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

(11) EP 2 706 235 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.03.2014 Bulletin 2014/11

(21) Application number: **13004383.9**

(22) Date of filing: **09.09.2013**

(51) Int Cl.:
F04B 43/08 *(2006.01)* ***F04B 43/113*** *(2006.01)*
F04B 45/02 *(2006.01)*

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

(30) Priority: **10.09.2012 JP 2012198289**

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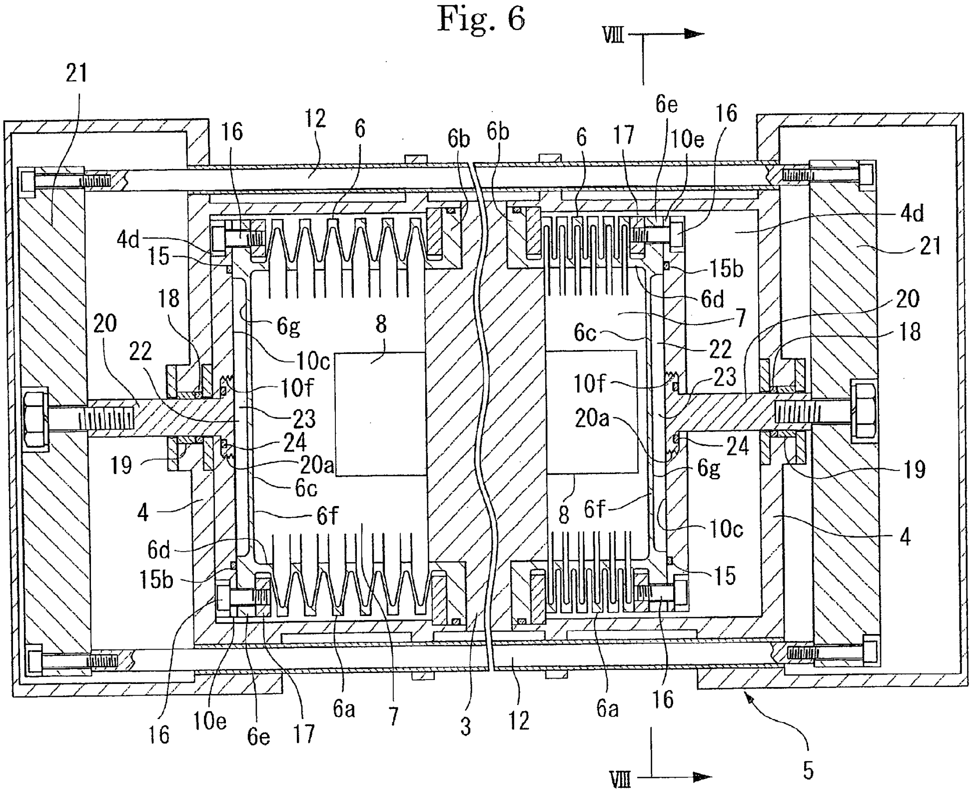
(54) **Bellows pump**

(57) A bellows pump including in its pump case (5) a pair of plastic bellows (6) that expand and contract to alternatively execute an output stroke that sends fluid out of pump chambers (7) defined by the bellows and a suction stroke that supplies fluid to the pump chambers. Metal actuation plates (10) are provided in the pump case so as to be movable in the axial direction. Said actuation plates are fixedly connected to the bottom walls (6a) of the bellows in peripheral portions thereof. Sealed spaces (22) are provided between said opposed end faces. Said sealed spaces, which are sealed by O-rings (15), are filled with an incompressible fluid, such as oil.

Fig. 6



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Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a bellows pump used for feeding and circulating chemicals (e.g., chemicals and the like employed in fabrication processes of semiconductors, liquid crystals, and organic EL (electroluminescence) elements) and slurries containing solid components and other slurry components (e.g., polishing fluid used in CMP (chemical mechanical polishing) machines (semiconductor wafer surface-polishing machines, in which CMP methods are used)).

2. Description of the Related Art

[0002] Of the bellows pumps of the type described above, one that is well-known includes a plastic, bottom-closed cylindrical bellows with its aperture portions connected to a pump case so as to be caused to expand and contract in the axial direction. With the repeated extension and contract, this bellows pump is adapted to alternate between an output stroke, during which fluid is sent from a pump chamber formed by the surrounding bellows to an output passage through an output check valve, and a suction stroke, during which the fluid is supplied from a suction passage to the pump chamber through a suction check valve (see, e.g., FIG. 1 of Japanese Patent Application Laid-Open (Kokai) No. 2002-174180 or FIG. 2 of Japanese Patent Application Laid-Open (Kokai) No. 2012-122380)

[0003] In such a bellows pump, during the output stroke, the pump chamber is compressed, and/or during the suction stroke, the pump chamber is decompressed (negatively pressurized), which creates a risk that the bottom wall of the plastic bellow could be subject to deformation, such as buckling and the like. For example, during the output stroke, in which the bellows is actuated to contract, there is a risk that the bottom wall of the bellows may be pushed out and buckle in a convex shape under the pressure of the pump chamber. On the other hand, conversely, during the suction stroke, in which the bellow is actuated to expand, the pump chamber is negatively pressurized, thereby creating a risk that the bottom wall of the bellows may be sucked in and buckle in a concave shape. Alternatively, when an air-cylinder mechanism (see paragraph 0024 below) is used as a means for actuating the bellows to expand and contract, there is a risk that the bottom walls of the plastic bellows could be subject to deformation such as buckling and the like under the action of the pressurized air supplied to the intake/discharge spaces. For example, on the output stroke, during which the bellows is actuated to contract, the pressure in the intake/discharge space becomes lower than the pressure in the pump chamber, thereby creating a risk that the bottom wall of the bellows may be pushed in by the pressurized air supplied to the intake/discharge space and may buckle in a concave shape into the pump chamber. Thus, when the bottom walls of the bellows undergoes deformation in this manner, the bellows pump is unable to achieve the proper pump functionality because of the unstable bellows-pump flow rates (output-fluid volumes) and circulating-fluid volumes, generation of random fluctuations, and the like.

[0004] In such a bellows pump, the pump chamber is compressed on the output stroke and/or on the suction stroke the pump chamber is decompressed (negatively pressurized), creating a risk that the bottom walls of the plastic bellows could be subject to deformation, such as buckling and the like. For example, during the output stroke, in which the bellows is actuated to contract, there is a risk that the bottom wall of the bellows may be pushed out and buckle in a convex shape under the pressure of the pump chamber, and, conversely, during the suction stroke, in which the bellows is actuated to expand, the pump chamber is negatively pressurized, thereby creating a risk that the bottom wall of the bellows may be sucked in and buckle in a concave shape. Thus, when the bottom walls of the bellows undergoes deformation in this manner, the bellows pump cannot achieve proper pump functionality because of substantial changes in pump-chamber volume, unstable bellows-pump flow rates (output-fluid volumes) and circulating-fluid volumes, generation of random fluctuations, and the like.

[0005] As disclosed in FIG. 1 of Japanese Patent Application Laid-Open (Kokai) No. 2002-174180 and in FIG. 2 of Japanese Patent Application Laid-Open (Kokai) No. 2012-122380, in bellows pumps, actuation plates provided so as to be movable in the axial direction are attached to the bottom walls of the bellows, so that these actuation plates can work as a means for guiding the axial-direction motion (contractile actuation) of the bellows or as a means for synchronizing the contractile actuations of the two bellows in a double-acting bellows pump. Accordingly, using actuation plates that are made of metal can allow the bottom walls of the bellows, which can be easily deformed because they are made of plastic, to be reinforced.

[0006] However, as seen from FIG. 1 of Japanese Patent Application Laid-Open (Kokai) No. 2002-174180 and in FIG. 2 of Japanese Patent Application Laid-Open (Kokai) No. 2012-122380, the bottom walls of the bellows are attached to the actuation plates only in the peripheral portions thereof, which is why the above-described deformation induced by the pump-chamber pressure fluctuations during the output stroke and/or suction stroke cannot be prevented in the central portion of the bottom wall of the bellows, that is, in the portion not attached to the actuation plate. For example, when the pump chamber is negatively pressurized during the suction stroke, there is a risk that the central portion of the bottom wall of the bellows, which is not secured to an actuation plate, is subject to buckling deformation (and can be deformed in a concave shape) into the pump chamber by the action of the suction force produced by the negative pressure.

BRIEF SUMMARY OF THE INVENTION

[0007] Accordingly, in the light of the above-described circumstances, the object of the present invention is to provide a bellows pump that is capable of reliably preventing deformation, such as buckling, of the bottom wall of a bellows due to pressure fluctuations in the pump chamber during the output stroke and/or suction stroke and that can achieve proper pump functionality, providing stable flow rates (output-fluid volumes) and circulating-fluid volumes and eliminating random fluctuations.

