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(54) **Positive displacement pump for transporting a fluid with automatic adaptation to the compressibility of the fluid**

(57) A positive displacement pump (1) for transporting a thud with automatic adaptation to the compressibility of that fluid has a pumping chamber (15) with a variable volume (V) which is on the one hand delimited by a rigid chamber cover plate (10) and on the other hand by an elastic diaphragm (9), a suction channel (29) which is in flow connection with the pumping chamber (15) for sucking the fluid to be transported into the pumping chamber (15), an outlet channel (24) which is in flow connection with the pumping chamber (15) for discharging the fluid to be transported from the pumping chamber (15), and a drive device (29) for cyclically increasing and reducing the current volume (V) of the pumping chamber (15), with the drive device (29) being connected to the diaphragm (9) by means of a diaphragm connecting element (34; 34a; 34b) which is spring-mounted in the drive device (29) by means of a spring element (33; 33a; 33b).

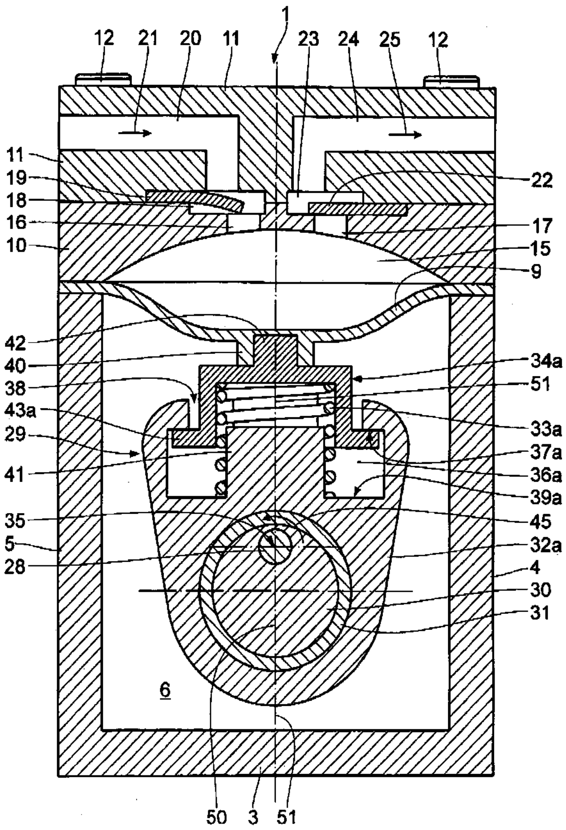

Fig. 11

EP 1 953 387 A2

Description

[0001] The invention relates to a positive displacement pump.

[0002] Positive displacement pumps for transporting a fluid have been known for a long time. The dimensions and operating properties of such pumps are usually adapted to a particular type of fluid. They may in particular be adapted to the transport of a compressible fluid, such as a gas, or to the transport of an incompressible fluid, such as a liquid. A change in the composition, and thus the compressibility, of the fluid to be transported may, on the one hand, result in an unwanted reduction of the flow rate and, on the other hand, in an increased stress on the pump, in the worst case the pump may even be damaged.

[0003] Thus it is the object of the invention to create a positive displacement pump whose mechanical properties, such as the suction capacity of the pump, automatically adapt to the compressibility of that fluid.

[0004] This object is attained by the features of claim 1. The goal of the invention is to create a positive displacement pump in which a suction or displacement element, respectively, comprising a diaphragm is connected to a drive device in an elastically sprung manner. Depending on the compressibility of the fluid to be transported, this spring element is more or less stressed during each pumping cycle. This leads to an increased suction capacity at a constant flow rate of the fluid while the stress, in particular on the moving parts of the pump, is reduced.

[0005] Further advantageous embodiments of the invention are stated in the subclaims.

[0006] Further features and details of the invention will become apparent from the ensuing description of several embodiments, taken in conjunction with the drawings, in which

Fig. 1	shows an exploded view of a positive displacement pump according to a first embodiment;
Fig. 2	shows a central longitudinal section of the positive displacement pump according to Fig. 1 with the spring element unstressed, such as during the transport of a compressible fluid at the beginning of a suction-discharge cycle;
Fig. 3	shows a central longitudinal section of the positive displacement pump according to Fig. 1 differing by a quarter cycle from the position shown in Fig. 2;
Fig. 4	shows a central longitudinal section of the positive displacement pump according to Fig. 1 differing by a half cycle from the position shown in Fig. 2;
Fig. 5	shows a central longitudinal section of the positive displacement pump according to Fig.1 differing by a three-quarter cycle from the position shown in Fig. 2;
Fig. 6	shows a central longitudinal section of the positive displacement pump according to Fig. 1 corresponding to the position shown in Fig. 2 but with the spring element stressed, such as during the transport of an incompressible fluid;
Fig. 7	shows a central longitudinal section of the positive displacement pump according to Fig. 1 corresponding to the position shown in Fig. 5 but with the spring element stressed, such as during the transport of an incompressible fluid;
Fig. 8 to Fig. 14	show a positive displacement pump according to a second embodiment corresponding to Figs. 1 to 7;
Fig. 15 to Fig. 21	show a positive displacement pump according to a third embodiment corresponding to Figs. 1 to 7; and
Fig. 22 and Fig. 23	show a positive displacement pump according to a fourth embodiment.

[0007] The following is a description of a first embodiment, taken in conjunction with Figs. 1 to 7.

[0008] A positive displacement pump 1 has a substantially cuboid-shaped housing 2 with a housing base 3 aligned perpendicularly to a longitudinal direction, a first and a second side wall 4 and 5, a housing back wall 6 and a housing cover 7. Additionally, the housing 2 may have a cover, not shown in the drawings, at the housing front side opposite the housing back wall 6. The housing cover 7 has a square cross-section in the direction perpendicular to the longitudinal axis and has a circular opening 8. According to the embodiment shown in the drawings, the side walls 4 and 5 have the shape of an L, the width of the side walls 4 and 5 in the area of the housing cover 7 thus exceeding that in the area of the housing base 3. The housing is substantially mirror-symmetric to a central-longitudinal plane 51. Alternative geometric configurations of the housing 2 are conceivable. The housing 2 consists of a solid material, such as plastics or metal. A suction or displacement element, respectively, comprising a flexible diaphragm 9 is located adjacent to the housing cover 7 opposite the housing base 3. In a plane perpendicular to the longitudinal direction, the diaphragm 9 has the same external dimensions as the housing cover 7 and completely covers the opening 8. Alternative embodiments of the displacement element, such as pistons, are also conceivable. A chamber cover plate 10 and a cap 11 are located adjacent thereto, both of which having, in a direction perpendicular to the longitudinal direction, the same external dimensions as the housing cover 7. Thus, the diaphragm 9 of a fluid-tight material, the chamber cover plate 10 and the cap 11 all have a cross-section in a direction perpendicular to the longitudinal direction which is identical to that of the housing cover 7. On its side facing towards the diaphragm 9, the chamber cover plate 10 has a recess in the shape of a spherical segment which is substantially rotation-symmetric to the longitudinal axis and is thus plane-concave.

[0009] The diaphragm 9, the chamber cover plate 10 and the cap 11 have one bore each 13 in each corner for receiving a cap screw 12. Each of the cap screws 12 engages with a corresponding threaded bore 14 in the housing 2. By means of the cap screws 12, the housing 2, the diaphragm 9, the chamber cover plate 10 and the cap 11 are safely held in place. In particular, the diaphragm 9 is clamped in an immovable and/or gas- or fluid-tight manner along its edge between the housing cover 7 and the chamber cover plate 10. In its central area covering the opening 8, the diaphragm 9 is displaceable along the longitudinal axis in a way as to pass through the opening 8 on the one hand and into the spherical-segment shaped recess of the chamber cover plate 10 on the other hand until it bears against the chamber cover plate 10.

[0010] The chamber cover plate 10 on the one hand and the diaphragm 9 on the other hand define, or delimit, a pumping chamber 15 with a variable volume V. The chamber cover plate 10 has at least one inlet opening 16 disposed, or arranged, slightly off-centre and at least one outlet opening 17. Via the inlet opening 16, the pumping chamber 15 is connected to a suction channel 20 in the cap 11. A suction valve 19 is disposed between the suction channel 20 and the inlet opening 16. The suction valve 19 comprises a flexible non-return flap. The non-return flap is pivotally disposed in a suction passage 18 between the chamber cover plate 10 and the cap 11. A part of the cap 11 forms a stop for the non-return flap. The suction valve 19 is configured in a way as to allow fluid to enter the pumping chamber 15 in an inlet direction 21 through a suction channel 20, the suction passage 18 and the inlet opening 16 but prevents a fluid flow in the opposite direction, i.e. from the pumping chamber 15 through the inlet opening 16 and the suction passage 18 into the suction channel 20. The outlet opening 17, on the other hand, is connected to an outlet channel 24 in the cap 11 by means of an outlet valve 22 also comprising a flexible non-return flap in a discharge passage 23. The outlet valve 22 enables fluid to be discharged from the pumping chamber 15 through the outlet opening 17 into the outlet channel 24 but prevents a backflow of the fluid opposite to the discharge direction 25 into the pumping chamber 15. A part of the chamber cover plate 10 forms a stop for the non-return flap of the outlet valve 22. The suction channel 20 and the outlet channel 24 may for example be configured as bores or independent pipes in the cap 11. Alternative designs of the suction or outlet valve 19, 22, respectively, are conceivable.

[0011] A motor 26 is attached to the outside of the housing back wall 6 in a non-rotational manner by means of fixing screws 27. The motor 26 has a shaft 28 which projects into the inside of the housing 2 through a recess, not shown in the figures, in the housing back wall 6. A drive device 29 is attached to the shaft 28. The drive device 29 may be driven by means of alternative drives such as a linear or piezoelectric drive. The drive device 29 comprises an eccentric disk 30, a rod 32 connected to the eccentric disk 30 in a virtually frictionless manner by means of a bearing 31, and a diaphragm connecting element 34 which is displaceable along the rod 32 and spring-mounted by means of a spring element in the shape of a leaf spring 33. Advantageously, the spring element is replaceable. The spring elements illustrated in the description of the embodiments are only used as examples. Alternative embodiments of any type of the spring elements, such as gas springs, are conceivable. The eccentric disk 30 has a circular cross-section with a symmetry axis and is eccentrically secured to the shaft 28, which is mounted rotatably about an axis of rotation 35, by means of a force-fit and/or a form-fit and/or bonding. The symmetry axis of the circular eccentric disk 30 is located at a distance d from the axis of rotation 35. The bearing 31 may be a slide bearing or, advantageously, a rolling-element bearing. The distance d delimits the maximum travel, or displacement, of the diaphragm 9 and, therefore, the maximum displacement volume of the positive displacement pump 1.

[0012] The rod 32 has a longitudinal rod axis 50 and is substantially symmetric to the central longitudinal plane 51 when in the top or bottom dead-centre position, respectively, i.e. when the symmetry axis of the eccentric disk 30 and the longitudinal rod axis 50 coincide with the central longitudinal plane 51. The diaphragm connecting element 34 is spring-mounted in the rod 32 and is displaceable along the longitudinal rod axis 50. Moreover, the diaphragm connecting element 34 is secured to the leaf spring 33 by means of a force-fit and/or a form-fit and/or bonding. Additionally, the leaf spring 33 is force-fitted and/or form-fitted to the rod 32.

[0013] The leaf spring 33 is mounted in a rod recess 36 in the rod 32 in an elastically deformable manner. The rod recess 36 substantially has the shape of a D. On the side facing towards the diaphragm 9, it is delimited by a substantially flat upper stop 37. In the area of the central longitudinal plane of the rod 32, a through-opening 38 passes through the upper stop 37. On the side of the rod recess 36 opposite the upper stop 37, the rod recess 36 is delimited by a lower stop 39. The lower stop 39 substantially has the shape of a circular arc. Passing through the through opening 38, the diaphragm connecting element 34 is disposed between the leaf spring 33 in the rod recess 36 and the diaphragm 9. In this position, the diaphragm connecting element 34 is at least force-fitted to both the leaf spring 33 and the diaphragm 9. The diaphragm connecting element 34 may be integral with the leaf spring 33.

[0014] The diaphragm connecting element 34 has a cylindrical projection 42. On the side facing towards the diaphragm connecting element 34, the diaphragm 9 has a hollow cylindrical recess 40 into which the cylindrical projection 42 is inserted in a form-fit engagement.

[0015] The function of the pump is described further below.

[0016] The following is a description of a second embodiment, taken in conjunction with Figs. 8 to 14. Identical parts are referred to with the same reference numerals as used for the first embodiment to the description of which reference is made. Parts that differ in design but have the same function are referred to with the same reference numerals with a subsequent a. The essential difference with respect to the first embodiment is that the spring element is a helical compression spring 33a. The helical compression spring 33a is replaceable. The rod recess 36a has a substantially cuboid shape. The helical compression spring 33a is disposed on the rod 32a on a cylindrical spring mandrel 41 disposed in the centre of the rod recess 36a. The length of the spring mandrel 41 at least equals the length of the helical compression spring 33a in a fully compressed state. In this embodiment, the diaphragm connecting element 34a comprises a hollow cylinder which is substantially closed on one side and surrounds the helical compression spring 33a. The cylinder barrel may be interrupted, thus ensuring that the diaphragm connecting element 34a does not protrude beyond the rod 32a in the direction of the axis of rotation 35. On the side facing towards the diaphragm 9, the diaphragm connecting element 34a is form-fitted to the receiving element 40 of the diaphragm 9 by means of the cylindrical projection 42. At the open end of the cylindrical diaphragm connecting element 34a, a stop collar 43a is attached to the outside of the cylinder barrel. The diaphragm connecting element 34a is thus mounted in the rod recess 36a for displacement in the longitudinal direction, with the stop collar 43a bearing against the upper stops 37a in a first end position and against the lower stop 39a in a second end position. In this embodiment, the lower stops 39a are plane and extend parallel to the upper stops 37a. In the second end position, the front wall closing one end of the hollow cylinder is advantageously flush with the spring mandrel 41. In that case, it is not absolutely necessary for the stop collar 43 to bear against the lower stops 39a in the second end position. The length and compressibility of the helical compression spring 33a are adapted to the dimensions of the spring mandrel 41, or in particular to the distance between the upper stops 37a and the lower stops 39a, in a way that said helical compression spring 33a is pre-stressed both in the first end position of the diaphragm connecting element 34a as well as in the second end position of the diaphragm connecting element 34a.

[0017] The function of this positive displacement pump 1 is described further below.

[0018] The following is a description, taken in conjunction with Figs. 15 to 21, of another embodiment of the invention. Identical parts are referred to with the same reference numerals as used for the second embodiment to the description of which reference is made. Parts that differ in design but have the same function are referred to with the same reference numerals with a subsequent b. The essential difference with respect to the second embodiment is that the spring element comprises an elastomer spring 33b. The elastomer spring 33b is replaceable. It is advantageously made of an elastically deformable plastic material, such as EPDM or NBR. The elastomer spring 33b has a substantially cuboid shape, with a length 1 along the longitudinal rod axis 50, a depth t in the direction of the axis of rotation 35 and a width b perpendicular to the two other directions. The rod recess 36b has a substantially cuboid shape. It may be delimited by a support plate 44 on the side facing towards the housing back wall 6. Moreover, the recess 36b may be at least partially delimited by another support plate on the side facing away from the housing back wall 6. In the direction of the longitudinal rod axis 50, the recess has upper and lower stops 37b and 39b. In this embodiment, the diaphragm connecting element 34b has an angled U-profile. Stop collars 43b are disposed on the outside of the two free ends of the U-profile. The cylindrical projection 42 is disposed on the side of the U-profile facing towards the diaphragm 9.

