed along the rotational trajectory of the respective balls **45**, and the output shaft **4***a* of the driving motor **4** is coupled to the central portion of the rotor **40** in a direction perpendicular to the flat surface of the rotor **40**.

[0083] At the time of rotary-driving of the rotor **40** by the driving motor **4**, the balls **45** on the rotor **40** rotate so as to press and crush the flow path of a cross sectional shape swelling out to be a mountain shape to rotate while pressing its outer circumferential surface against the circular arc shaped flow path **21** in the microfluidic chip **20** in parallel to the rotary shaft of the rotor **40**, to send the liquid in the circular arc shaped flow path **21**. Therefore, the rotor **40** is rotary-driven with the extremely low rotary load. Therefore, it is possible to use a low-output and compact motor as the driving motor **4**, and considerably downsize the micro peristaltic pump.

REFERENCE SIGNS LIST

[0084] **1** Base
[0085] **2** Cover body
[0086] **3** Attaching portion
[0087] **4** Driving motor
[0088] **4***a* Output shaft
[0089] **5** Roller
[0090] **8** Chip housing portion
[0091] **9** Opening portion
[0092] **10** Rotor
[0093] **11** Flat surface portion
[0094] **11***a* Cover portion
[0095] **12** Cylindrical portion
[0096] **13** Spring holding portion
[0097] **13***a* Flange portion
[0098] **13***b* Tip end portion
[0099] **15** Rollers
[0100] **15***a* Spindle
[0101] **17** Retention hole
[0102] **20** Microfluidic chip
[0103] **21** Circular arc shaped flow path
[0104] **22** First elastic sheet
[0105] **23** Second elastic sheet
[0106] **24** Flow path
[0107] **25** Connecting pipe
[0108] **27** Concave portion
[0109] **40** Rotor
[0110] **41** Flat surface portion
[0111] **41***a* Cover portion
[0112] **42** Cylindrical portion
[0113] **45** Balls
[0114] **46** Shaft hole
[0115] **47** Retention holes

1. A micro peristaltic pump comprising:
a base having a chip housing portion;
a sheet-like microfluidic chip housed in the chip housing portion, and having a circular arc shaped flow path which swells out of a flat surface in a substantially mountain shape at its cross section, to be formed into a circular arc shape:

a rotor installed in the base so as to be able to he rotary-driven opposite the flat surface of the microfluidic chip a plurality of free-rotating bodies held so as to be pressed in contact with the circular arc shaped flow path to he freely rotatable on a flat surface perpendicular to a rotary shaft of the rotor:

a rotary driving means which is attached to an attaching portion of the base, and rotatory-drives the rotor: and

a solid member fixed to the base so as to cover the microfluidic chip, wherein

the circular arc shaped flow path is formed such that its radius is the same as a radius of the rotational trajectory of the free-rotating bodies,

the rotor is installed so as to be rotatable in an opening portion provided near the chip housing portion of the base,

the sheet-like microfluidic chi is house n the chip housing portion with the circular arc shaped flow path faced toward the rotor,

the solid member is fixed to the base so as to cover the microfluidic chi) from a side opposite to the free-rotating bodies on the rotor and so as to be detachable by a retainer, and

the microfluidic chip is exposed so as to be detachable when the solid member is detached.

2. (canceled)

3. The micro peristaltic pump according to claim **1**, wherein a spring holding portion v tit into an output shaft of the rotary driving means, a spring is mounted between the spring holding portion and the rotor, and the free-rotating bodies on the rotor are pressed against the circular arc shaped flow path in the microfluidic chip, to be biased by the spring.

4. The micro peristaltic pump according to claim **1**, wherein a plurality of rollers are disposed as the free-rotating bodies so as to locate outer circumferential surfaces of the rollers on the flat surface perpendicular to the rot-my shaft of the rotor, and to slightly protrude from the flat surface of the rotor to be capable of pressing the outer circumferential surfaces against the circular arc shaped flow path, and the rollers are rotatably-pivotally supported via spindles radially installed on the rotor.

5. The micro peristaltic pump according to Claim I, wherein a plurality of balls are rotatable housed in retention holes provided in the flat surface of the rotor, and a part of the ball slightly protrudes from the flat surface of the rotor, and the outer circumferential surface of the ball is pressed in contact with the circular arc shaped flow path in the microfluidic chip.

6. The micro peristaltic pump according to claim **1**, wherein the circular arc shaped flow path in the microfluidic chip is formed such that two polymeric elastic sheets are superposed, and the two polymeric elastic sheets are bonded to one another in a state in which one of the polymeric elastic sheets on a side with which the free-rotating bodies come into contact is caused to bow at a circular arc shaped portion of the flow path, so as to swell out to be a mountain shape.

7. The micro peristaltic pump according to claim **4**, wherein the roller on the rotor is formed into a substantially circular truncated cone shape such that circumferential velocities at an inner circumferential side and an outer circumferential side of the roller are the same during rotation, and a spindle of the roller is pivotally supported in a sloped manner such that the outer circumferential surface of the roller is parallel to the surface of the circular arc shaped flow path in the microfluidic chip.

8. The micro peristaltic pump according, to claim **1**, wherein three free-rotating bodies are installed at intervals of approximately 120 degrees on the rotor, and the circular arc shaped flow path in the microfluidic chip is formed into a circular arc shape within an angular range of approximately 240 degrees.

9. (canceled)

10. (canceled)

11. The micro peristaltic pump according to claim **1**, wherein, as the solid member, a transparent plate-like solid cover body is fixed to the base by a retainer so as to be detachable from a side opposite to the free-rotating bodies, so as to cover the circular arc shaped flow path.

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