[0008] In order to accomplish the above-described object, the present invention provides, in particular, the configuration (1) or the configuration (2) below for a bellows pump that is adapted, by causing plastic bottom-closed cylindrical bellows with its aperture portions connected to the pump case to expand and contract in the axial direction, to alternate between the output stroke that sends fluid from a pump chamber, defined by the surrounding bellows, to an output passage through an output check valve and the suction stroke that supplies fluid supplied from a suction passage to the pump chamber through a suction check valve.

(1) A metal actuation plate supported by the pump case so as to be movable in the axial direction and the bottom wall of the bellows are fixedly connected in their peripheral portions, and opposed end faces of the actuation plate and the central area of the bottom wall of the bellows, that is, a fluid-contact portion that comes into contact with the fluid in the pump chamber, are provided in a close contact with each other, with such a close-contact portion being sealed by an annular sealing member.

(2) A metal actuation plate supported by the pump case so as to be movable in the axial direction and the bottom wall of the bellows are fixedly connected in their peripheral portions, and a sealed space is formed by an annular sealing member provided between the opposed end faces of the actuation plate and the central area of the bottom wall of the bellows, that is, a fluid-contact portion that comes into contact with the fluid in the pump chamber, with such a sealed space being filled with an incompressible fluid.

[0009] In a preferred embodiment of the bellows pump of the present invention, the annular sealing member is an O-ring, and this said O-ring is held in engagement with an O-ring groove formed in the actuation plate or in the bottom wall of the bellows.

[0010] In the bellows pump of the present invention configured as described in (1) above, the fluid-contact portion, that is, the central area of the bottom wall of the bellows, is in a close contact with the actuation plate in a sealed state, and as a result, the fluid-contact portion and the actuation plate are always held in a state of inseparable close contact regardless of any pressure fluctuations occurring in the pump chamber. In addition, in the bellows pump of the present invention configured as described in (2) above, the sealed space formed between the actuation plate and the fluid-contact portion, that is, the central area of the bottom wall of the bellows, is filled with incompressible fluid, and as a result, the sealed space filled with such incompressible fluid functions as a type of rigid body, and as a result, regardless of any pressure fluctuations in the pump chamber, the fluid-contact portion, as well as the sealed space acting as a rigid body and the actuation plate, are held in such a state that they are in a mutually inseparable close contact.

[0011] As seen from the above, in either one of configurations (1) and (2), the fluid-contact portion of the bottom wall of the bellows is reinforced by the metal actuation plate against the pressure of the pump chamber, and deformation of the fluid-contact portion of the bottom wall of the bellows caused by the pressure fluctuations in the pump chamber can be reliably prevented. Alternatively, when the means used in the bellows pump of the present invention for actuating the bellows to expand and contract is an air-cylinder mechanism (see paragraph 0024 below), the pressurized air supplied to the intake/discharge space for actuating the bellows to expand and contract is prevented from getting between the bottom wall of the plastic bellows and the metal actuation plate, thereby reliably preventing deformation of the bottom wall of the plastic bellows that is caused by the pressurized air supplied to the intake/discharge space. For this reason, the volume of the pump chamber during the suction stroke and during the output stroke does not vary due to the deformation of the bottom wall of the bellows while the flow rate (output-fluid volume) and circulating-fluid volume produced by the pump remains stable, and the pump can achieve proper pump functionality. In addition, the bottom wall of the bellows itself does not have to possess a strength sufficient to prevent deformations induced by pump-chamber pressure fluctuations; accordingly, in the case of configuration (2), as well as in the case of configuration (1), the bottom wall of the bellows can be made as thin as possible, and this can ensure that the weight of the bellows is significantly reduced.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012]

FIG. 1 is a cross-sectional side view illustrating one example of the bellows pump according to the present invention.

FIG. 2 is a cross-sectional front view of the main portion taken along the line II-II in FIG. 1.

FIG. 3 is a cross-sectional side view illustrating a modification of the bellows pump according to the present invention.

FIG. 4 is an enlarged view of the main portion of FIG. 3.

FIG. 5 is a cross-sectional front view taken along the line V-V in FIG. 3.

FIG. 6 is a cross-sectional side view illustrating another modification of the bellows pump according to the present invention.

FIG. 7 is an enlarged view of the main portion of FIG. 6.

FIG. 8 is a cross-sectional front view taken along the line VIII-VIII in FIG. 6.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The modes for carrying out the present invention will be described specifically with reference to the drawings.

[0014] FIG. 1 is a cross-sectional side view showing an example of the bellows pump according to the present invention, and FIG. 2 is a cross-sectional front view of the main portion taken along the line II-II in FIG. 1. It should be noted that in the description below the phrase "left and right" is intended to mean "left and right in FIG. 1".

[0015] The bellows pump shown in FIG. 1 (hereinafter referred to as "first pump) is a horizontal double-acting bellows pump used for feeding and circulating fluid (e.g., chemicals and the like employed in the fabrication processes of semiconductors, liquid crystals, organic EL elements, and the like). The bellows pump is comprised of a pump case 5 comprised of a pump head 3, having an output passage 1 and a suction passage 2 formed therein, and a pair of left and right cylinder cases 4, 4 provided on both sides thereof. The bellows pump further includes: a pair of left and right bellows 6, 6 respectively disposed inside of each one of the cylinder cases 4 so as to make expansion and contraction (thus being expandable and contractable) in the axial direction (horizontal direction) of the pump head 3; a pair of left and right pump chambers 7, 7 defined by being surrounded by the respective bellows 6; a pair of left and right output check valves 8, 8 mounted to the pump head 3 in a protruding fashion into each one of the pump chambers 7; and a pair of left and right suction check valves 9, 9 provided in the pump head 3 so as to protrude into each one of the pump chambers 7. This bellows pump is adapted, by alternatingly actuating the two or a pair of bellows 6, 6 to expand and contract, to simultaneously carry out an output stroke that sends fluid out of one of the pump chambers 7 to the output passage 1 through the output check valve 8, and a suction stroke that supplies fluid from the suction passage 2 into the other pump chamber 7 through the suction check valve 9. It should be noted that, with the exception of their left-and right-hand symmetrical structure, the two cylinder cases 4, 4, two bellows 6, 6, two pump chambers 7, 7, two output check valves 8, 8, and two suction check valves 9, 9 making up the bellows pump have identical structures to each other.

[0016] The pump head 3 is shaped like a disk that has therein an output passage 1 connected to a fluid-feed line and a suction passage 2 connected to a fluid-supply line, and, as shown in FIG. 1, an upstream end of the output passage 1 and a downstream end of the suction passage 2 are open on the left and right sides thereof.

[0017] As seen from FIG. 1 to FIG. 4, each cylinder case 4 is a bottom-closed cylindrical casing mounted to the pump head 3. The pump case 5 is thus made of the pump head 3 and the two cylinder cases 4, 4; and the space inside the pump case 5 is split into two in a side-to-side direction with the pump head 3 in between.

[0018] As shown in FIG. 1 and FIG. 2, each bellows 6 is a bottom-closed cylinder made of plastic, and its peripheral wall 6a has a bellows configuration with a zigzag cross-section. By being expanded and contracted in the axial direction (side-to-side horizontal direction), it enlarges and reduces the volume of the pump chamber 7. The open-end portion 6b of each one of the bellows 6 is intimately secured or connected to the pump head 3, with the space inside the bellows 6 defining the pump chamber 7 closed by the pump head 3. Though it depends on the consistency and other characteristics of the fluid handled by the pump, fluororesins (such as polytetrafluoroethylene (PTFE) and perfluoroalkoxy (PFA) fluororesins and the like are preferably used as the materials to make the bellows 6. In the shown example, PTFE is employed. The bottom wall 6c of each one of the bellows 6 is a disk-like part that has a constant thickness (thickness in the axial direction) and an outer diameter that matches that of the peripheral wall 6a (the maximum diameter thereof), and the end portion 6d of a trough part of the peripheral wall 6a is coupled to the bottom wall 6c.