[0019] The following is a description of the functioning of the positive displacement pump 1 according to the previous embodiments. During the operation of the positive displacement pump 1, the pumping cycle may substantially be sub-divided into two phases, i.e. a suction phase on the one hand during which the suction valve 19 is open and fluid enters the pumping chamber 15 through the suction channel 20 and the inlet opening 16 while the outlet valve 22 is closed, thus preventing a backflow of fluid opposite to the discharge direction from the outlet channel 24 into the pumping chamber 15, and a discharge phase on the other hand during which the suction valve 19 is closed and the outlet valve 22 is open, thus preventing a backflow of fluid opposite to the inlet direction 21 from the pumping chamber 15 through the suction channel 20, and enabling fluid to flow through the outlet channel 24 and out of the pumping chamber 15 in the discharge direction 25.

[0020] Therefore, one of the two valves 19, 22 is open at a particular time substantially during the normal operation of the positive displacement pump 1, while the other of the two valves 19, 22 is closed, and vice versa. The pressure difference applied to the valve 19 or 22, respectively, i.e. the difference between the fluid pressure $pK(t)$ in the pumping chamber 15 and the pressure pI in the suction channel 20 or the pressure pO in the outlet channel 24, respectively, determines whether the valve 19 or 22, respectively, is open or closed. Generally, the following applies: $pO \geq pI$, with both pO as well as pI being substantially constant at least for the duration of a cycle. The fluid pressure pK(t) in the pumping chamber 15, however, varies cyclically due to the movement of the drive device 29, in particular the corresponding movement of the diaphragm 9, thereby causing a cyclic variation of the volume V(t) of the pumping chamber 15. Generally, the pressure pK(t) in the pumping chamber 15 may be increased by reducing the volume V(t) while the pressure pK(t) in the pumping chamber 15 may be reduced by increasing the volume V(t). The exact details of the pressure increase or pressure reduction, respectively, depend amongst other things on the speed of rotation of the shaft 28 about the axis of rotation 35, the geometric shape of the inlet opening 16 and the outlet opening 17 or the inlet channel 20 and the outlet channel 24, respectively, the mechanical properties of the suction valve 19 and the outlet valve 22, the viscosity and compressibility of the fluid to be transported as well as the properties of the spring element 33; 33a; 33b. The goal of the positive displacement pump 1 according to the invention is to connect the diaphragm 9 to the rod 32 in a spring-mounted manner by means of a spring element 33; 33a; 33b, thereby damping in particular the pressure increase or pressure reduction, respectively, in the pumping chamber 15, the amount of damping being a function of the stiffness of the spring element 33; 33a; 33b and said pressure increase or pressure reduction, respectively, depending on the compressibility of the fluid to be transported.

[0021] During the normal operation of the positive displacement pump 1, the shaft 28 is driven by a motor 26 about the axis of rotation 35 in a direction of rotation 45.The following is a description of a complete pumping cycle starting from a top dead centre position of the drive device 29. First of all, a pumping cycle is described during which the spring element 33; 33a; 33b is rigid, therefore not changing its shape. This may be the case during the transport of a compressible fluid and/or at a low speed of rotation of the shaft 28 and/or if the spring element 33; 33a; 33b is very stiff. In the top dead centre position of the drive device 29, the diaphragm 9 is substantially pressed against the concave side of the chamber cover plate 10 (Fig. 2; Fig. 9; Fig. 16). In this position, the pumping chamber 15 has a minimum volume. A rotation of the shaft 28 in the direction of rotation 45 causes the diaphragm 9 to be pulled away from the chamber cover plate 10 (Fig. 3; Fig. 10; Fig. 17). Thereby, the volume of the pumping chamber 15 increases. When the volume of the pumping chamber 15 increases, pK(t) is reduced. Thus, a relative low pressure is generated in the pumping chamber 15, with pK(t) < pI. This causes the outlet valve 22 to close the outlet opening 17 while the suction valve 19 opens, thus enabling fluid to flow into the pumping chamber 15 through the suction channel 20, the suction passage 18 and the inlet opening 16. The rotation of the eccentric disk 30 causes the volume of the pumping chamber 15 to increase until the drive device 29 has reached the bottom dead centre (Fig. 4; Fig. 11, Fig. 18).A further rotation of the eccentric disk 30 in the direction of rotation 45 (Fig. 5, Fig. 12, Fig. 19) causes the diaphragm 9 to be pressed in the direction towards the chamber cover plate 10, thereby reducing the volume of the pumping chamber 15. Consequently, the pressure pK(t) in the pumping chamber increases. A relative overpressure is generated in the pumping chamber 15, with pK(t) > pO. The overpressure in the pumping chamber 15 causes the suction valve 19 to close, thus preventing a backflow of the fluid from the pumping chamber 15 through the inlet opening 16 and into the suction channel 20. Moreover, the overpressure in the pressure chamber 15 causes the outlet valve 22 to open, thus enabling the fluid to flow out of the pumping chamber 15 through the outlet opening 17 and into the outlet channel 24.

A further rotation of the eccentric disk 30 in the direction of rotation 45 reduces the volume of the pumping chamber 15 until the drive device 29 has reached the top dead centre (cf. Fig. 2; Fig. 9; Fig. 16) again.

[0022] When the eccentric disk 30 continues to rotate, the cycle repeats.

[0023] The following is a description of a pumping cycle during which the spring element 33; 33a; 33b is flexible, thus being compressed to a maximum extent. This may be the case during the transport of an incompressible fluid and/or at a high speed of rotation of the shaft 28 and/or if the spring element 33; 33a; 33b is very soft. In the top dead centre position of the drive device 29, the spring element 33; 33a; 33b is compressed to a maximum extent (Fig. 6; Fig. 13; Fig. 20). At this point of time, the pumping chamber 15 has a minimum volume. A rotation of the eccentric disk 30 in the direction of rotation 45 causes the force acting on the spring element 33; 33a; 33b to be reduced. This allows the spring element 33; 33a; 33b to relax, thus resulting in a relative displacement of the diaphragm connecting element 34; 34a; 34b in the rod recess 36; 36a; 36b along the longitudinal rod axis 50 until the spring element 33 or the stop collar 43a; 43b, respectively, comes to bear against the upper stops 37; 37a; 37b (Fig. 3; Fig. 10; Fig. 17). A further rotation of the eccentric disk 30 in the direction of rotation 45 increases the distance between the diaphragm connecting element 34; 34a; 34b and the chamber cover plate 10. Due to the diaphragm connecting element 34; 34a; 34b being at least force-fitted to the diaphragm 9, the volume of the pump chamber 15 increases, this in turn causing the pumping chamber pressure pK(t) to be reduced to a low pressure in the pumping chamber 15, pK(t) < pI. The low pressure, if pK(t) > pI, causes the suction valve 19 to open, thus enabling fluid to flow from the suction channel 20 through the inlet opening 16 and into the pumping chamber 15. The volume of the pumping chamber 15 increases until the drive device 29 has reached the bottom dead centre (Fig. 4; Fig. 11; Fig. 18). A further rotation of the eccentric disk 30 about the axis of rotation 35 then reduces the distance along the longitudinal rod axis 50 between the drive device 29 and the diaphragm 9. Thereby, the force acting on the spring element 33; 33a; 33b increases, thus causing the diaphragm connecting element 34; 34a; 34b to be displaced in the rod recess 36; 36a; 36b until the force of the spring element 33; 33a; 33b acting on the diaphragm connecting element 34; 34a; 34b prevents any further displacement, at the most until the diaphragm connecting element 34; 34a; 34b comes to bear against the lower stops 39; 39a; 39b or the spring mandrel 41, respectively (Fig. 7; Fig. 14; Fig. 21).

[0024] During a further rotation of the eccentric disk 30 about the axis of rotation 35, the rod 32; 32a; 32b presses the diaphragm 9 in the direction towards the chamber cover plate 10 by means of the diaphragm connecting element 34; 34a; 34b, thus causing the volume of the pumping chamber 15 to be reduced. This results in an increase of the pressure pK(t) in the pumping chamber 15, thus in turn, if pK(t) < pI, causing the suction valve 19 to close, thus preventing a backflow of the fluid in a direction opposite to the inlet direction 21, i.e. from the pumping chamber 15 through the inlet opening 16 and into the suction channel 20. On the other hand, the outlet valve 22 opens ifpK(t) > pO, thus enabling the fluid to flow out of the pumping chamber 15 in the discharge direction 25, i.e. through the outlet opening 17 and into the outlet channel 24. The volume of the pumping chamber 15 reduces until the drive device 29 has reached its top dead centre (Fig. 6; Fig. 13; Fig. 20).

[0025] When the eccentric disk 30 continues to rotate, the cycle repeats.

[0026] Both the extent of deformation of the spring element 33; 33a; 33b during a particular cycle and the particular phase of the cycle during which the diaphragm connecting element 34; 34a; 34b comes to bear against the upper stop 37; 37a; 37b and, as the case may be, against the lower stop 39; 39a; 39 are individually determined by, amongst other things, the compressibility of the fluid to be transported, the speed of rotation of the shaft 28 and the stiffness of the spring element 33; 33a; 33b. Force peaks on the drive device 29, the diaphragm 9, the pumping chamber 15 and the valves 19, 22 occurring in particular in the top or bottom dead centre position, respectively, are damped due to the diaphragm 9 being spring-mounted to the drive device 29. A systematic selection of a spring element 33; 33a; 33b having corresponding damping properties enables the positive displacement pump 1 to be specifically adapted to the expected operating conditions. Thereby, the suction capacity of the positive displacement pump 1 may be optimized, depending on the fluid to be transported, while reducing the stress on the positive displacement pump 1, in particular on the moving parts thereof.

[0027] Moreover, due to the displacement unit, i.e. the diaphragm 9, being spring-mounted to the drive device 29, the displacement volume of the positive displacement pump 1 is automatically adapted to the compressibility of the fluid to be transported and to the drive speed of the drive device 29. Generally, it can be determined that the less the displacement of the diaphragm connecting element 34; 34a; 34b in the rod recess 36; 36a; 36b during a pumping cycle, i.e. the higher the compressibility of the fluid to be transported while using the same spring element 33; 33a; 33b, or the stiffer the spring element 33; 33a; 33b while retaining the compressibility of the fluid to be transported, respectively, the larger the compression ratio of the fluid to be transported in the pumping chamber 15. On the other hand, a lower compressibility of the fluid to be transported leads to a higher stress on the spring element 33; 33a; 33b, thus generally resulting in an increased displacement of the diaphragm connecting element 34; 34a; 34b in the rod recess 36; 36a; 36b and, consequently, in a reduced displacement volume.

[0028] Generally, it can be determined that a softer spring element 33; 33a; 33b causes the compression ratio, and thus me displacement volume of the positive displacement pump 1, to be reduced.

[0029] The following is a description, taken in conjunction with Figs. 22 and 23, of another embodiment of the invention. Identical parts are referred to with the same reference numerals as used for the first embodiment to the description thereof reference is made. Parts that differ in design but have the same function are referred to with the same reference numerals with a subsequent c. The essential difference with respect to the previous embodiments is that the rod 32c is elastic, thus comprising the spring element 33c. The rod 32c of the drive device 29c is in particular made of plastics. Therefore, it is configured in a flexibly resilient manner. The rod 32c comprises a rod drive area 46 which is concentric with the eccentric disk 30, two rod recess side walls 47 extending parallel to the longitudinal rod axis 50 and tangentially adjoining said rod drive area 46 in an integral manner as well as rod stop walls 48 which are integral with said rod-recess side walls 47. The upper rod stop walls 48 are deformable with respect to the rod-recess side walls 47. Each of the upper rod stop walls 48 has a free end 56 facing towards the through-opening 38c. When the rod 32c is unstressed, the upper rod stop walls 48 are substantially perpendicular to the rod-recess side walls 47. The rod-recess side walls 47 and the rod stop walls 48 form the spring element 32c. The side of the upper rod stop wall 48 facing towards the rod recess 36c forms the upper stop 37c for the diaphragm connecting element 34c. The lower stop 39c is formed by the side of the rod stop area 46 facing towards the rod recess 36c. In this embodiment, the through-opening 38c disposed between the upper rod stop walls 48 is advantageously configured as a longitudinal recess extending in the direction parallel to the axis of rotation 35 along the entire depth of the rod 32c. This results in an improved deformability of the upper rod stop walls 48 with respect to the rod-recess side walls 47. Moreover, this provides for a simpler arrangement of the diaphragm connecting element 34c in the rod 32 during the assembly. The diaphragm connecting element 34c is slidable in particular over the rod 32c.

[0030] The diaphragm connecting element 34c is symmetric, in particular rotation-symmetric, with respect to the longitudinal rod axis 50. It has a rod connecting portion 49 which is integral with the cylindrical projection 42. The rod connecting portion 49 comprises an upper transverse wall 52, a lower transverse wall 53 and a connecting piece 54 disposed therebetween. The upper transverse wall 52 and the lower transverse wall 53 define a bead-like groove 55.

There may also be two grooves 52 facing towards the rod-recess side walls 47. The diaphragm connecting element 34c is relatively stiff. In particular, the modulus of elasticity thereof exceeds that of the material the rod 32c is made of. This results in a particularly effective transmission of force from the rod 32c to the diaphragm 9. Alternatively, the diaphragm connecting element 34c may also be elastic, thus contributing to the resilience of the diaphragm 9. The diaphragm connecting element 34c is replaceable. It may be chosen in particular in accordance with the respective requirements.

[0031] In the unstressed state, for example when the drive device 29c is situated at the bottom dead centre, as shown in Fig. 23, the side of the upper transverse wall 52 facing towards the groove 55 is positioned at an angle w_1 with respect to a horizontal plane which is perpendicular to the longitudinal rod axis 50. The angle w_1 is in the range of 1° to 10°. Accordingly, in the unstressed state, for example in the top dead centre position of the drive device 29c, as shown in Fig. 22, the side of the lower transverse wall 53 facing towards the groove 55 is positioned at an angle w_2. The angle w_2 is in the range of 0.5° to 5°. The angle w_2 is in particular small enough to ensure a maximum deflection of the diaphragm 9 in the bottom dead centre position of the drive device 29c. The following applies: $w_2 \leq w_1$. The groove 55 thus widens outward. At its inner end, i.e. in the area of the connecting piece 54, the configuration of the groove 55 substantially corresponds to that of the free ends 56 of the upper rod stop walls 48. Each of the upper rod stop walls 48.is in engagement with the groove 55. The lower transverse wall 53 of the diaphragm connecting element 34c is thus disposed in the rod recess 36c. In the direction perpendicular to the longitudinal rod axis 50, the dimensions thereof are thus smaller than those of the rod recess 36c in this direction. Thus, a clearance is formed between the lower transverse wall 53 of the diaphragm connecting element 34c and the rod-recess side walls 47.

[0032] On its side facing towards the lower stop 39c, the lower transverse wall 53 has a central recess in the shape of a cylindrical portion the curvature of which just corresponds to that of the lower stop 39c in the area of the longitudinal rod axis 50.

[0033] In the top dead centre position, shown in Fig. 22, of the drive device 29c, the rod 32c is substantially mirror-symmetric to the central longitudinal plane 51. In this position, the dimension of the through-opening 38c in the direction perpendicular to the central longitudinal plane exceeds the dimension of the connecting piece 34 of the diaphragm connecting element 34c in the same direction. The diaphragm connecting element 34c is thus displaceable in the directions perpendicular to the longitudinal rod axis 50 and perpendicular to the axis of rotation 35.

[0034] The functioning of the positive displacement pump 1 substantially corresponds to that of the previous embodiments to which reference is made. In this embodiment, however, the function of the spring element 33c is performed by the elastic rod 32c, in particular by the upper rod stop walls 48. During the suction phase, the rod 32c exerts a tensile force on the diaphragm connecting element 34c. Thereby, the upper rod stop walls 48 increasingly come to bear against the lower transverse wall 53 of the diaphragm connecting element 34. During this deformation, the angle, measured inside the rod recess 36c, between the upper rod stop walls 48 and each of the rod-recess side walls 47 adjacent thereto increases more and more until it has reached the value of 90° + w_2. In this position shown in Fig. 23, at least part of the surface of the upper rod stop wall 48 bears against the side of the lower transverse wall 53 facing towards the groove 55. When the eccentric disk 30 performs a rotation in the direction of rotation 45 during the discharge phase, thus reducing the volume of the pumping chamber 15, the rod 32c exerts a thrust force on the diaphragm connecting element 34c. Thereby, the upper rod stop wall 48 is increasingly pressed against the side of the upper transverse wall 52 of the diaphragm connecting element 34c facing towards the groove 55. The upper rod stop wall 48 is thus more and more pressed into the rod recess 36c. Thereby, the angle between the upper rod stop wall 48 and each of the adjacent rod-recess side walls 47 is reduced to an angle of 90°-w_1 at which at least part of the surface of the upper rod stop wall 48 bears against the upper transverse wall 52. The respective sides of the upper transverse wall 52 and the lower transverse wall 53 of the diaphragm connecting element 34c facing towards the groove 55 are inclined by the angles w_1 or w_2, respectively, thus ensuring that the diaphragm connecting element 34a gradually comes to bear against the upper rod stop wall 48. Due to the increasing contact surface between the upper rod stop wall 48 and the upper transverse wall 52 or lower transverse wall 53, respectively, the effective length of the spring arm of the upper rod stop wall 48, measured between the passage area and the rod-recess side wall 47, is more and more reduced, thus causing the spring action to increase steadily. The elastic rod 32c is thus a spring element 33c providing a progressive damping effect. The damping behavior may be influenced by means of the exact configuration of the upper transverse wall 52 or the lower transverse wall, respectively.

Claims

1. Positive displacement pump (1) for transporting a fluid comprising

a. a pumping chamber (15) with a variable volume (V), said pumping chamber (15) being at least partially delimited by a suction and displacement element;
b. at least one suction channel (20) which is in flow connection with the pumping chamber (15) for sucking the

fluid to be transported into the pumping chamber (15);
c. at least one outlet channel (24) which is in flow connection with the pumping chamber (15) for discharging the fluid to be transported from the pumping chamber (15); and
d. a drive device (29) for cyclically increasing and reducing the current volume (V) of the pumping chamber (15);
e. with the drive device (29) being spring-mounted to the suction and displacement element by means of a spring element (33; 33a; 33b) so as to transmit force.

2. Positive displacement pump (1) according to claim 1, **characterized in that** the spring element (33) is a leaf spring.

3. Positive displacement pump (1) according to claim 1, **characterized in that** the spring element (33a) is a helical spring.

4. Positive displacement pump (1) according to claim 1, **characterized in that** the spring element (33b) comprises an elastomer.

5. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** the spring element (33; 33a; 33b) is replaceable.

6. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** the suction and discharge element comprises a diaphragm (9).

7. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** the drive device (29) has a rod (32) which is supported on an eccentric disk (30) force-fitted to a drive shaft (28).

8. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** a suction valve (19) is provided in the direction of flow between the suction channel (20) and the pumping chamber (15).

9. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** an outlet valve (22) is provided in the direction of flow between the pumping chamber (15) and the outlet channel (24).

10. Positive displacement pump (1) according to one of the preceding claims, **characterized in that** at least one of the valves (19, 22) comprises a valve flap.

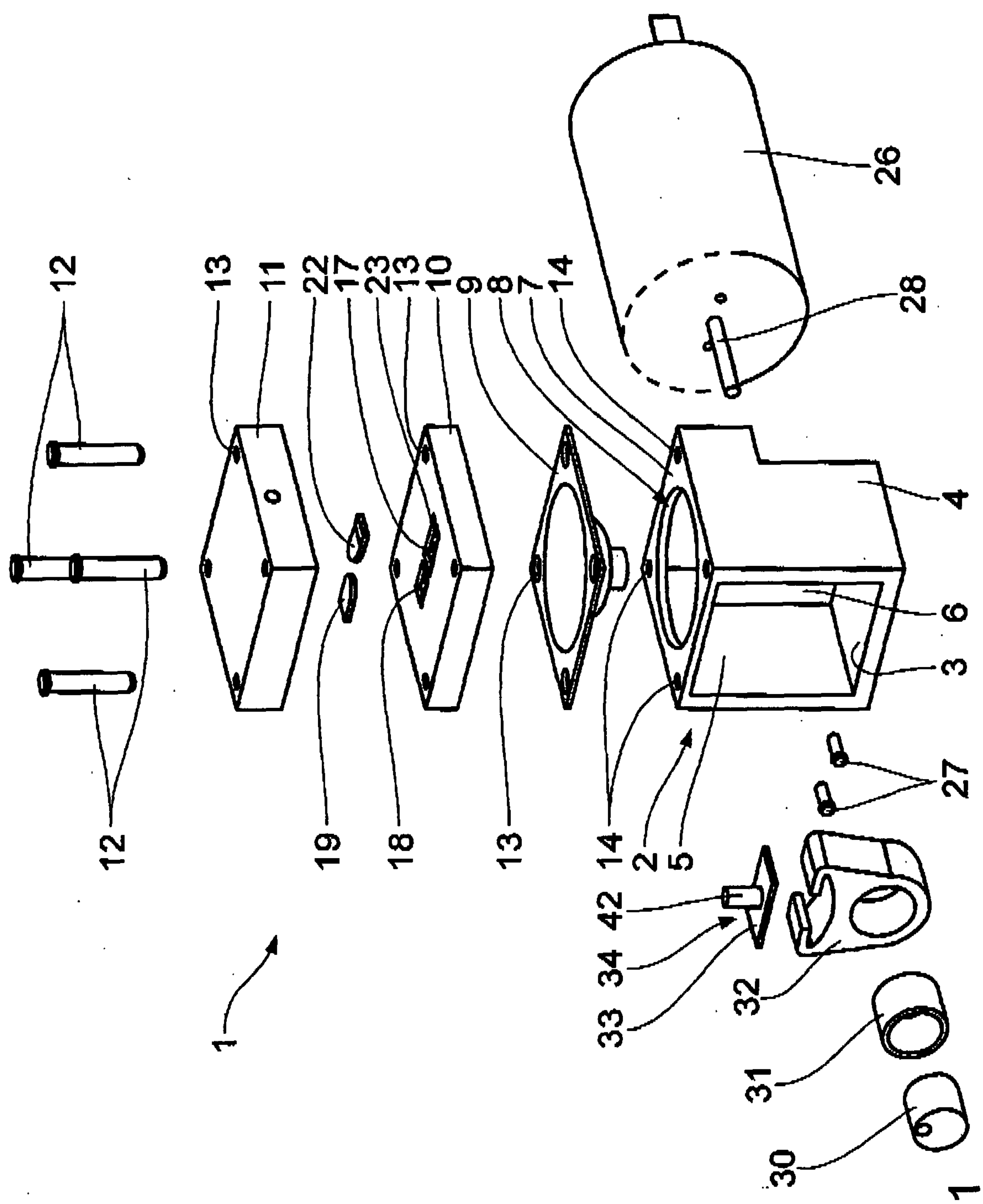
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Fig. 1

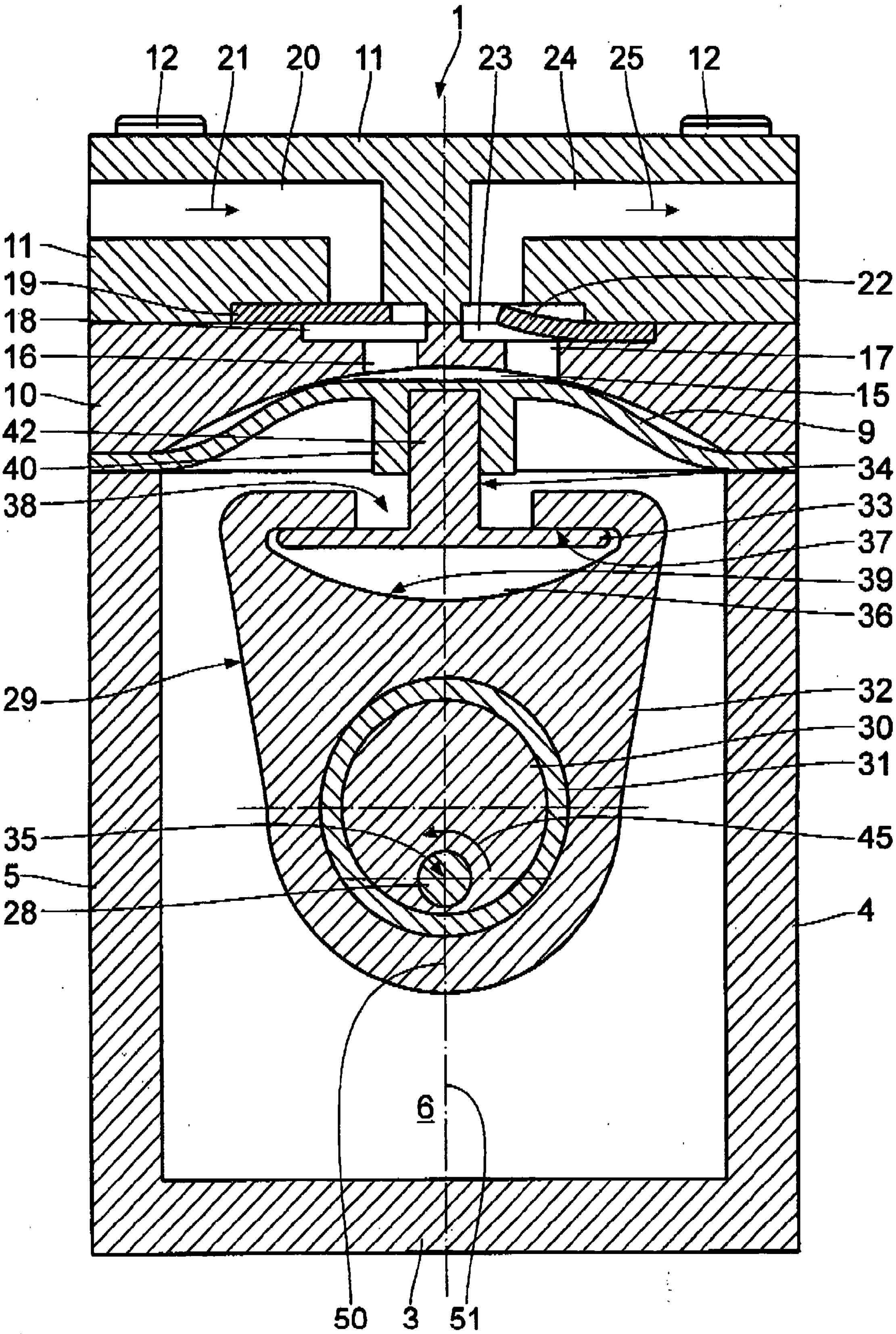
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Fig. 2

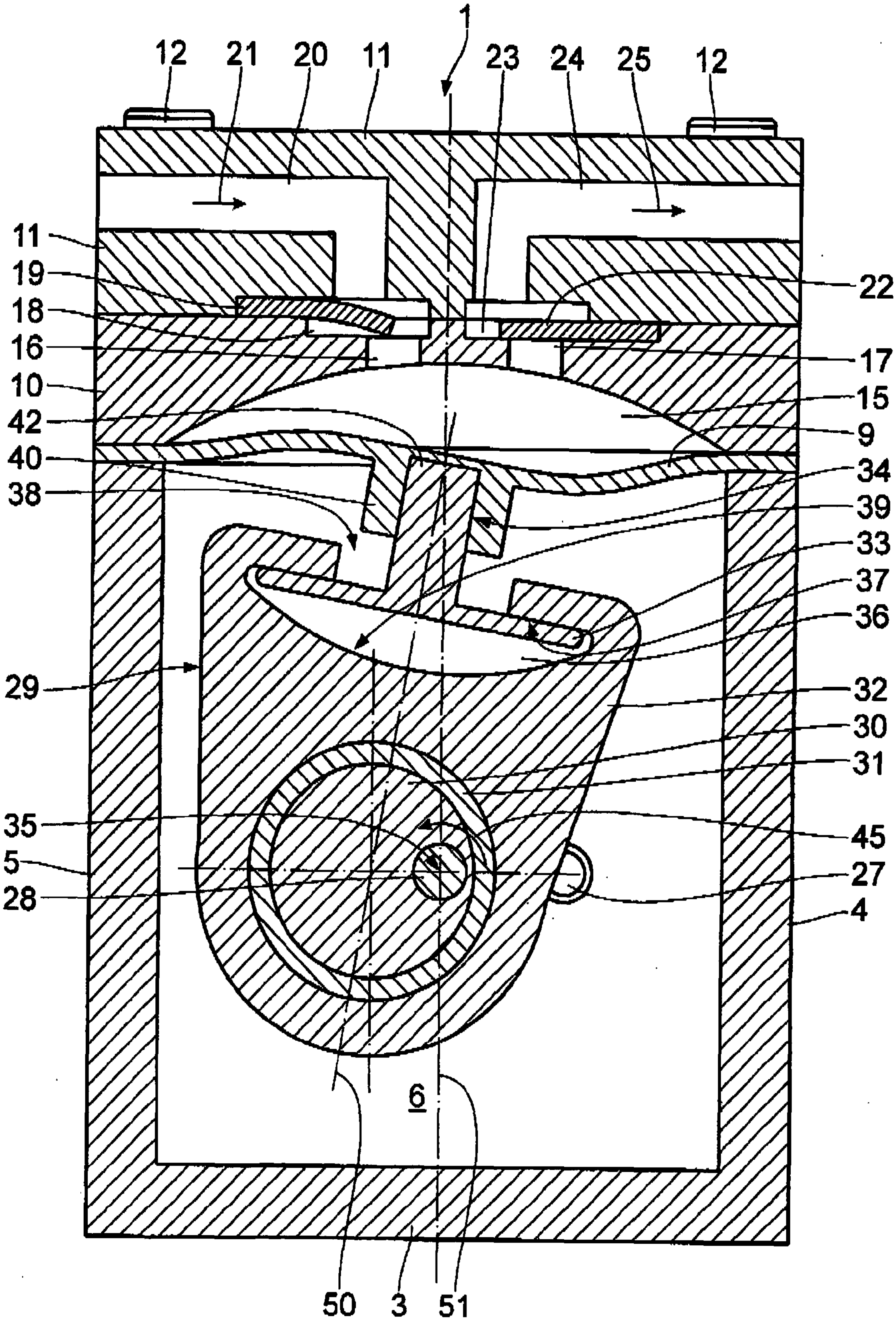
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Fig. 3