[0019] As shown in FIG. 1, a disk-shaped actuation plate 10 made of metal (such as stainless steel) is fixedly attached to the bottom wall 6c of each bellows 6. Each actuation plate 10 is comprised of a thin-walled disk-shaped main portion 10a and a thick-walled annular coupling portion 10b formed in the peripheral portion thereof, and this actuation plate 10 is fixedly attached to the bottom wall 6c of the bellows 6 in such a manner that the main portion 10a of the actuation plate 10 is abutted in a close contact to the bottom wall 6c of the bellows 6 and the bottom wall 6c is fitted into the annular coupling portion 10b. In other words, the thickness of the bottom wall 6c of the bellows 6 is set to be identical to or somewhat greater than the thickness (the thickness in the axial direction) (or depth) of the annular coupling portion 10b of the actuation plate 10, and the peripheral portion 6e (which is of the bottom wall 6c and located more outboard of the portion used for coupling to the end portion 6d of the trough part of the peripheral wall 6a) of the bottom wall 6c of the bellows 6 is clamped between the main portion 10a of the actuation plate 10 and a mounting plate 11 mounted to the coupling portion 10b of the actuation plate 10. Accordingly, as shown in FIG. 1, the bottom wall 6c of the bellows 6 and actuation plate 10 are connected and integrated in the peripheral portion thereof such that the bottom wall 6c of the bellows is in a close contact with the main portion 10a of the actuation plate 10.

[0020] By way of connecting the actuation plates 10, 10 and the bellows 6, 6 together with a plurality of (e.g., four) coupling rods 12, the two bellows 6, 6 are actuated in synchronism to expand and contract in opposite directions. In another words, as illustrated in FIG. 1, the two bellows 6, 6 are operatively connected to the actuation plates 10 such that when one of the bellows 6 is in its most contracted state, the other bellows 6 is in its most expanded state, and when one of the bellows 6 is actuated to contract, the other bellows 6 is actuated to expand in unison therewith.

[0021] The plurality of coupling rods 12 connect the coupling portions 10b, 10b, that are the peripheral portions of the actuation plates 10, 10, at locations spaced apart at regular intervals in the circumferential direction; and by way of thus coupling the two actuation plates 10, 10 with these coupling rods 12, the attachment of the bottom wall 6c of each bellows 6 to each actuation plate 10 is obtained. More specifically, the coupling rods 12, which are provided inside the cylinder cases 4, 4, are held in the pump case 5 so as to be movable in the axial direction by means of O-rings 13; and with nut members 14 threadably mounted to and engaged with the distal threaded portions 12a that pass through the coupling portions 10b of the actuation plates 10 and the mounting plates 11, the two actuation plates 10, 10 are coupled together while fixedly connecting the bottom wall 6c of each bellows 6 to each of the actuation plates 10. The thickness of the main portion 10a of the actuation plate 10 is set to have a strength sufficient to prevent the deformation under the action of the pressure in the pump chamber 7, at least during the suction stroke and output stroke; and it is preferable that the main portion 10a of the actuation plate 10 be as thin as possible as long as such strength to prevent deformation can be ensured.

[0022] The means used for actuating the bellows 6 to expand and contract include, generally, piston-cylinder mechanisms, crank mechanisms, air-cylinder mechanisms, and the like; and in the shown embodiment, an air-cylinder mechanism is employed. More specifically, the actuating means is adapted to actuate the bellows 6 to expand and contract in the axial direction by supplying and discharging pressurized air 4c through intake/discharge ports 4a formed in the bottom walls of the cylinder cases 4 to/from intake/discharge spaces 4b formed between the cylinder cases 4 and the actuation plates 10 and bellows 6. The intake and discharge of air through the two intake/discharge ports 4a, 4a is carried out synchronously in an alternating manner, such that when pressurized air 4c is supplied to the intake/discharge space 4b through one of the intake/discharge ports 4a, air is simultaneously discharged from the other intake/discharge port 4a, and as a result of which the contractile actuation of the two bellows 6, 6, that is, the contractile actuation of the two pump chambers 7, 7, is carried out in synchronism in opposite directions. In other words, a suction stroke (or an output stroke) in one of the pump chambers 7 is carried out in synchronism with an output stroke (or a suction stroke) in the other pump chamber 7, and the switching between an output stroke (a stroke in which fluid is sent from the pump chamber 7 to the output passage 1 through the output check valve 8) and a suction stroke (a stroke in which fluid is supplied from the suction passage 2 to the pump chamber 7 through the suction check valve 9) in the two pump chambers 7, 7 is carried out simultaneously. FIG. 1 illustrates the final state of the suction stroke in the left-side pump chamber 7 and the output stroke in the right-side pump chamber 7.

[0023] As shown in FIG. 1, each output check valve 8 is configured such that on the suction stroke, during which the bellows 6 is actuated to expand (the volume of the pump chamber 7 changes so as to expand), the valve plug 8b is held in the closed position under the urging force of the spring 8a, while on the output stroke, during which the bellows 6 is actuated to contract (the volume of the pump chamber 7 changes so as to contract), the valve plug 8b is displaced to the open position against the urging force of the spring 8a by the high pressure in the pump chamber 7. Furthermore, as shown in FIG. 1, each suction check valve 9 is configured such that on the output stroke, during which the bellows 6 is actuated to contract, the valve plug 9b is held in the closed position by back pressure (the pressure of the pump chamber 7) and by the urging force of the spring 9a, while on the suction stroke, during which the bellows 6 is actuated to expand, the valve plug 9b is displaced to the open position against the urging force of the spring 9a as a result of a pressure drop in the pump chamber 7.

[0024] Of the components making the bellows pump above, those coming into contact with fluid are formed by the materials suited to the characteristics of the fluid to be handled, etc. In the shown example, those components coming into contact with fluid are made of fluororesin-base plastics, such as polytetrafluoroethylene, that have superior corrosion resistance and resistance to chemicals.

[0025] As seen from the above, in the first pump, the opposed end faces 10c, 6g of the actuation plate 10 and the central area of the bottom wall 6c of the bellows 6 are in a close contact with each other as shown in FIG. 1. In other words, the actuation plate 10 and the fluid-contact portion 6f (the portion of the bottom wall 6c located more inboard of the portion used for coupling to the end portion 6d of the trough part of the peripheral wall 6a) that comes into contact with the fluid in the pump chamber 7 make a close contact relationship with each other. In addition, the close-contact portions 10c, 6g are sealed with an annular sealing member 15. In the shown example, the annular sealing member 15 is an O-ring made of an incompressible elastic material (such as fluororubber), and this O-ring 15 is held in engagement within an O-ring groove 15a formed in the bottom wall 6c of the bellows.

[0026] Accordingly, even if the pressure in the pump chamber 7 varies following the contractile actuation (contractile changes in pump-chamber volume) of the bellows 6, the bottom wall 6c of the bellows is not deformed, and such problems as described in the section of the Related Art above do not arise, and proper pump functionality is achieved.

[0027] More specifically, in the pump chamber 7 (e.g., the left-side pump chamber in FIG. 1) that is in a suction stroke, the suction stroke, during which the bellows 6 is actuated to expand, reduces the pressure in the pump chamber 7 and makes it negative, thereby creating the risk that the central area, that is, the fluid-contact portion 6f, of the bottom wall 6c of the bellows having only its peripheral portion 6e connected to the actuation plate 10 may be sucked into the negatively pressurized pump chamber 7 and buckle in a concave shape. However, the fluid-contact portion 6f of the bottom wall 6c of the bellows is in a close contact with the main portion 10a of the actuation plate 10 and, at the same time, the close-contact portions 6g and 10c are sealed by the O-ring 15; accordingly, it does not separate from the main portion 10a of the actuation plate 10 under the action of the above-described suction force produced by the negative pressure. In other words, the fluid-contact portion 6f of the bottom wall 6c of the bellows is held in a state of inseparable close contact with the main portion 10a of the actuation plate 10. Therefore, the suction force that acts on the fluid-contact portion 6f of the bottom wall 6c of the bellows is received by the main portion 10a of the metal actuation plate 10, and thus there is no risk that the fluid-contact portion 6f deforms during the suction stroke.

[0028] On the other hand, in the other pump chamber 7 (e.g., the right side pump chamber in FIG. 1) that is in an output stroke, the output stroke, during which the bellows 6 is actuated to contract, increases pressure in the pump chamber 7 and brings the chamber under high pressure, thereby creating the risk that the central area, that is, the fluid-contact portion 6f, of the bottom wall 6c of the bellows having only its peripheral portion 6e connected to the actuation plate 10, may be subject to buckling deformation in a convex shape under the action of the pushing force produced by the pressure in the pump chamber 7. However, the fluid-contact portion 6f of the bottom wall 6c of the bellows is in a close contact with the main portion 10a of the actuation plate 10; accordingly, the above-described pushing force acting on the fluid-contact portion 6f is received by the main portion 10a of the metal actuation plate 10, and thus there is no risk that the fluid-contact portion 6f deforms during the output stroke.

[0029] As seen from the above, in the first pump, the bottom walls 6c of the bellows are prevented from being deformed by the pressure of the pump chambers 7 during the suction stroke or the output stroke. As a result, problems such as unstable flow rates (output-fluid volumes) and circulating-fluid volumes, and generation of random fluctuations due to substantial changes in pump-chamber volume do not arise, and proper pump functionality is achieved.

[0030] Furthermore, in the first pump, the fluid-contact portion 6f of the bottom wall 6c of each of the bellows is reinforced by the actuation plate 10 as described above. Accordingly, the bottom walls 6c of the bellows do not need to be so thick as to possess enough strength to withstand the pressure in the pump chambers 7, and the bottom walls 6c can be those that have a thickness that is necessary and sufficient for being connected to the actuation plates 10 via the mounting plates 11, distal threaded portions 12a of the coupling rods 12, and nut members 14. Accordingly, in comparison with the conventional bellows pump described in the section of the Related Art above, the bottom walls 6c of the bellows can be made as thin as possible, and thus the weight of the bellows 6 can be reduced.

[0031] Incidentally, the configuration of the bellows pump according to the present invention is not limited to the one described above and can be suitably improved and modified without deviating from the principles of the present invention.

[0032] In the configuration of the first pump shown in FIG. 1, the two actuation plates 10, 10 are coupled via the coupling rods 12 which are movably supported by the pump case 5 in the axial direction, so that each actuation plate 10 is supported by the pump case 5 via the coupling rods 12 so as to be movable in the axial direction; and further, by way of coupling each actuation plate 10 to the coupling rods 12, the actuation plate 10 is connected to the bottom wall 6c of the bellows 6 with the mounting plate 11 in between. However, in the present invention, as a modification, the means used for supporting the actuation plates 10 in the pump case 5 and the means used for attaching the actuation plates 10 to the bottom wall 6c of the bellows can be, as shown in FIG. 3 to FIG. 5, separate and independent.

[0033] FIG. 3 is a cross-sectional side view illustrating a modification of the bellows pump of the present invention, and FIG. 4 is an enlarged view of the main portion of FIG. 3, and further FIG. 5 is a cross-sectional front view taken along the line V-V in FIG. 3. With the exception of the following features, the bellows pump illustrated in FIG. 3 (hereinafter referred to as "second pump") is a horizontal double-acting bellows pump of the same configuration as the first pump. For the components that are identical to those of the first pump, the same reference numbers are in FIG. 3 to FIG. 5 as those in FIG. 1 and FIG. 2, and detailed descriptions thereof are omitted.

[0034] As shown in FIG. 3 and FIG. 4, in the second pump, the bottom wall 6c of each bellows 6 and the actuation plate 10 are shaped as disks of the same diameter with a fixed thickness (thickness in the axial direction). The bottom wall 6c of the bellows and the actuation plate 10 are connected in a state of close contact by threadably engaging and fastening a plurality of connecting bolts 16 passing through their peripheral portions 6e, 10e to a mounting plate 17. In the shown example, as seen from

FIG. 5, the peripheral portion 6e of the bottom wall 6c of the bellows 6 and the peripheral portion 10e of the actuation plate 10 are connected by eight (8) connecting bolts 16 arranged circumferentially at evenly spaced intervals. In addition, the thickness of the actuation plate 10 is set to possess a strength sufficient to prevent deformation under the action of the pressure in the pump chamber 7, at least during the suction stroke and output stroke, and it is preferable that the actuation plate 10 be as thin as possible as long as such strength to prevent deformation can be ensured.

[0035] An actuation shaft 20, which passes through and is supported by the bottom wall of the cylinder case 4 so as to be movable in the axial direction through the medium of an O-ring 18 and a bearing ring 19, is integrally formed in the central area of each one of the actuation plates 10. A disk-shaped coupling plate 21 is fixedly secured to the end of each actuation shaft 20 outside the cylinder case 4. The two coupling plates 21, 21 are disposed outside the cylinder cases 4, 4 and coupled together by an appropriate number of coupling rods 12, 12 (in the shown example two (2)) that are provided in the pump case 5 so as to be movable in the axial direction. Accordingly, because the two actuation plates 10, 10 are coupled together via the actuating shafts 20, 20, the coupling plates 21, 21, and the coupling rods 12, 12, the two bellows 6, 6 are actuated to in synchronism expand and contract in opposite directions. In other words, as illustrated in FIG. 3, the two bellows 6, 6 are operatively coupled such that when one of the bellows 6 is in its most contracted state, the other bellows 6 is in its most expanded state, and when one of the bellows 6 is actuated to contract, the other bellows 6 is actuated to expand in unison therewith.

[0036] In the same manner as in the first pump, the actuating means for actuating the bellows 6 to expand and contract is adapted to actuate the bellows 6 to expand and contract in the axial direction by supplying and discharging pressurized air through intake/discharge ports (not shown) formed in the bottom walls of the cylinder cases 4 to/from the intake/discharge spaces 4d formed between the cylinder cases 4, actuation plates 10, and the bellows 6. The intake and discharge of the air to/from the two intake/discharge spaces 4d, 4d is carried out synchronously in an alternating manner, and, as a result, the contractile actuation of the two bellows 6, 6, that is, the contractile actuation of the two pump chambers 7, 7, is carried out synchronously in opposite directions. In other words, a suction stroke (or an output stroke) in one of the pump chambers 7 is carried out in synchronism with an output stroke (or a suction stroke) in the other pump chamber 7, and the switching between the output stroke (a stroke in which fluid is sent from the pump chamber 7 to the output passage 1 through the output check valve 8) and the suction stroke (a stroke in which fluid is supplied from the suction passage 2 to the pump chamber 7 through the suction check valve 9) in the two pump chambers 7, 7 is carried out simultaneously. FIG. 3 illustrates the final state of the suction stroke in the left-side pump chamber 7 and the output stroke in the right-side pump chamber 7.

[0037] As seen from the above, in this second pump, in the same manner as in the first pump, as seen from FIG. 3 and FIG. 4, the opposed end faces 10c, 6g of the actuation plate 10 and the central area of the bottom wall 6c of the bellows 6 are in a close contact with each other. In other words, the actuation plate 10 and the fluid-contact portion 6f (the portion of the bottom wall 6c located more inboard of the portion used for being connected to the end portion 6d of the trough part of the peripheral wall 6a) that comes into contact with the fluid in the pump chamber 7 are in a closely contact relationship with each other. In addition, the close-contact portions 10c, 6g are sealed with the annular sealing member 15. In the shown example, in the same manner as in the first pump, the annular sealing member 15 is an O-ring made of an incompressible elastic material (such as fluororubber), and this O-ring 15 is held in engagement within the O-ring groove 15a formed in the actuation plate 10. The central portion of the fluid-contact portion 6f of the bottom wall 6c of each one of the bellows 6 is formed with a round positioning protrusion 6h that closely fits into a round recessed portion 10d formed in the central portion of each one of the actuation plates 10, and thus the bottom walls 6c of the bellows and the actuation plates 10 are abutted each other in a concentric manner.

[0038] Accordingly, in the second pump as well, in the same manner as in the first pump, even if the pressure in the pump chambers 7 varies following the contractile actuation (contractile changes in pump-chamber volume) of the bellows 6, the bottom walls 6c of the bellows do not deform since the bottom walls 6c of the bellows are reinforced by the metal actuation plates 10, and such problems as described in the section of the Related Art above do not arise, and thus proper pump functionality is achieved. In the second pump, since the coupling rods 12, 12 are disposed outside the cylinder cases 4, 4, the volume of the intake/discharge spaces 4d are smaller compared to the intake/discharge spaces 4b in the first pump, and it is thus possible to reduce the volume of the pressurized air used to actuate the bellows 6, 6 to expand and contract.

[0039] In addition, in the second pump, the fluid-contacts 6f of the bottom walls 6c of the bellows are reinforced by the actuation plates 10. Accordingly, the bottom walls 6c of the bellows do not need to be so thick as to possess enough strength to withstand the pressure in the pump chambers 7, and what is required for the bottom wall of the bellows 6 is that it has a thickness that is necessary and sufficient to be attached to the actuation plates 10 by the connecting bolts 16 and the mounting plates 17. In view of the above, in the same manner as in the first pump, the bottom walls 6c of the bellows in the second pump can be made as thin as possible in comparison with the conventional bellows pump described in the section of the Related Art above, and it is possible to reduce the weight of the bellows 6.

[0040] In addition, although the first and second pump are adapted to bring the opposed end faces 10c, 6g of the actuation plates 10 and the fluid-contact portions 6f of the bottom walls 6c of the bellows 6 into a close contact with each other while sealing these close-contact faces 10c, 6g with the annular sealing members (the O-ring) 15, sealed spaces 22 as shown in FIG. 6 to FIG. 8 that are sealed by the annular sealing members 15 can be formed between the opposed end faces 6g, 10c, so that the sealed spaces 22 are filled with an incompressible fluid 23.