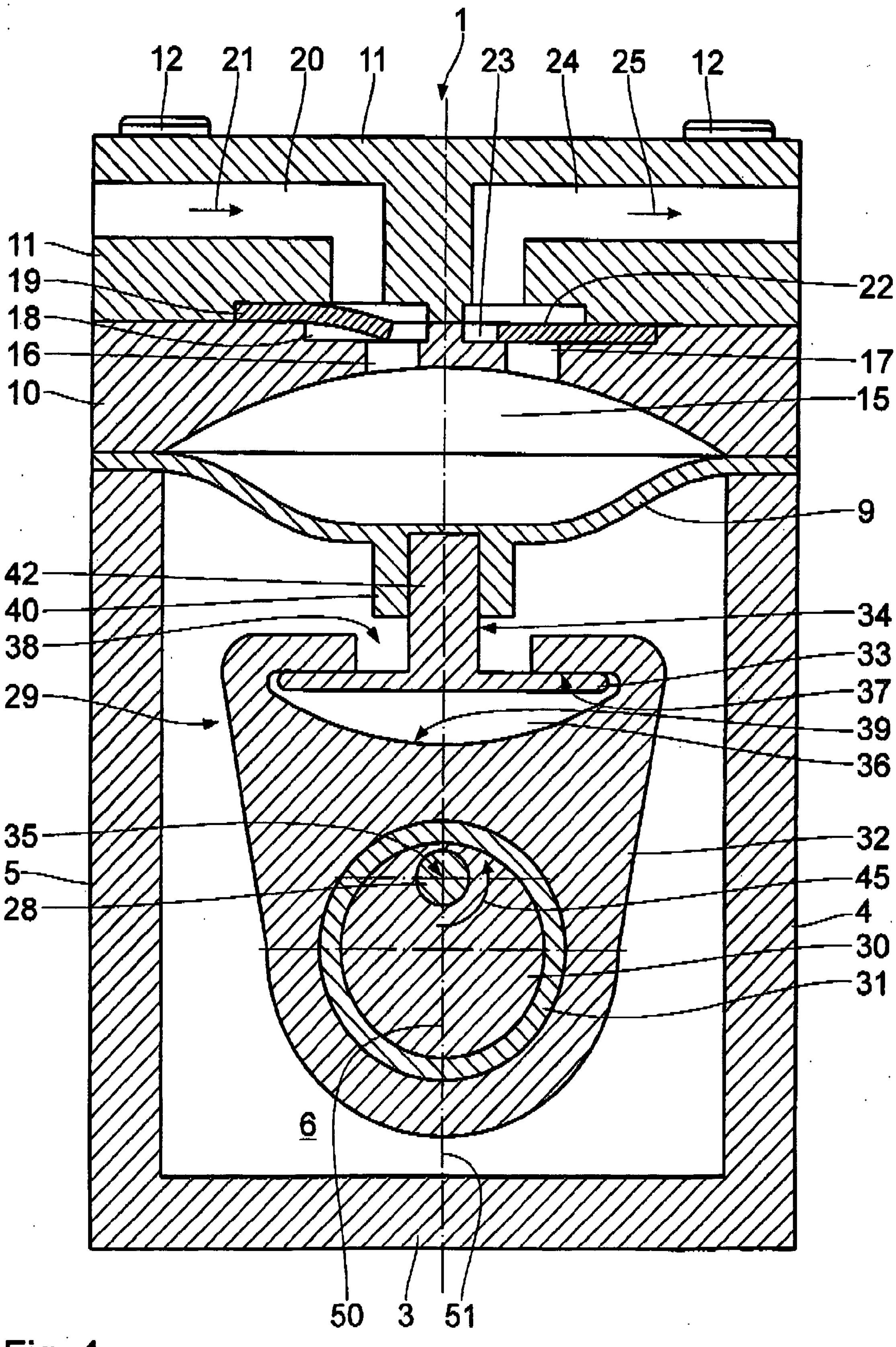
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Fig. 4

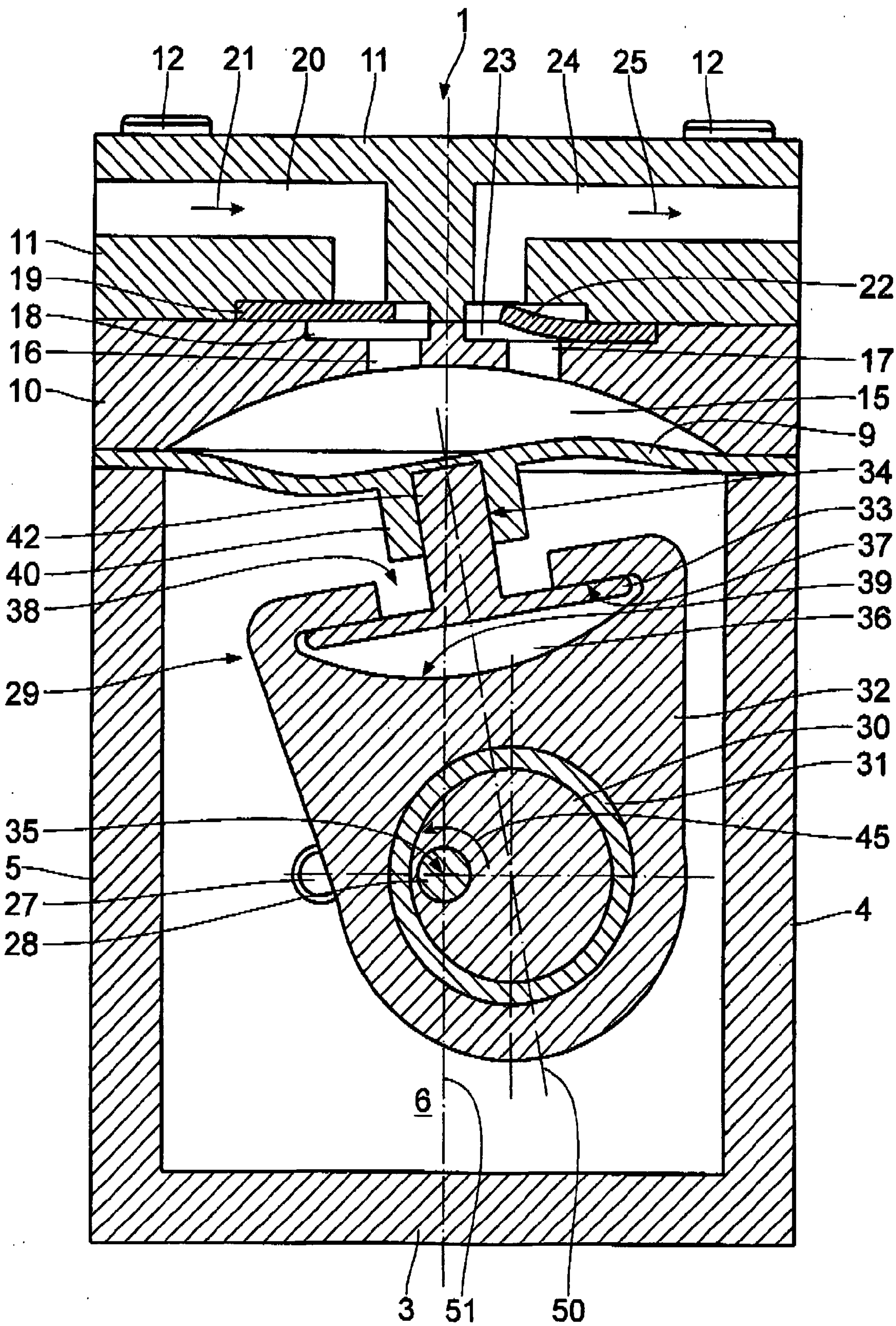
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Fig. 5

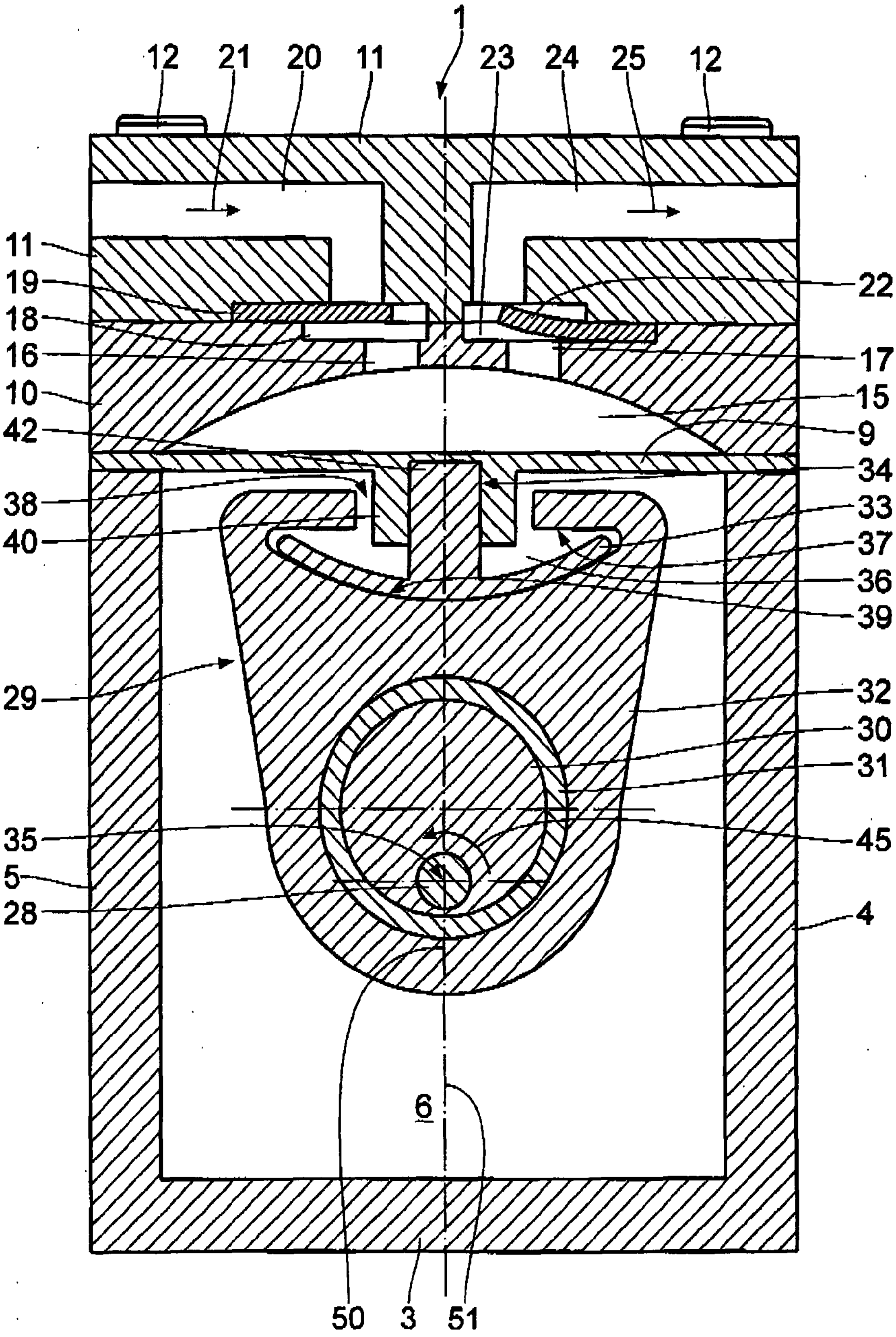
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Fig. 6

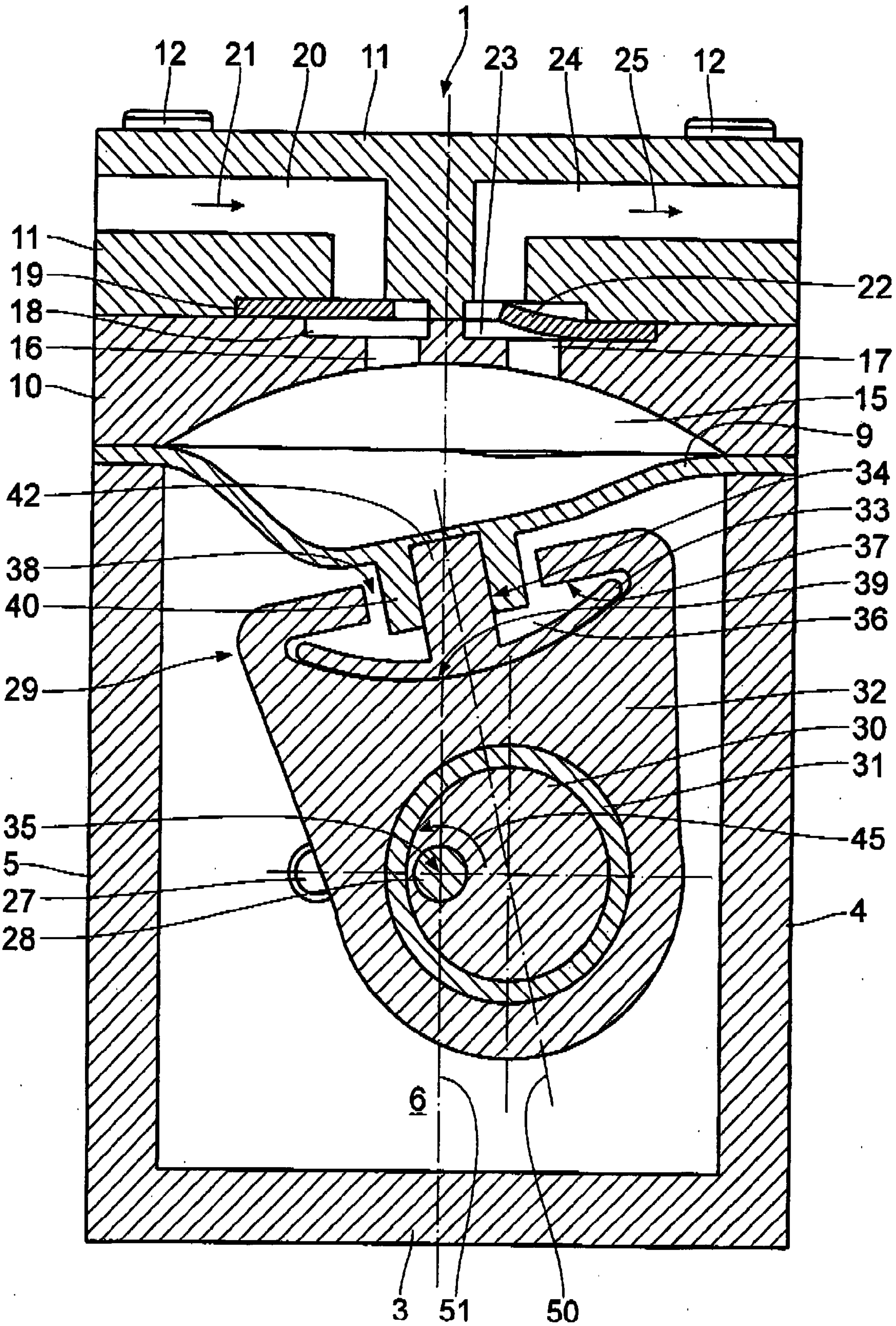
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Fig. 7

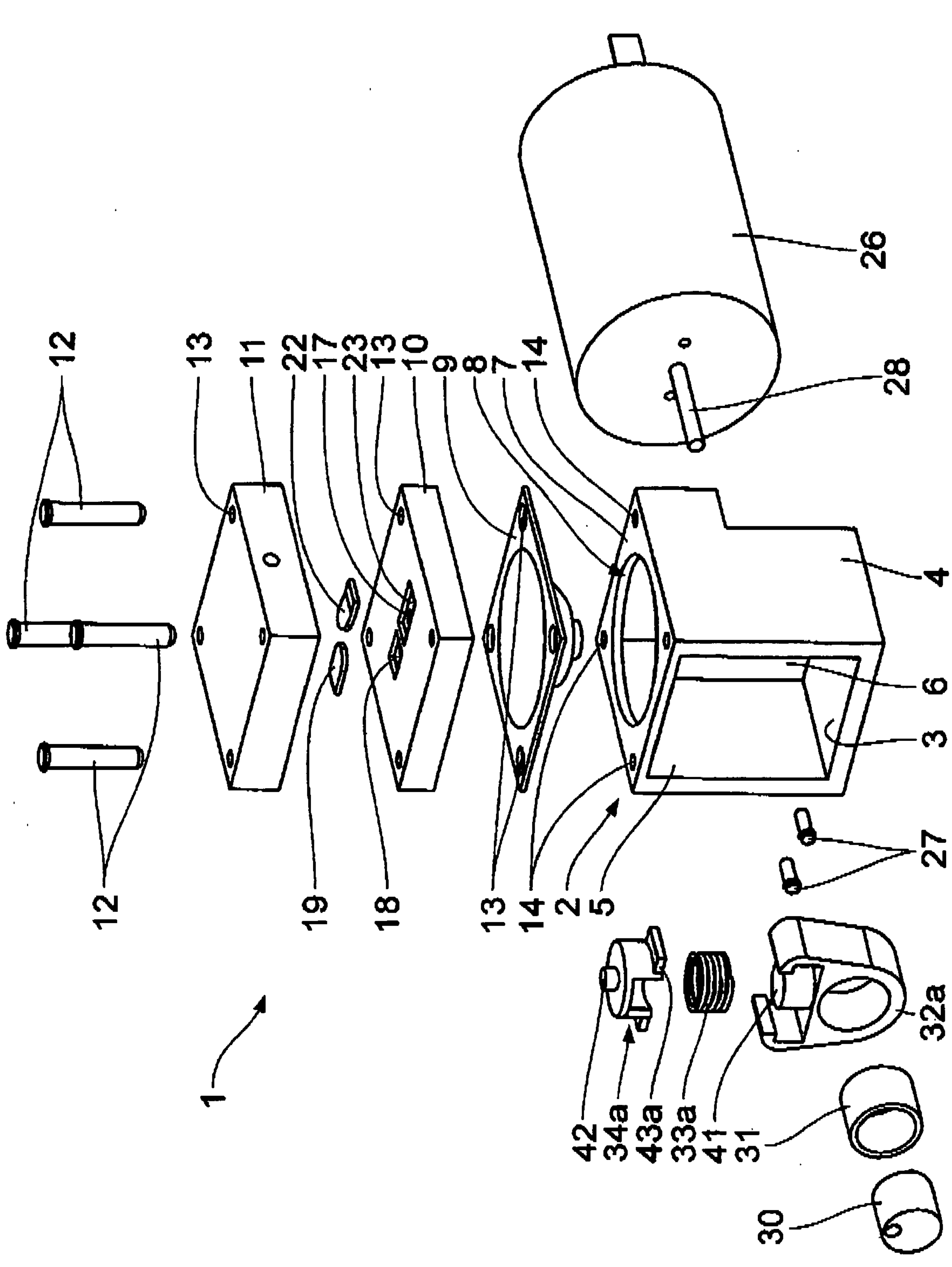
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Fig. 8

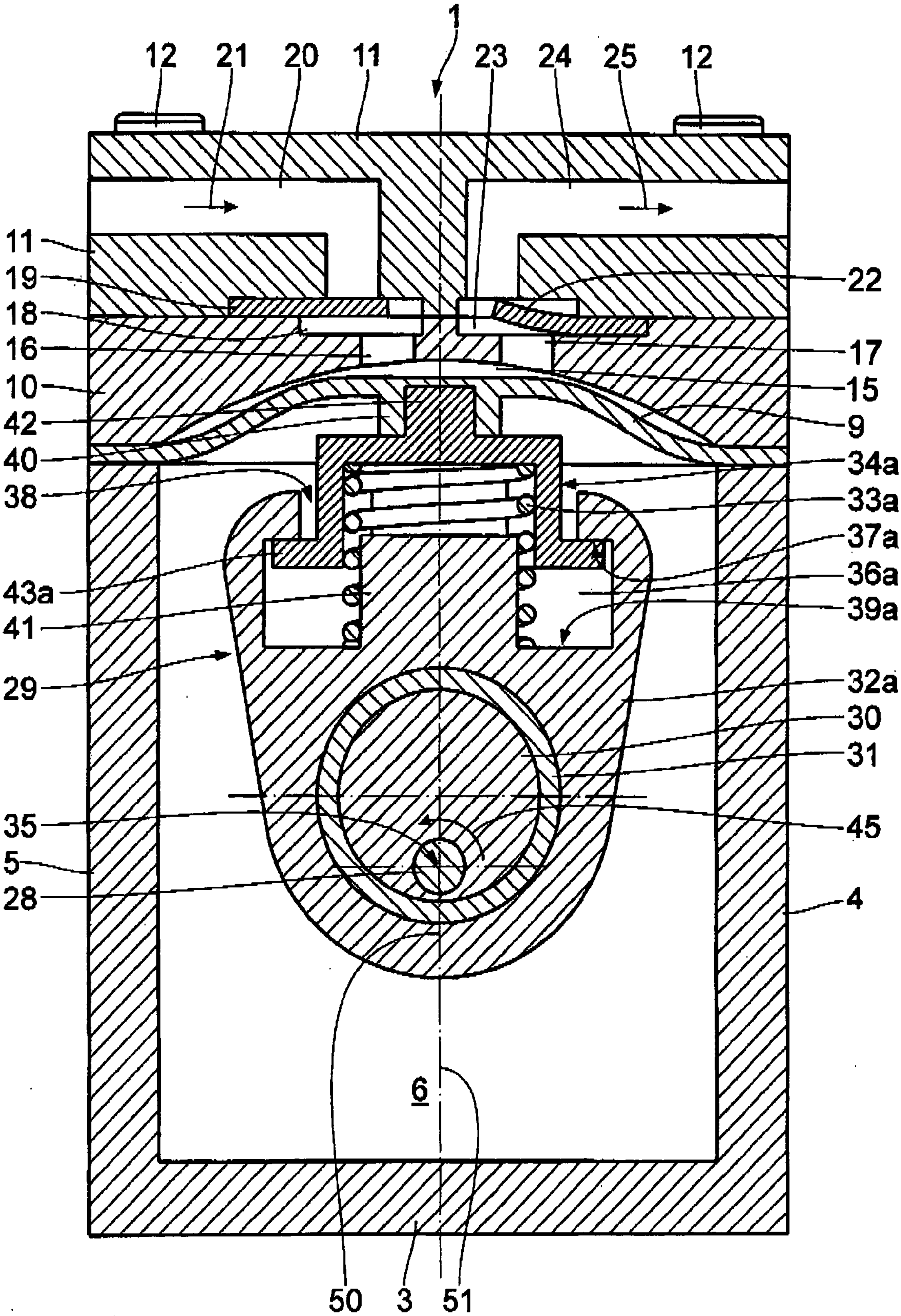
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Fig. 9

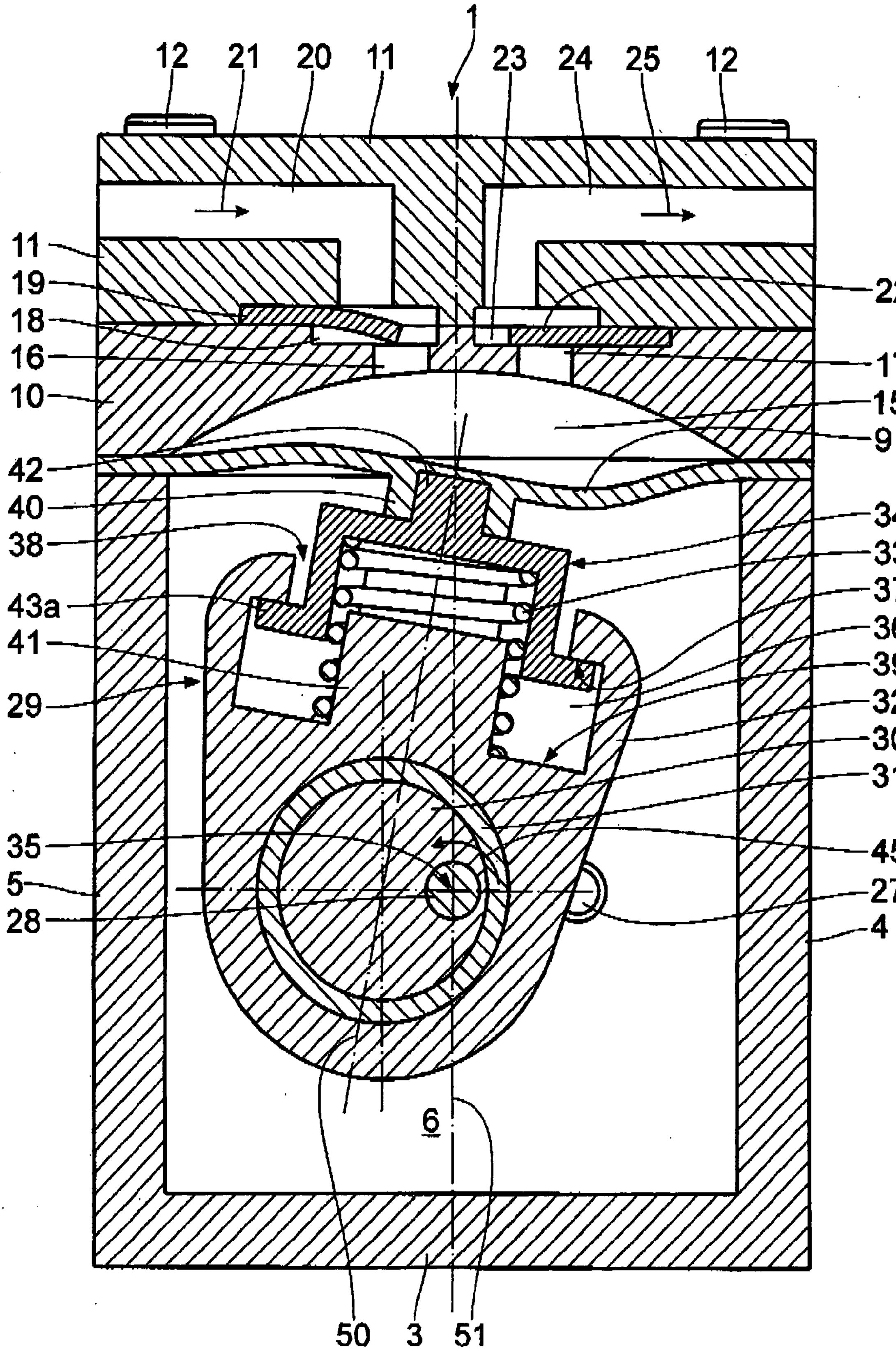
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Fig. 10

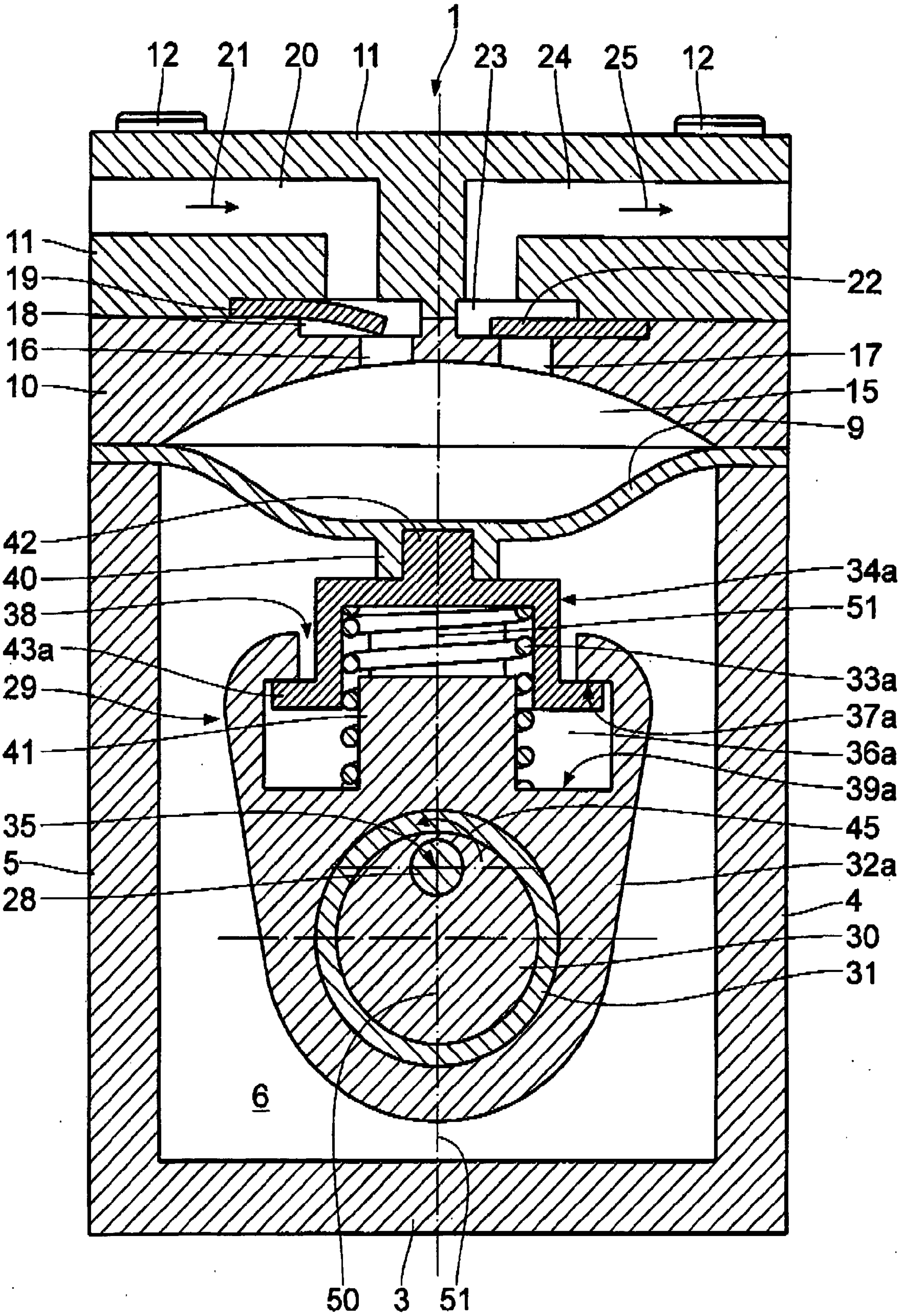
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Fig. 11