[0041] More specifically, FIG. 6 is a cross-sectional side view of another modification of the bellows pump according to the present invention, FIG. 7 is an enlarged view of the main portion of FIG. 6, and FIG. 8 is a cross-sectional front view taken along the line VIII-VIII in FIG. 6. With the exception of the following features, the bellows pump illustrated in FIG. 6 (hereinafter referred to as "third pump") is a horizontal double-acting bellows pump of the same configuration as the second pump. The reference symbols identical to those of FIG. 3 and FIG. 5 are assigned to the components identical to those of the second pump in FIG. 6 to FIG. 8, and detailed descriptions thereof are omitted.

[0042] As seen from FIG. 6 and FIG. 7, in the third pump, a round recessed portion is formed in the outer surface of the fluid-contact portion 6f of the bottom wall 6c of each one of the bellows 6. In other words, the thickness (thickness in the axial direction) of the fluid-contact portion 6f, that is, the central area of the bottom wall 6c of the bellows, is made thinner than the thickness of the peripheral portion 6e of the bottom wall 6c, and a space 22 corresponding to the above-described round recessed portion is formed between the opposed end faces 6g, 10c of the fluid-contact portion 6f and the actuation plate 10. This space 22 is made into a sealed space by way of using the annular sealing member 15 provided between the actuation plate 10 and the peripheral portion 6e of the bottom wall 6c of the bellows 6. In the same manner as in the second pump, the annular sealing member 15 is an O-ring, and this O-ring 15 is held in engagement within the O-ring groove 15b formed in the actuation plate 10.

[0043] The sealed space 22 is completely filled with incompressible fluid 23 (e.g., oil or another fluid).

[0044] Furthermore, as shown in FIG. 6 and FIG. 7, in this third pump, the actuating shafts 20 are the separate elements from the actuation plates 10, and each actuation plate 10 and each actuation shaft 20 are integrally coupled by threadably fastening the threaded portion 20a of the distal end of the actuation shaft 20 to the internally threaded recessed portion 10f formed in the actuation plate 10 while sealing the threaded connection portion with an O-ring 24.

[0045] With the above structure of the third pump, in the pump chamber 7 which is under the suction stroke (e.g., the left-side pump chamber illustrated in FIG. 6), the bellows 6 is actuated to expand, thus reducing the pressure in the pump chamber 7 and making it negative, thereby creating a risk that the central area, that is, the fluid-contact portion 6f, of the bottom wall 6c of the bellows 6 having only its peripheral portion 6e attached to the actuation plate 10 by two or more connecting bolts 16 may be sucked into the negatively pressurized pump chamber 7 and subject to buckling deformation in a concave shape. However, the sealed space 22 formed between the opposed end faces 10c, 6g of the actuation plate 10 and the fluid-contact portion 6f of the bottom wall 6c of the bellows is completely filled with the incompressible fluid 23, such as oil and the like; accordingly, the sealed space 22 filled with this incompressible fluid 23 can function as a type of rigid body. As a result, even when the pump chamber 7 is negatively pressurized, the fluid-contact portion 6f of the bottom wall 6c of the bellows, the sealed space 22 that is filled with the incompressible fluid 23 acting as a rigid body, and the actuation plate 10 are all held in a state of inseparable mutual contact. Accordingly, the fluid-contact portion 6f of the bottom wall 6c of the bellows 6 does not deform into a concave shape by being pulled into the pump chamber 7, and thus the volume of the pump chamber 7 does not change on the suction stroke.

[0046] On the other hand, in another pump chamber 7 which is under the output stroke (e.g., the right pump chamber illustrated in FIG. 6), the bellows 6 is actuated to contract, thus increasing the pressure in the pump chamber 7 and bringing the chamber under high pressure, thereby creating a risk that the central area, that is, the fluid-contact portion 6f, of the bottom wall 6c of the bellows 6 with its peripheral portion 6e only connected to the actuation plate 10, may deform in a convex shape into the sealed space 22 under the action of the pushing force produced by the pressure in the pump chamber 7. However, the sealed space 22, as described above, can function as a type of rigid body filled with the incompressible fluid 23, and the pushing force produced by the pressure in the pump chamber 7 that acts on the fluid-contact portion 6f of the bottom wall 6c of the bellows is received by the metal actuation plate 10 through the medium of the sealed space 22 acting as a rigid body. Consequently, there is no risk that the fluid-contact portion 6f may deform during the output stroke, and the volume of the pump chamber 7 does not change on the output stroke.

[0047] As seen from the above, as in the first and second pumps, the bottom walls 6c of the bellows of the third pump are not deformed by the pressure fluctuations in the pump chambers 7 during the suction stroke or the output stroke. Accordingly, problems such as unstable flow rates (output-fluid volumes) and circulating-fluid volumes, and generation of random fluctuations due to substantial changes in pump-chamber volume do not arise, and proper pump functionality is achieved.

[0048] In addition, in the third pump, as described above, the fluid-contact portions 6f of the bottom walls 6c of the bellows are reinforced by the actuation plates

10 through the medium of the sealed spaces 22. Accordingly, the bottom walls 6c of the bellows may have a thickness that is necessary and sufficient for attaching its peripheral portions 6e to the actuation plates 10 by means of the connecting bolts 16 and mounting plates 17, and the thickness of the fluid-contact portions 6f, that is, the central areas, can be reduced even more compared to the first and second pumps, and further the weight of the bellows 6 can be reduced significantly.

[0049] It should be noted that in addition to applications involving double-acting bellows pumps such as the first through third pumps, the present invention is suitably applicable to single-acting bellows pumps.

Claims

1. A bellows pump adapted to cause a plastic bottom-closed cylindrical bellows with aperture portions thereof connected to a pump case to expand and contract in an axial direction thereof, thereby alternating between an output stroke in which fluid is sent from a pump chamber defined by the bellows to an output passage through an output check valve and a suction stroke in which fluid is supplied from a suction passage to the pump chamber through a suction check valve, wherein:

    metal actuation plates are provided in the pump case so as to be movable in an axial direction thereof,
    the actuation plates and bottom walls of the bellows are fixedly connected in peripheral portions thereof,
    opposed end faces of the actuation plates and the fluid-contact portions are set in a close contact with each other, the fluid-contact portions being central areas of the bottom walls of the bellows and coming into contact with fluid in the pump chamber, and
    said close-contact portions are sealed with annular sealing members.

2. A bellows pump adapted to cause a plastic bottom-closed cylindrical bellows with aperture portions thereof connected to a pump case to expand and contract in an axial direction thereof, thereby alternating between an output stroke in which fluid is sent from a pump chamber defined by the bellows to an output passage through an output check valve and a suction stroke in which fluid is supplied from a suction passage to the pump chamber through a suction check valve, wherein:

    metal actuation plates are provided in the pump case so as to be movable in an axial direction thereof,
    the actuation plates and bottom walls of the bellows are fixedly connected in peripheral portions thereof,
    sealed spaces are provided between opposed end faces of the actuation plates and central areas of the bottom walls of the bellows, said spaces being sealed by annular sealing members, and
    said sealed spaces are filled with incompressible fluid.

3. The bellows pump according to Claim 1, wherein the annular sealing members O-rings, and said O-rings are held in engagement with O-ring grooves formed in either one of the bottom walls of the bellows and the actuation plates.

4. The bellows pump according to Claim 2, wherein the annular sealing members O-rings, and said O-rings are held in engagement with O-ring grooves formed in either one of the bottom walls of the bellows and the actuation plates.