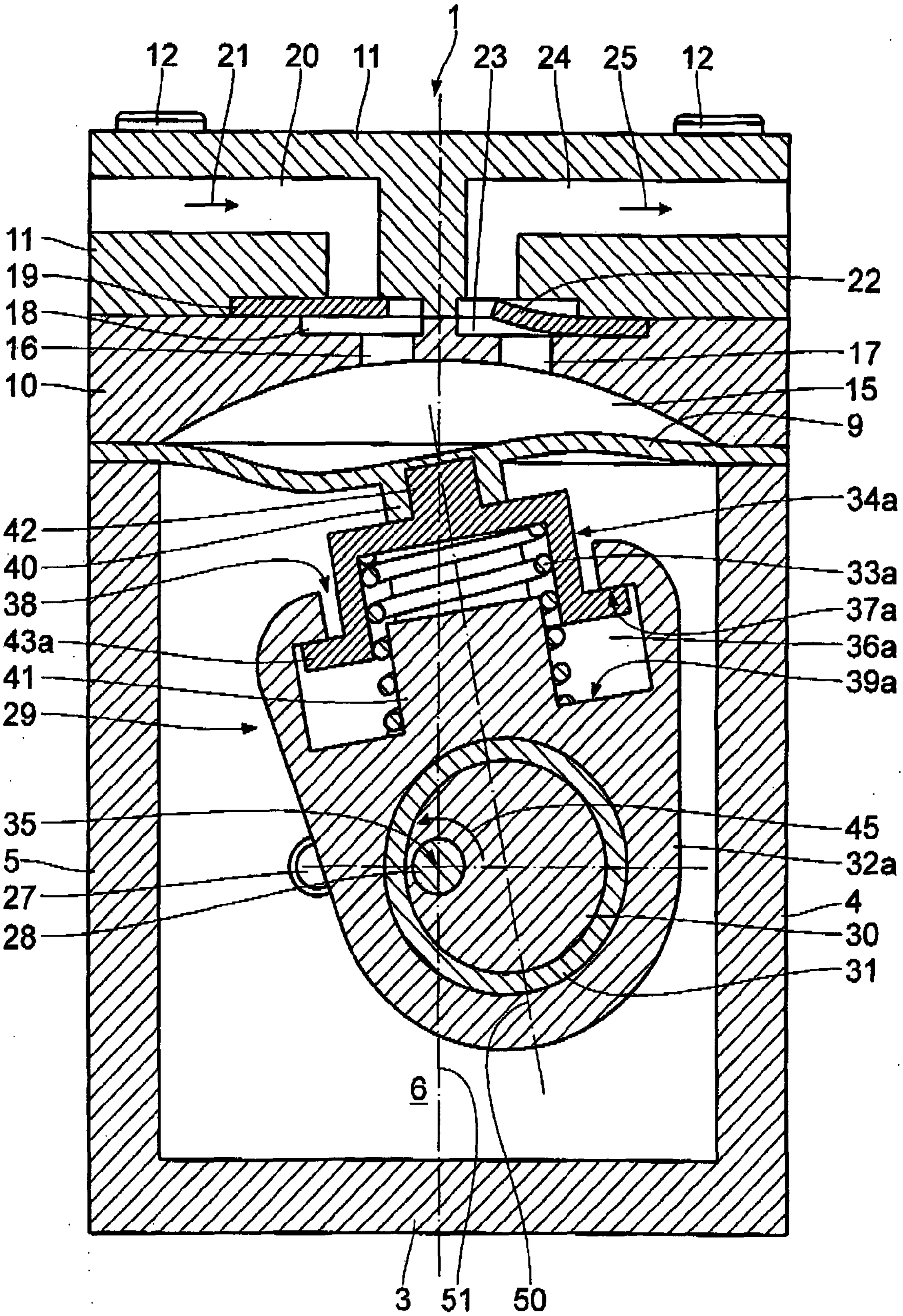
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Fig. 12

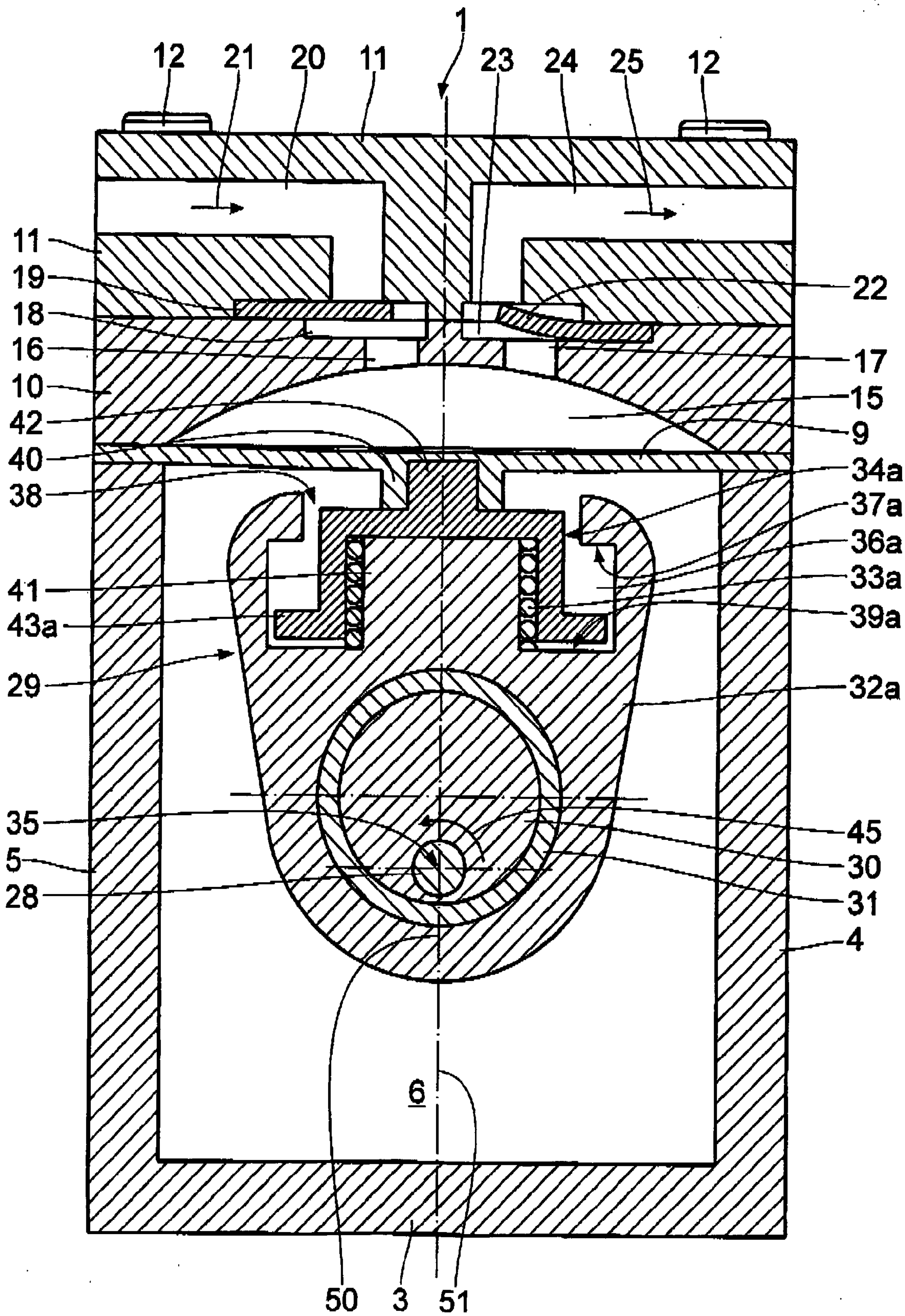
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Fig. 13

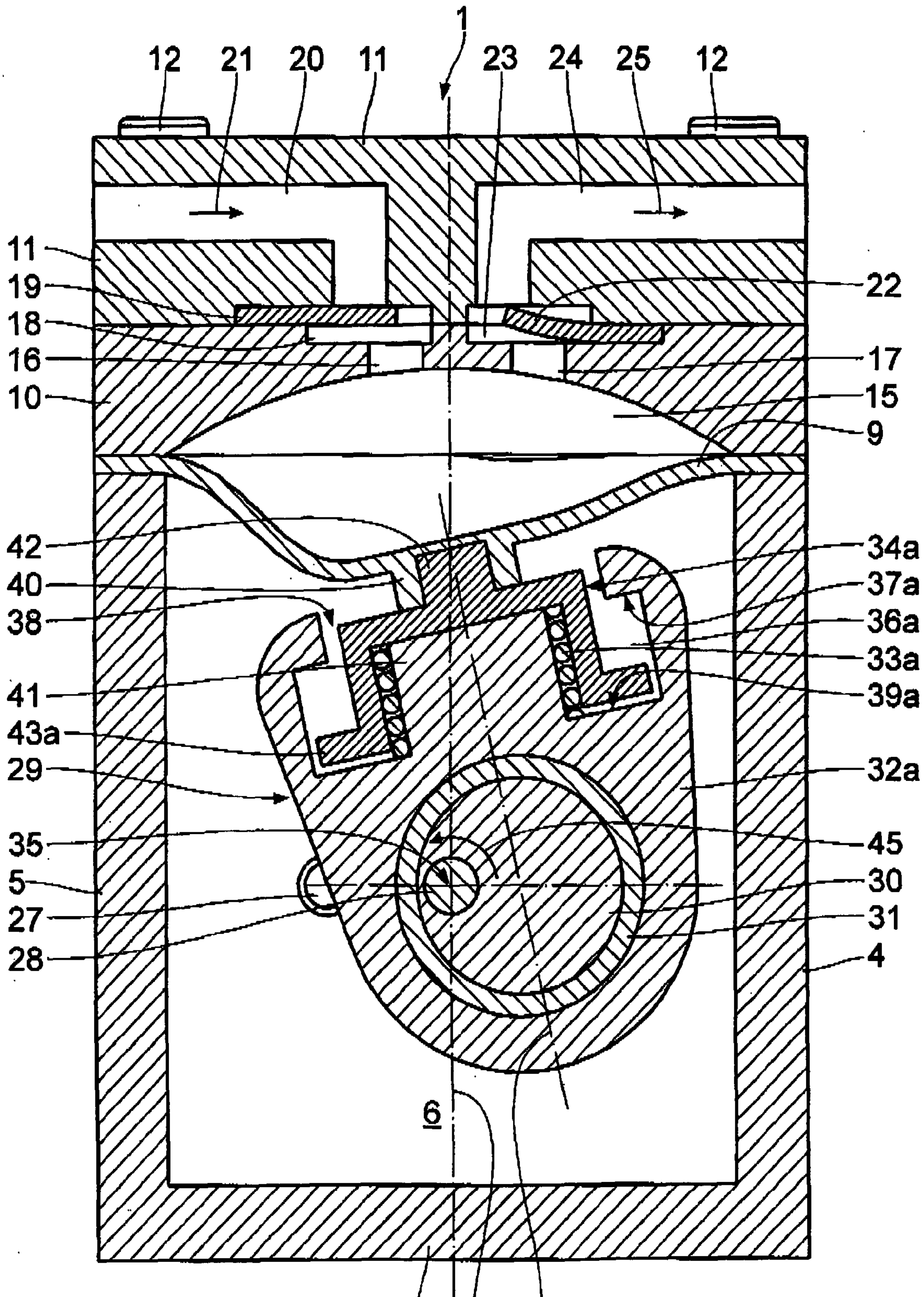
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Fig. 14

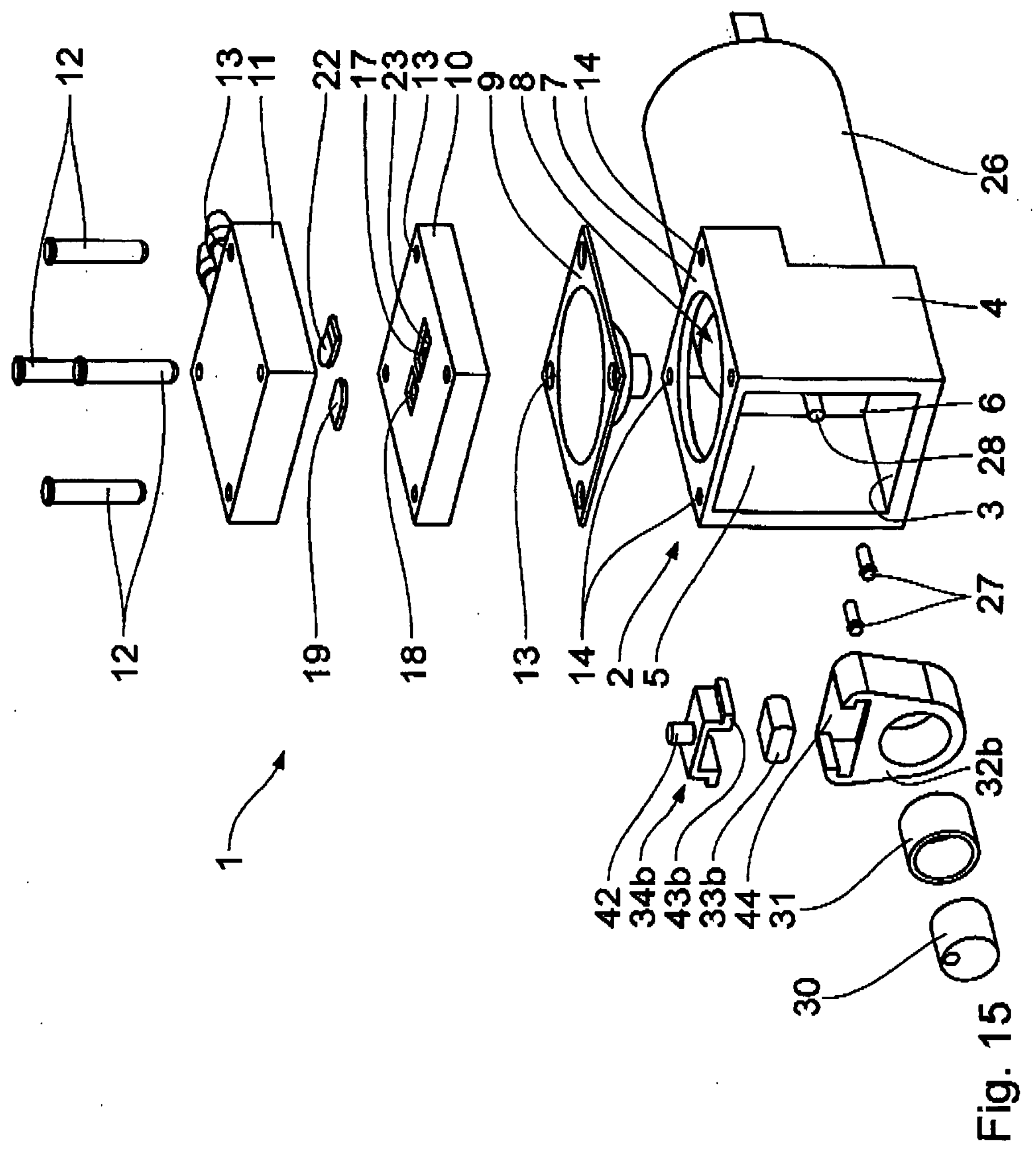
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Fig. 15

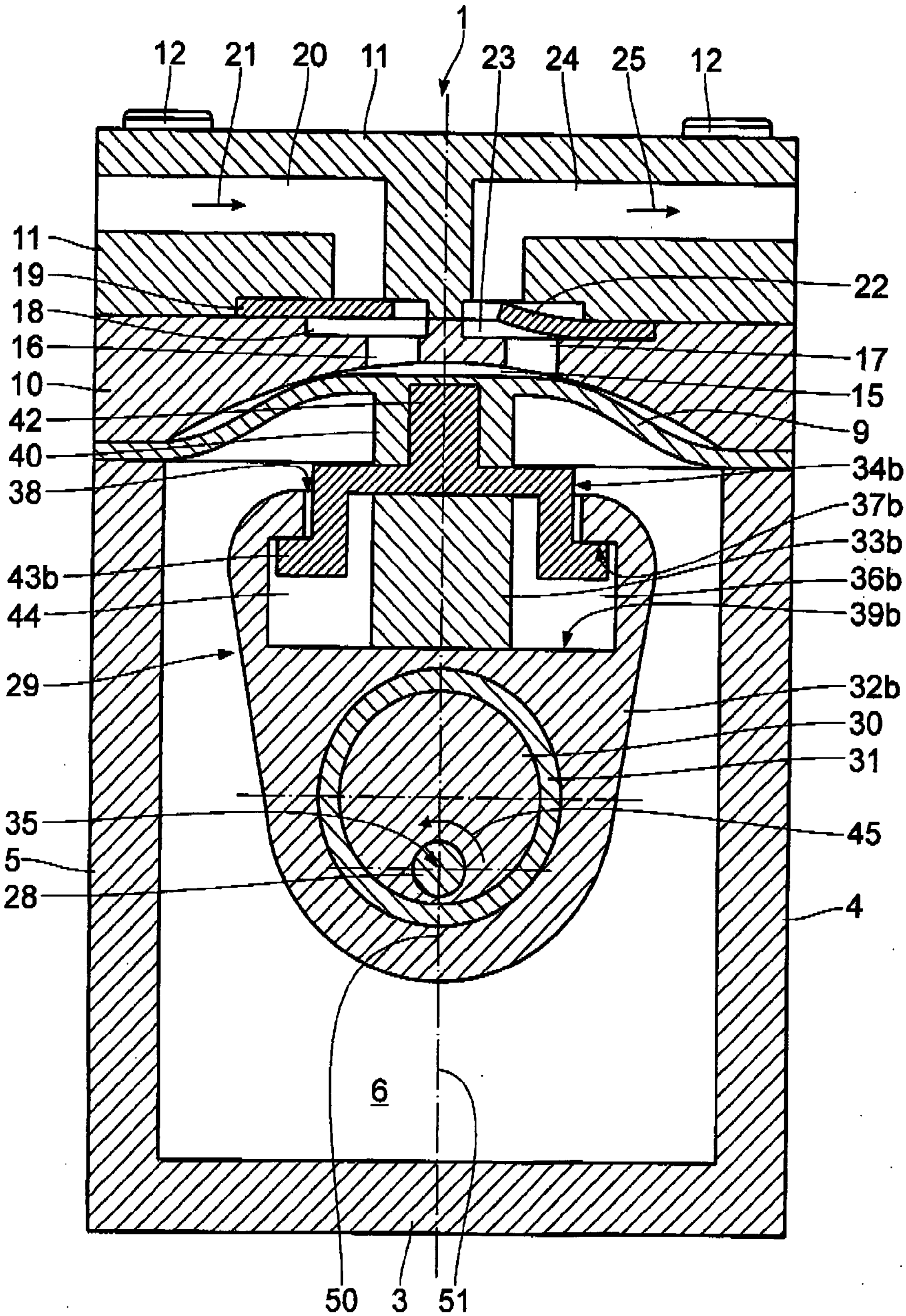
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Fig. 16

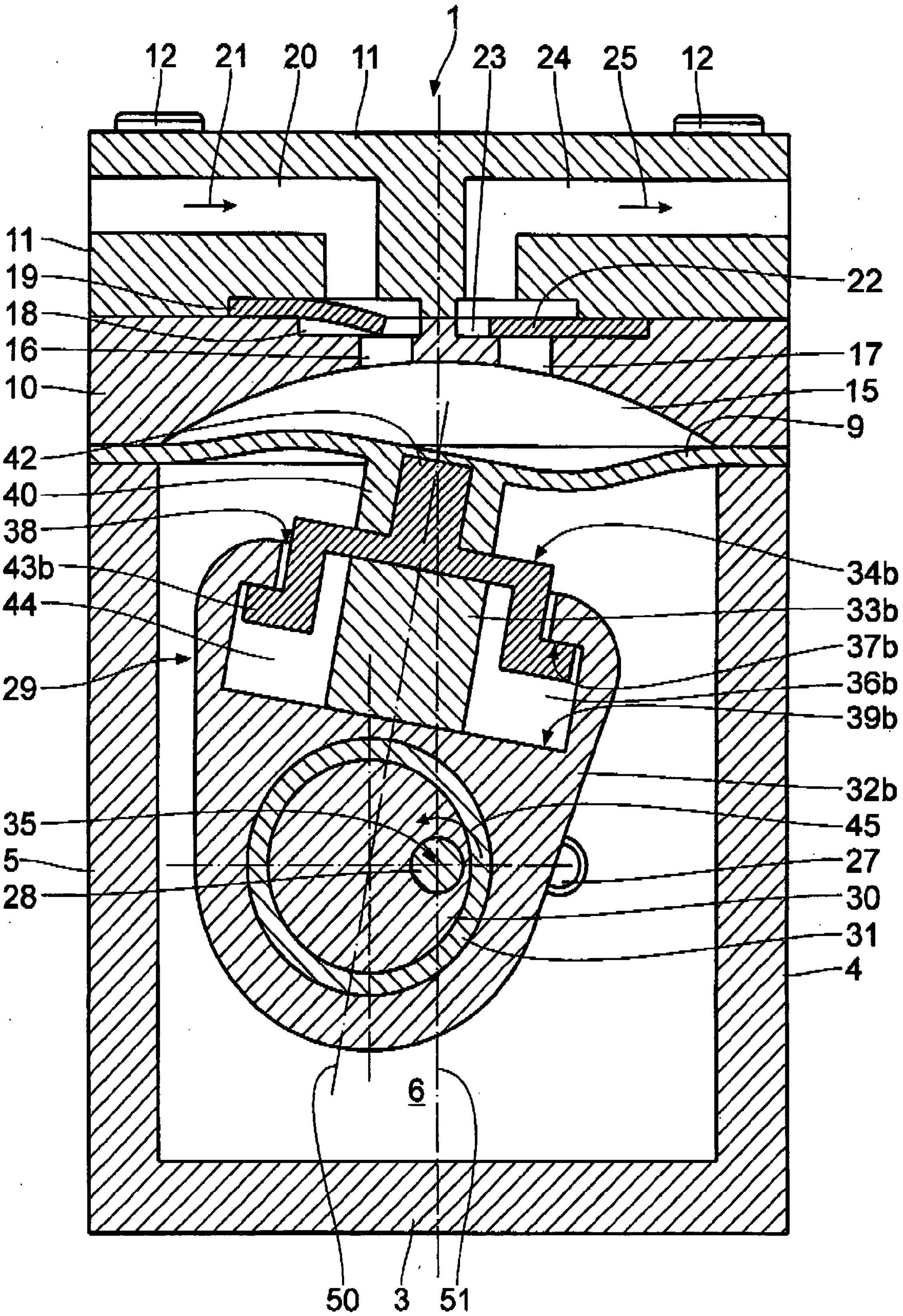
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Fig. 17

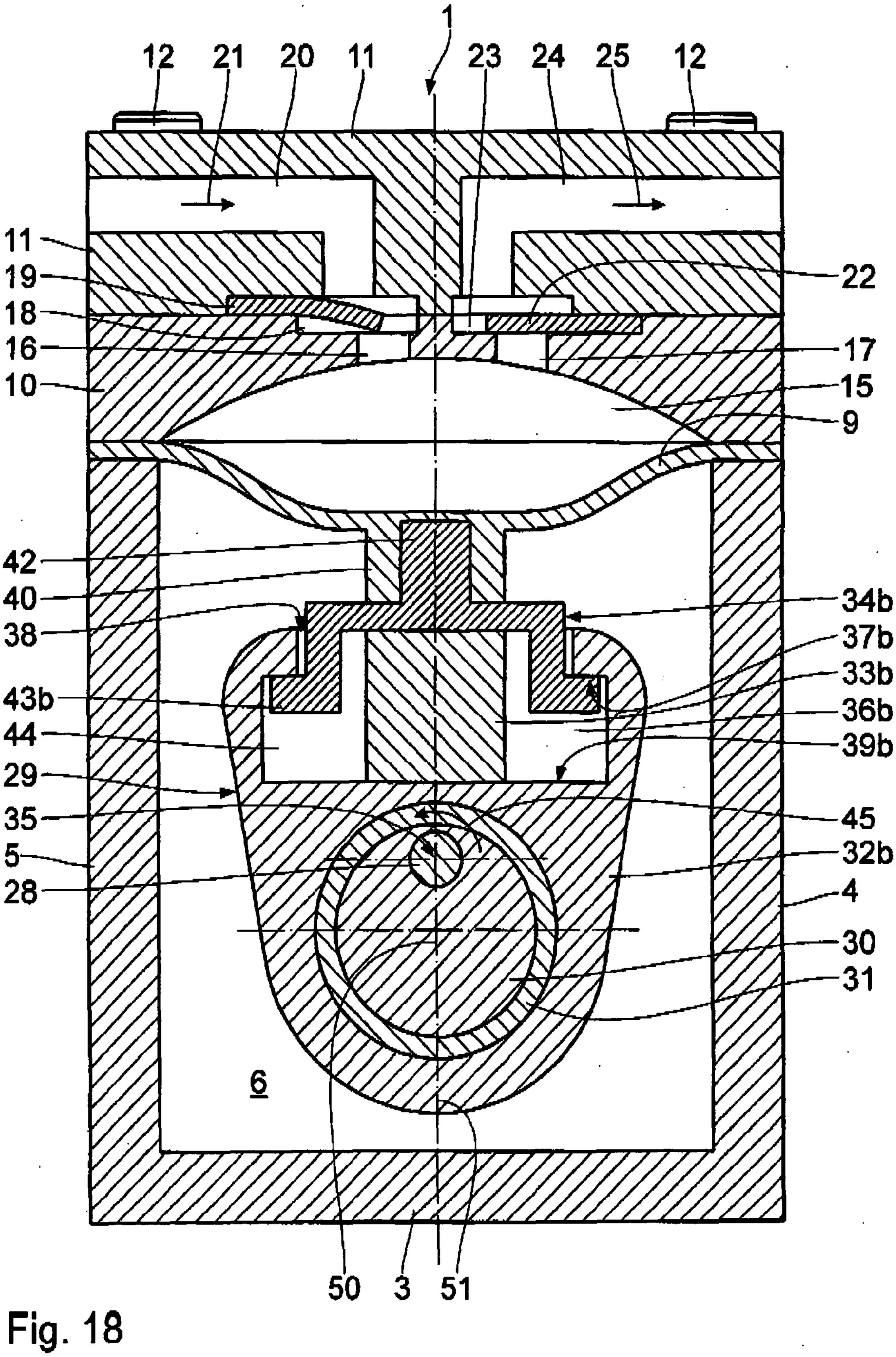
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Fig. 18

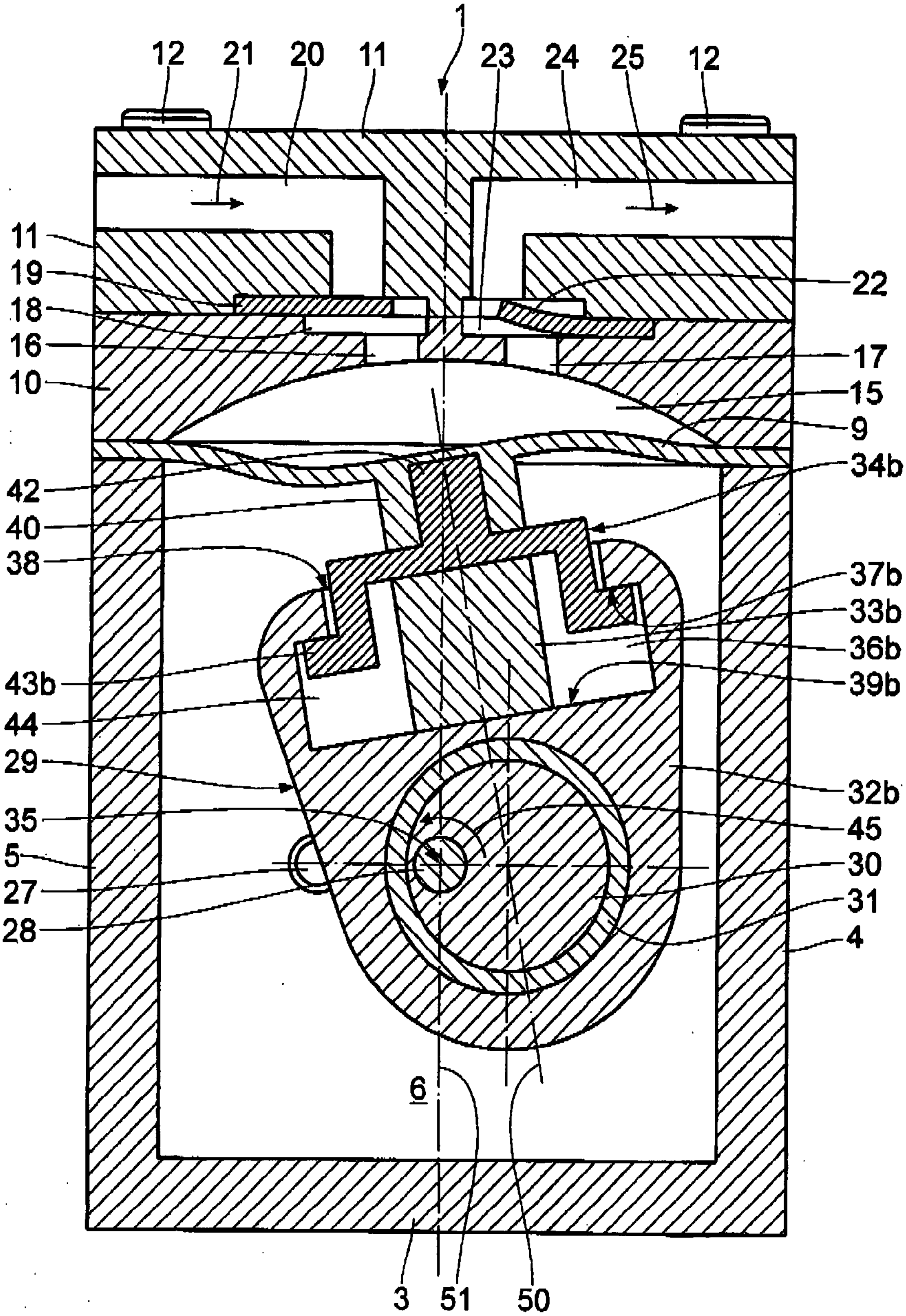
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Fig. 19