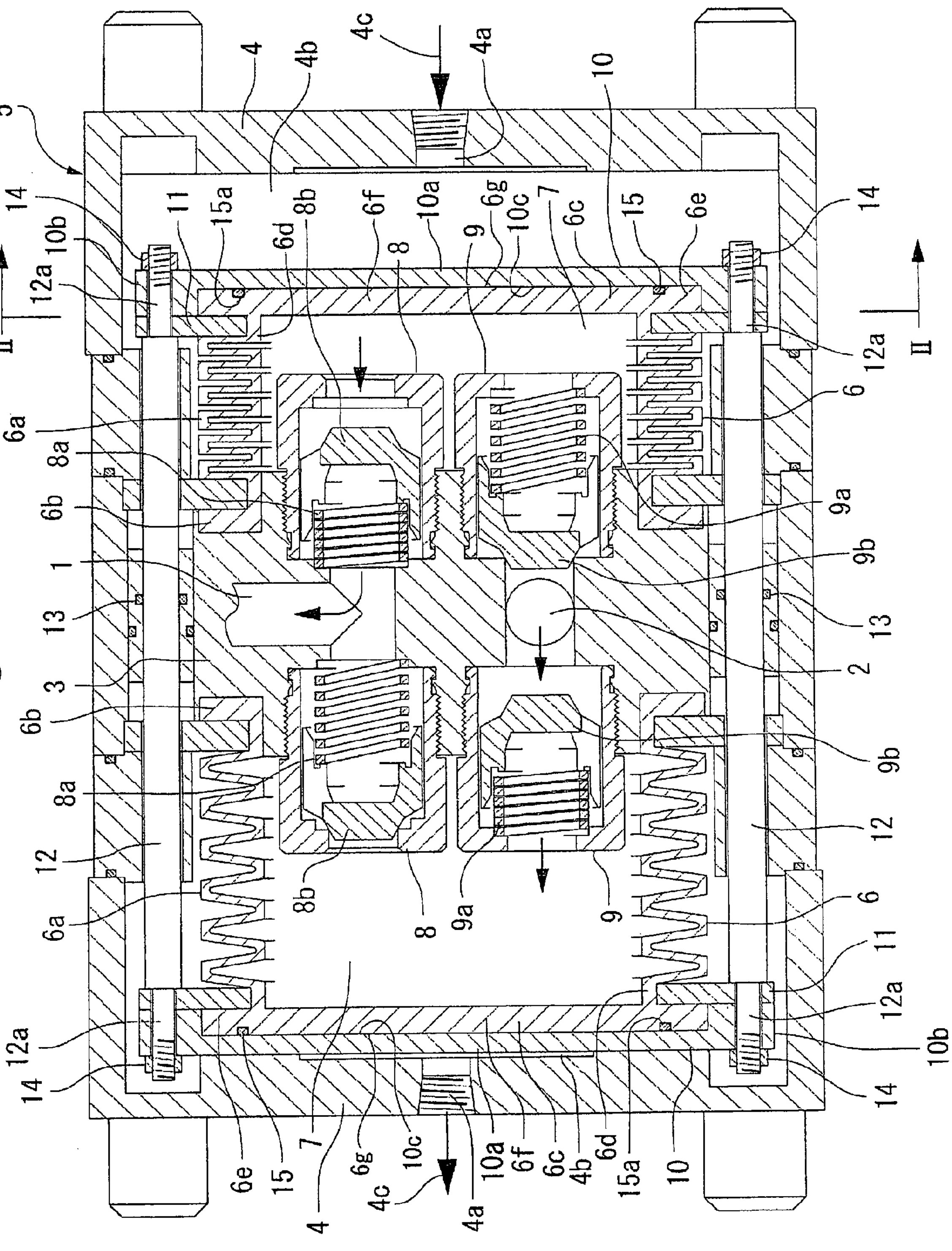

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Fig. 1

Fig. 2

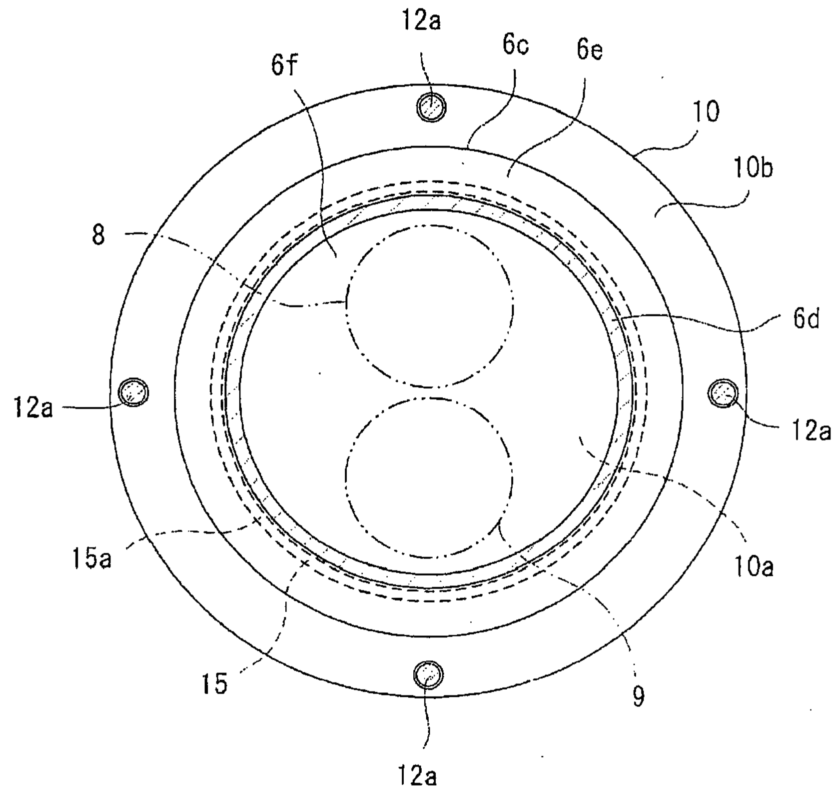

Fig. 3

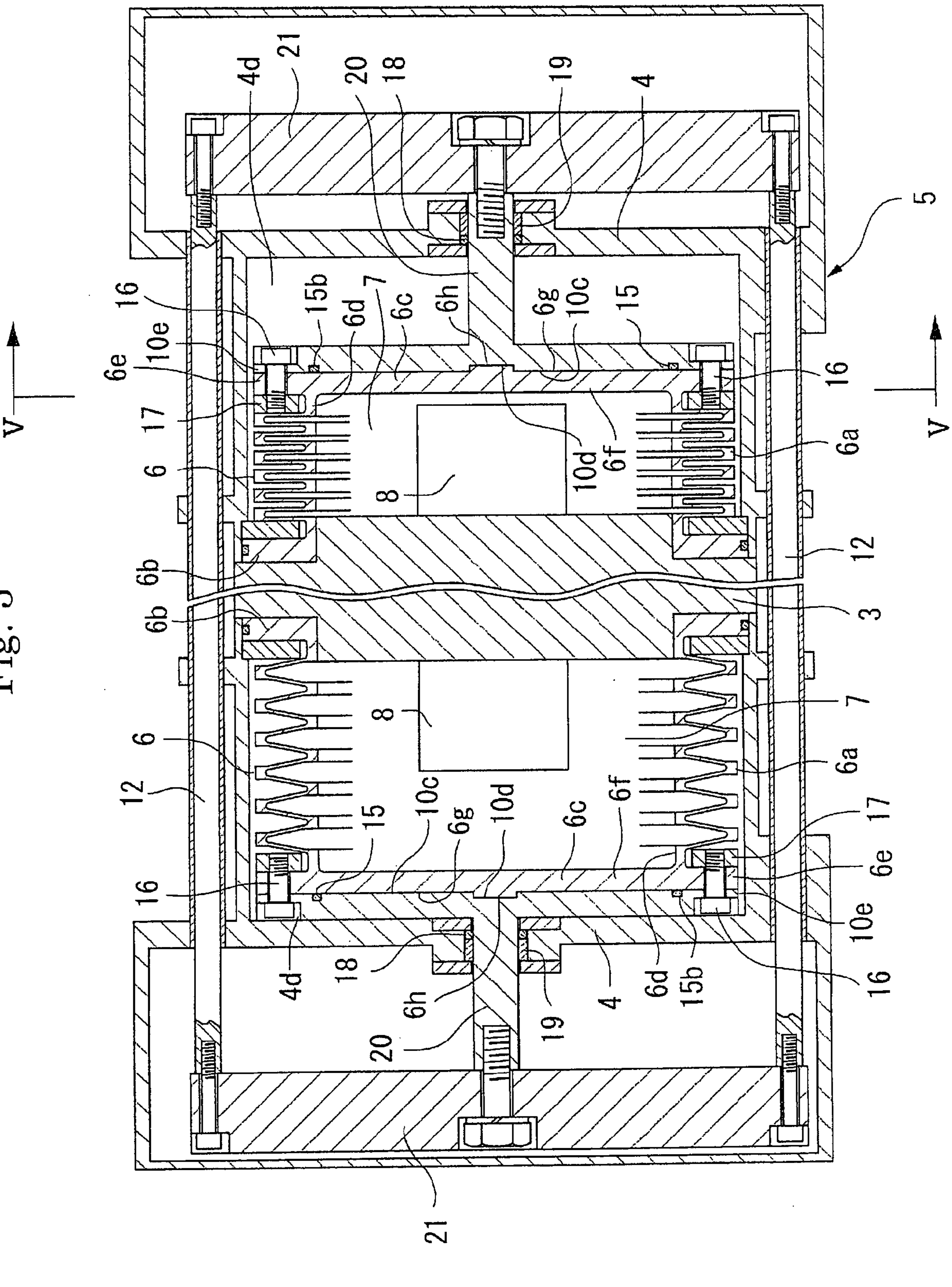
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Fig. 4

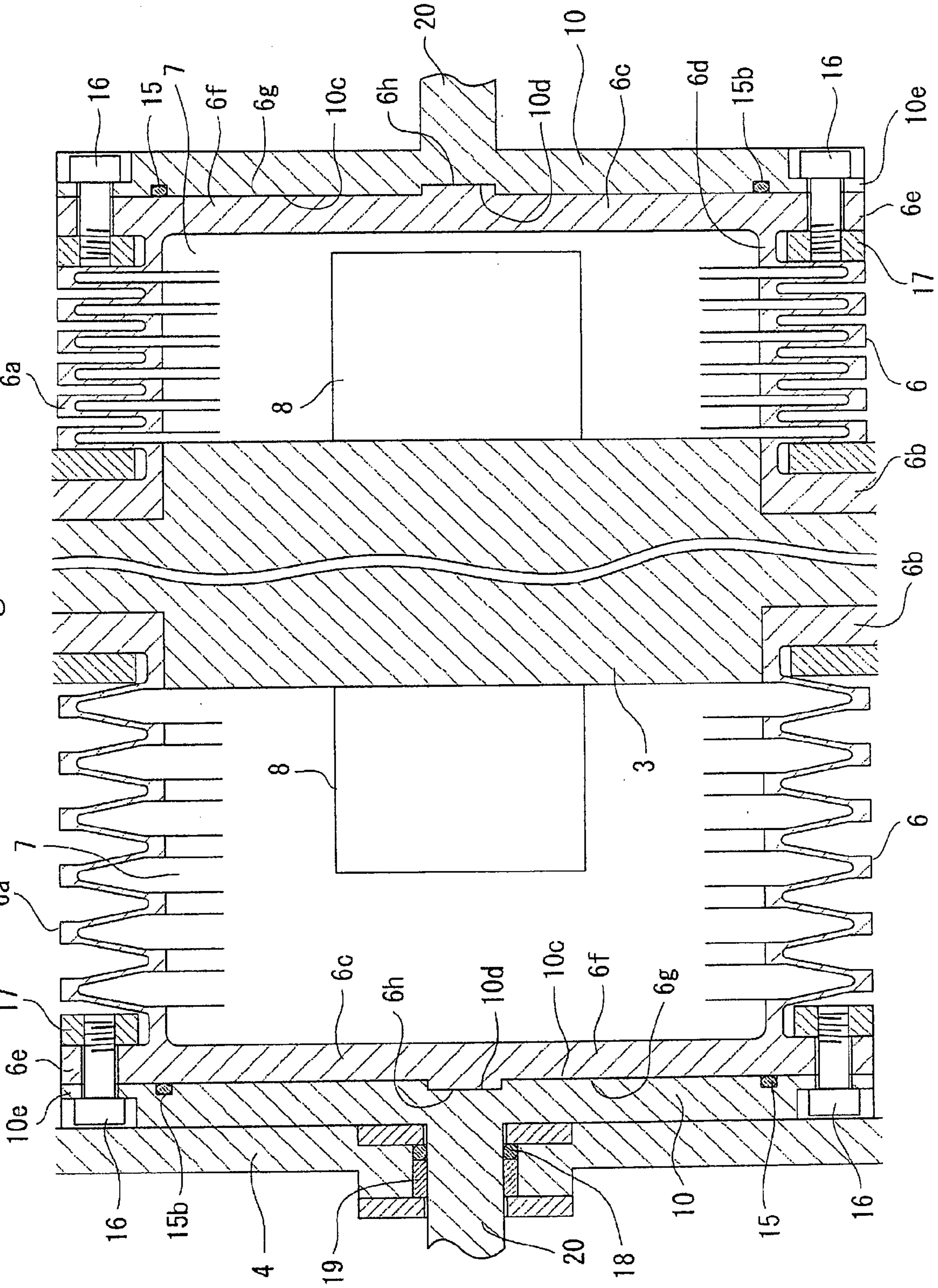
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Fig. 5

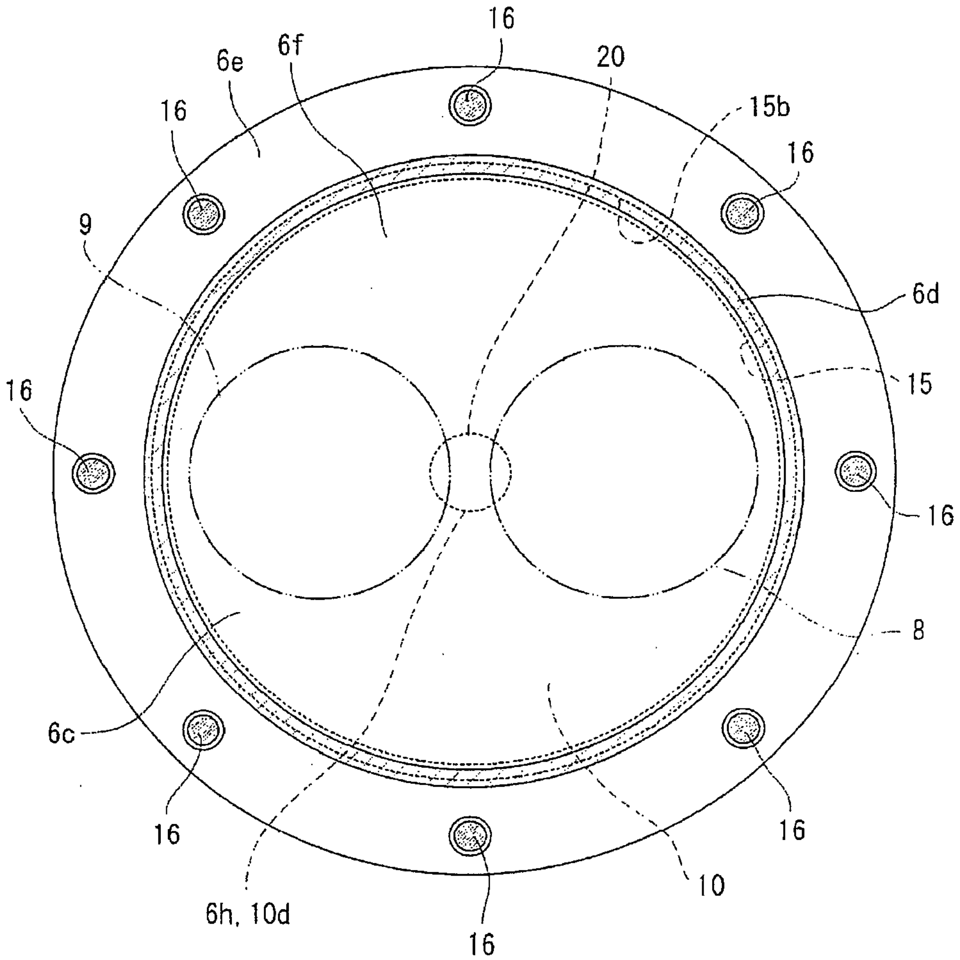

Fig. 6

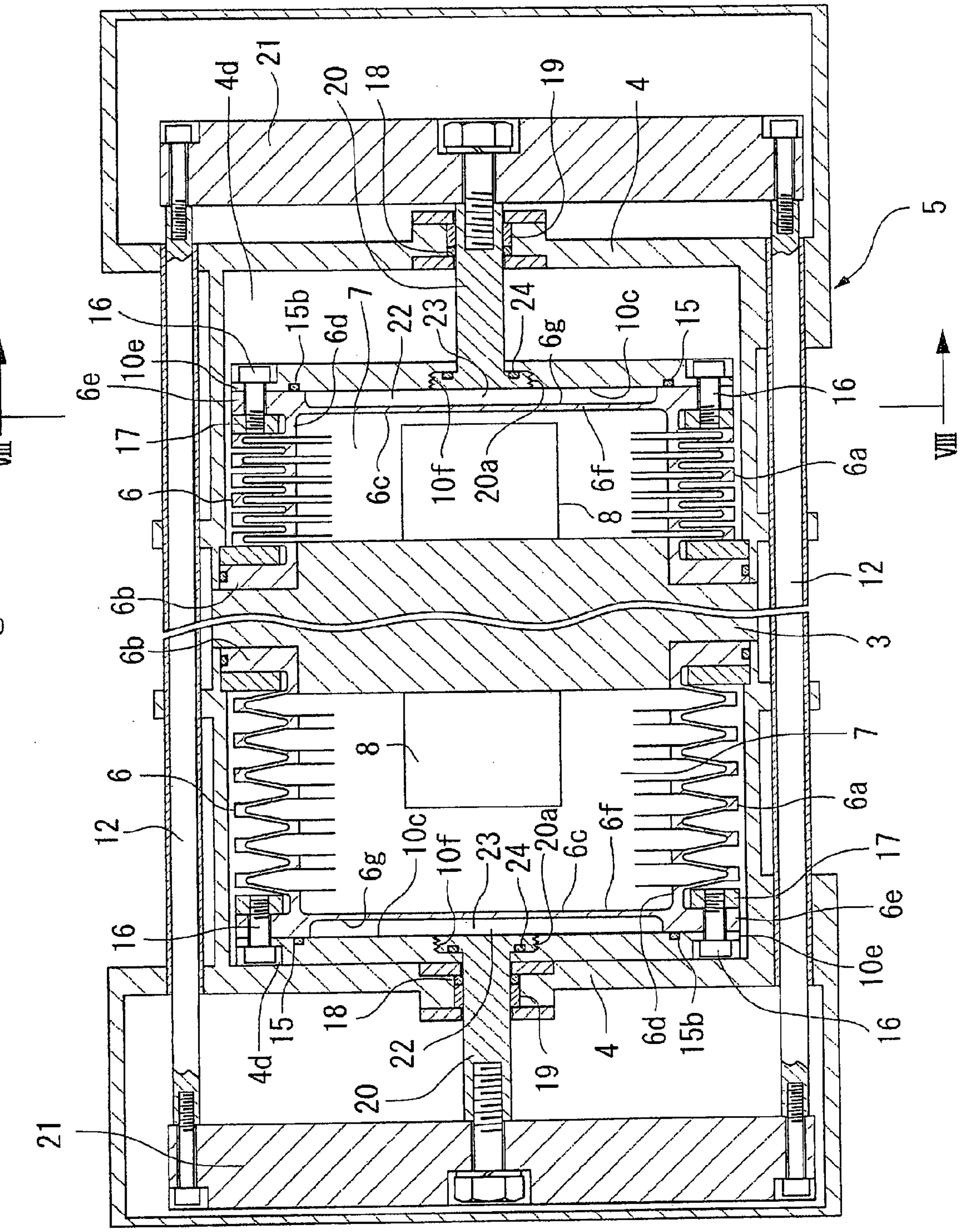
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Fig. 7