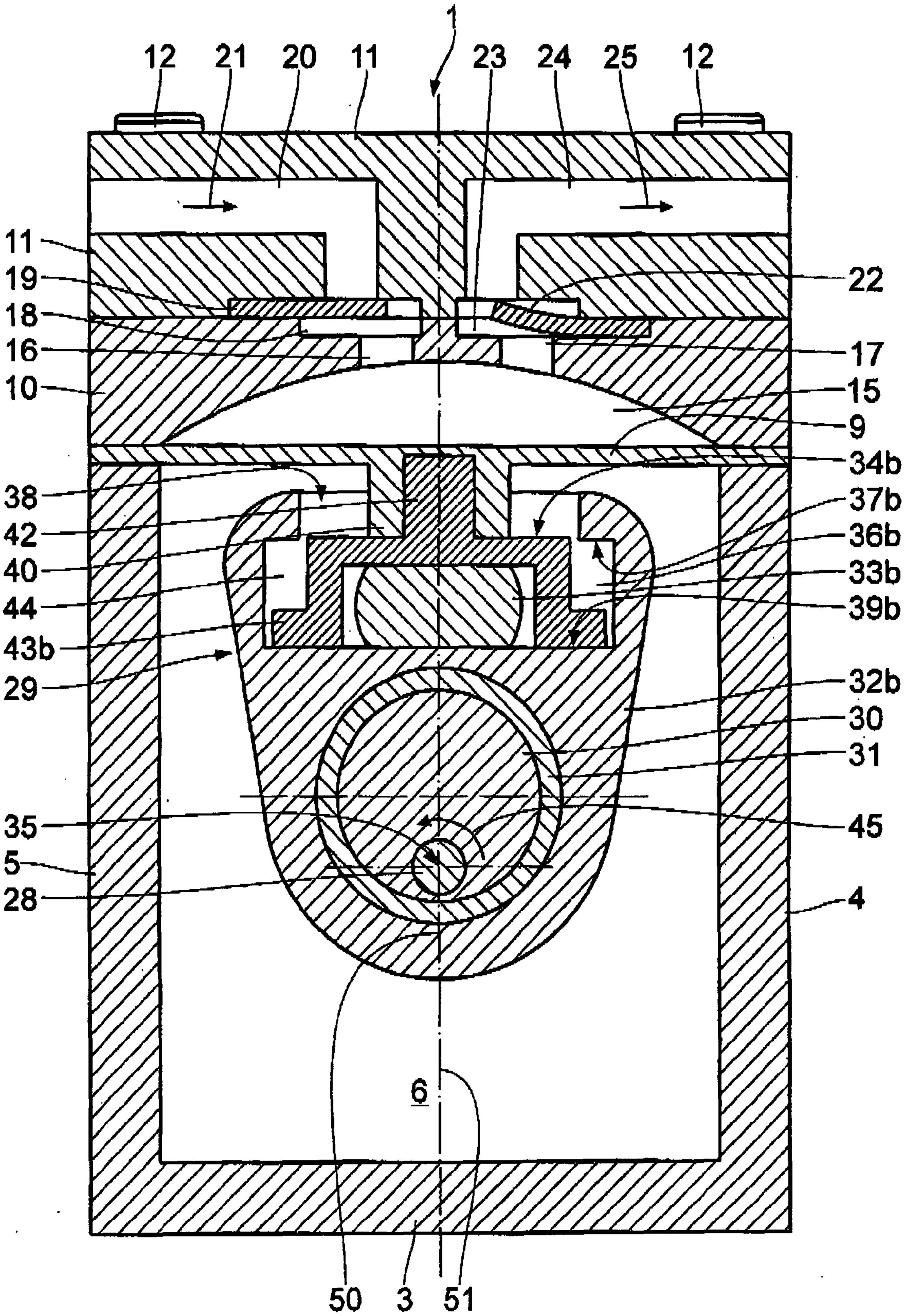
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Fig. 20

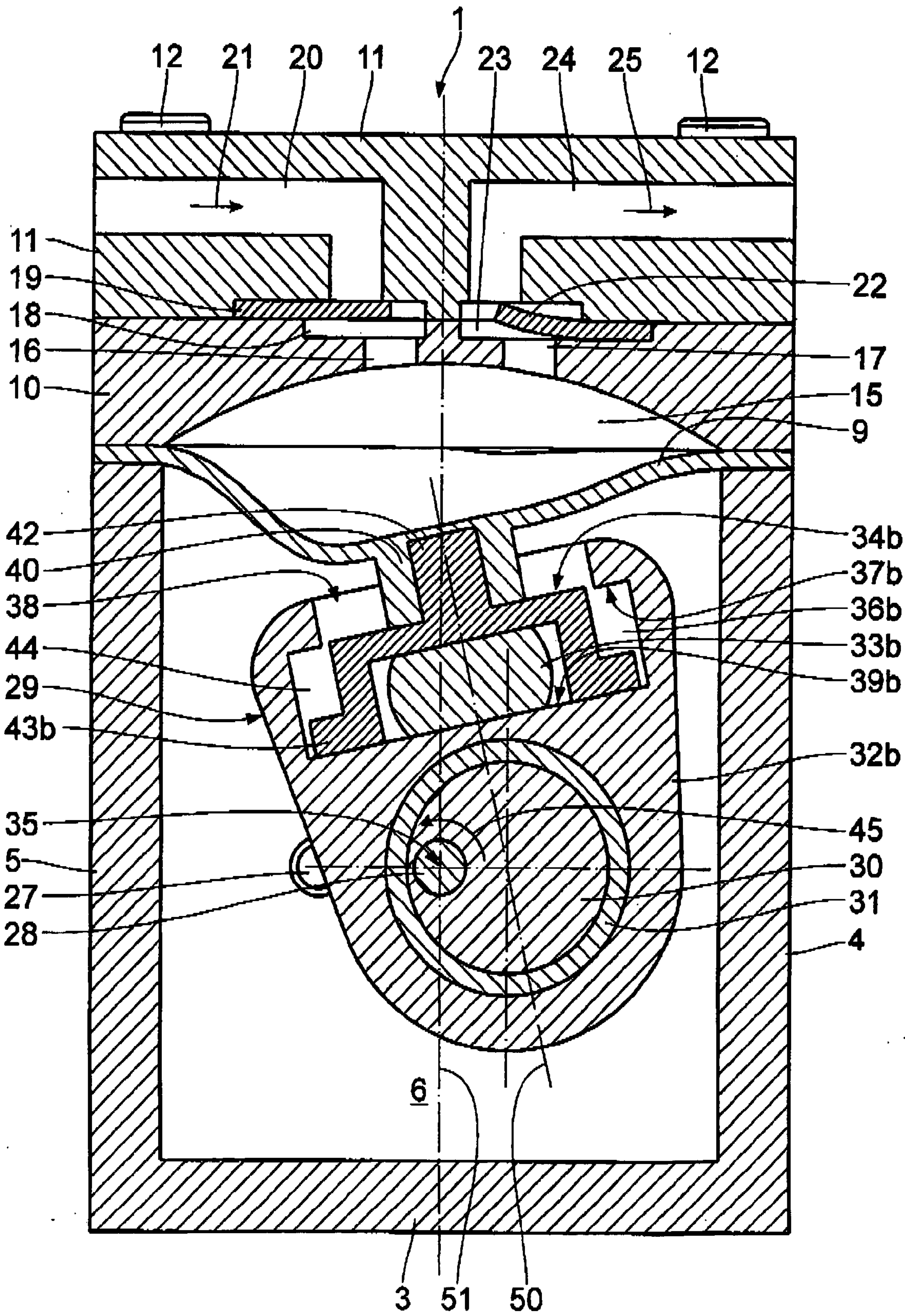
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Fig. 21

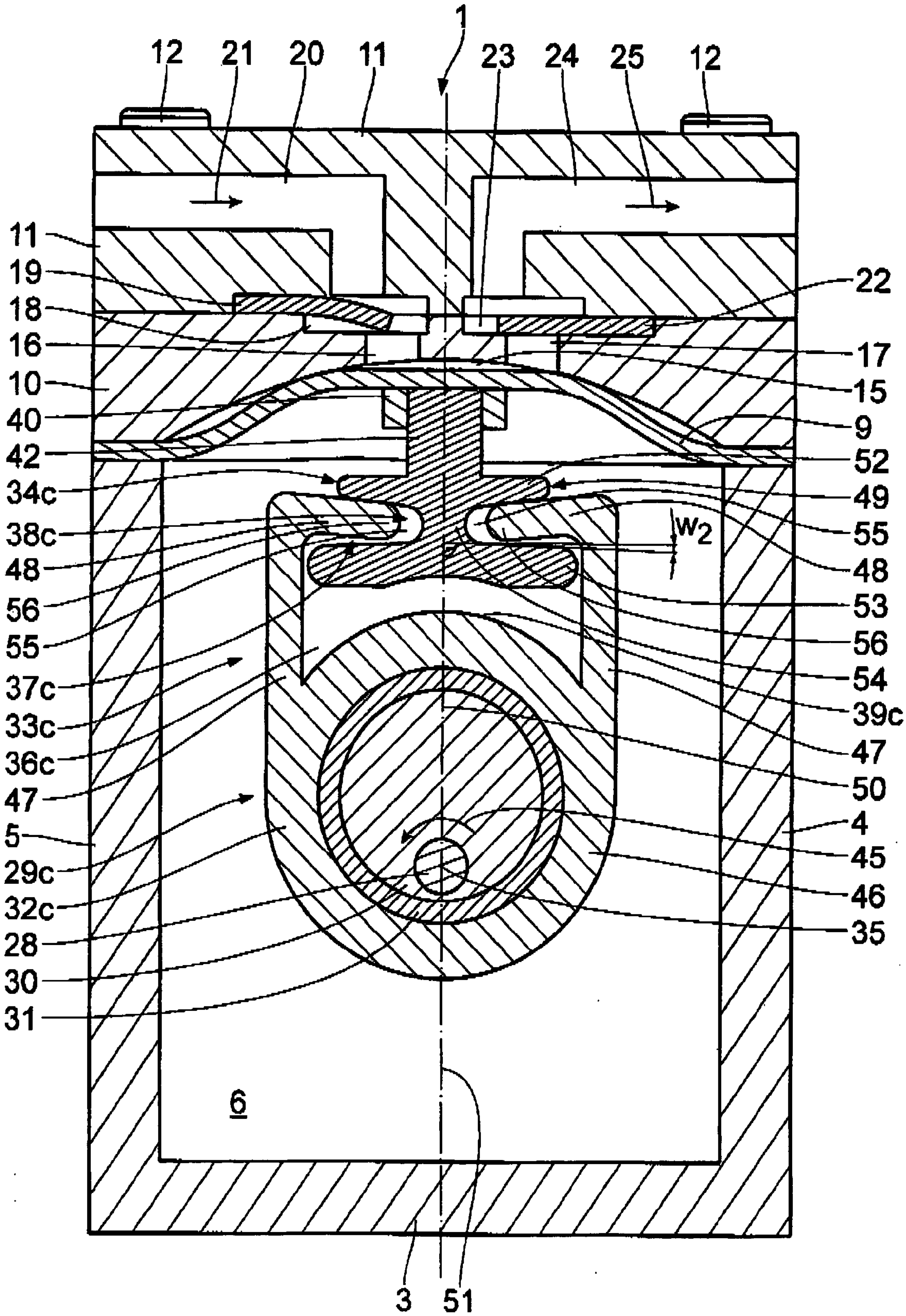
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Fig. 22

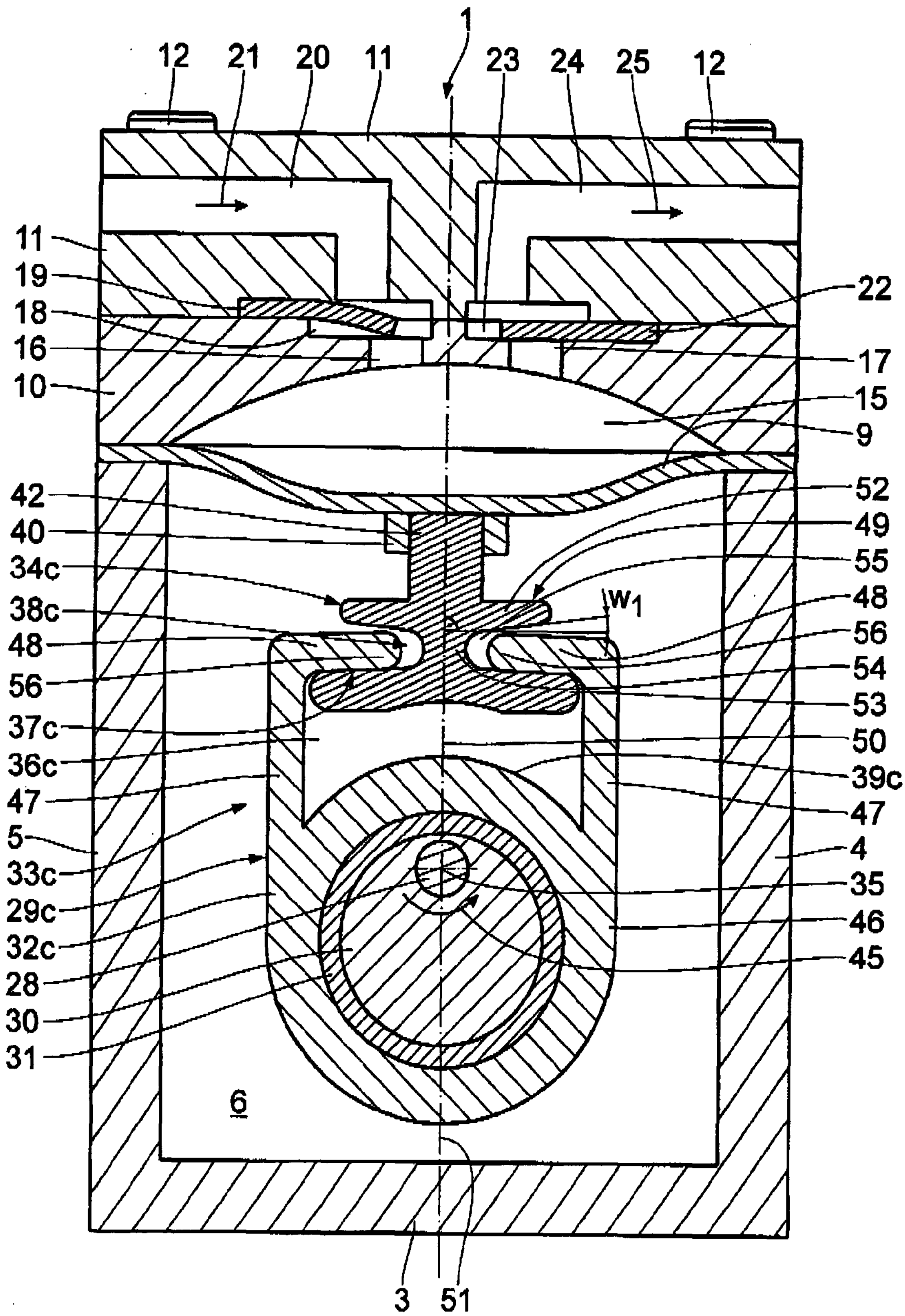
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Fig. 23