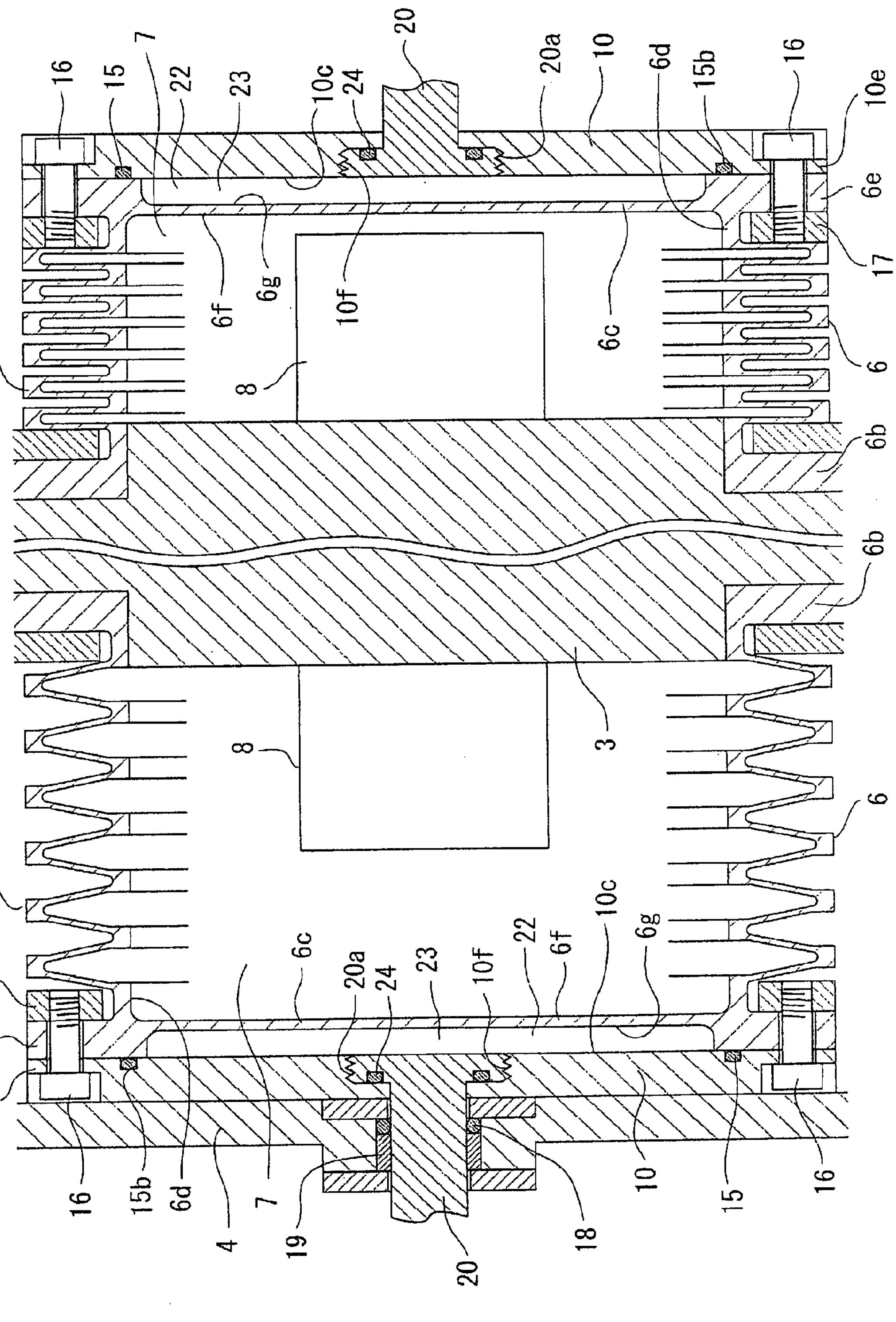
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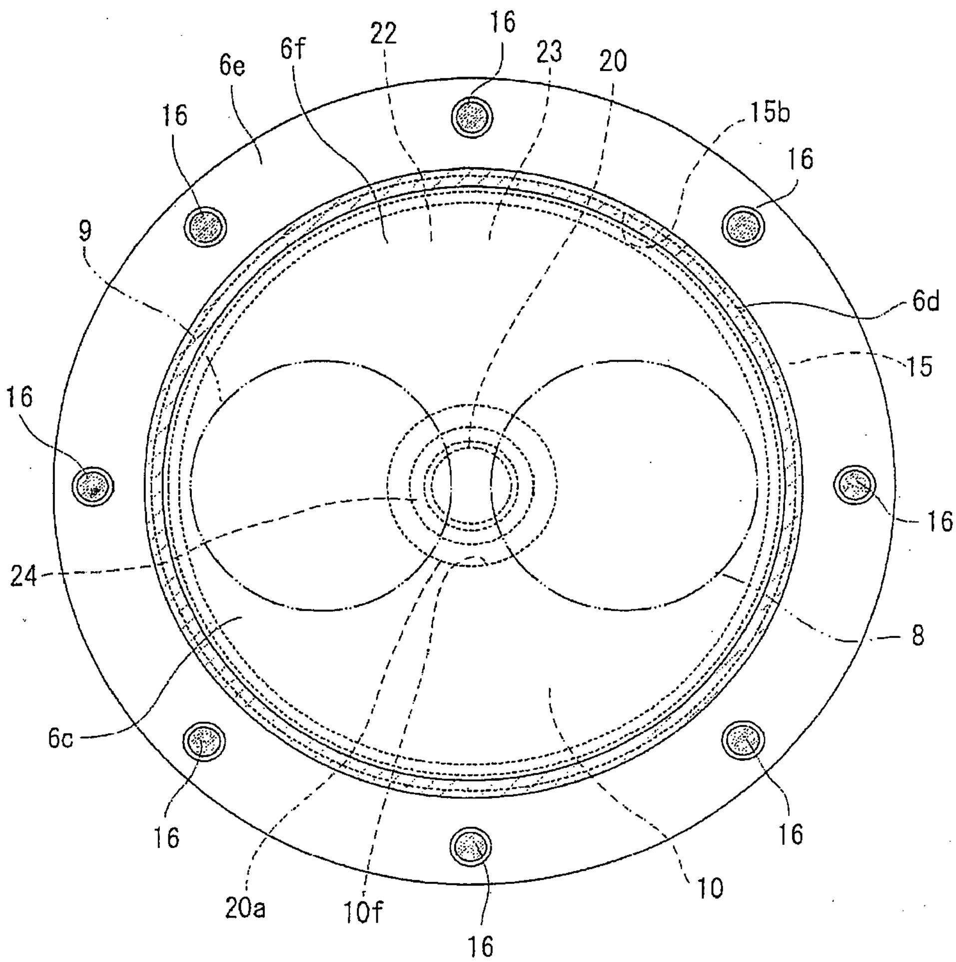
Fig. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 13 00 4383

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 December 2013	Olona Laglera, C

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