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(54) **POSITIVE-DISPLACEMENT ROTARY MACHINE**

(57) The positive-displacement rotary machine comprises a body, a rotor, a separator having a guiding part with an opening below the rotor, a piston which is mounted in a rotor groove so as to be able to carry out rotational oscillations relative to the rotor about an axis which intersects the axis of rotation of the rotor primarily at a right angle and has at least one slot into which the guiding part of the separator penetrates, and a spherical working cavity which is formed around the rotor and which is divided by the guiding part of the separator, upon interaction of the opening with the rotor, into chamber-forming cavities of variable cross section, each of which is divided by the piston into working chambers. A passage for a working fluid is provided in the minimum cross section of the chamber-forming cavity, and/or a duct permitting the working fluid to bypass the minimum cross section of the chamber-forming cavity is provided in the rotor. This makes it possible to change the character of the load and reduce wear of the piston and of the sealing synchronizing element, thus increasing the lifetime of the machine. Furthermore, said solution makes it possible to produce controllable variant embodiments of said machine.

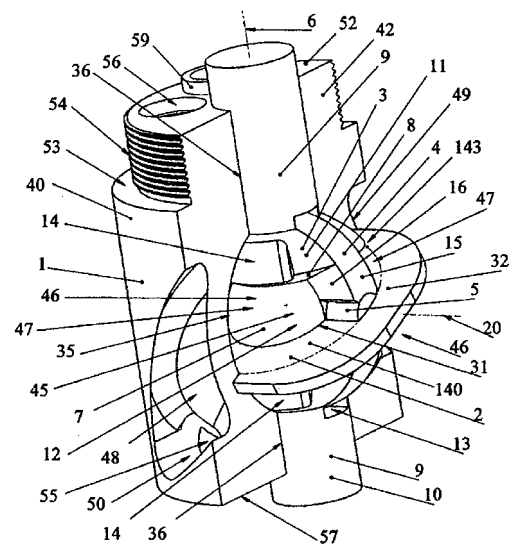


FIG.1

Description

Field of engineering to which the invention pertains

[0001] The invention pertains to machine-building, specifically to rotary positive-displacement machines, which can be used as pumps, compressors, hydraulic drives, including controllable ones.

State of the art

[0002] A positive-displacement rotary machine is known (GB 573278), containing a housing, a rotor and at least one piston, input and output ports of the working fluid.

[0003] The rotor has a working surface bounded by a surface of revolution and is installed in a housing with the capability of rotation.

[0004] At least one partially spherical working cavity is formed between the housing rotor, bounded by part of the sphere-like surface of the housing, the surface of the separator and the working surface of the rotor.

[0005] There is at least one groove in the rotor made mostly along the axis of rotation of the rotor on its working surface. The piston is installed in said rotor groove with the capability of rotary oscillations relative to the rotor. The piston emerging from the rotor groove has the capability of closing the working cavity.

[0006] The separator has the capability of rotating in the sphere-like working cavity to change the machine feed.

[0007] This machine has the following shortcomings. The piston has a nonsymmetric shape and unavoidable displacement of the center of mass from the axis of the rotary oscillations of the piston associated with this, leading to displacement of the center of mass from the axis of symmetry of the rotor during rotary oscillations of the piston, causing significant centrifugal forces that act on the center of mass of the piston and moments of forces around the axis of the piston caused by them. The latter load the friction pair piston-separator or, in the presence of a sealing synchronizing element (SSE) the frictions pairs piston-SSE-separator. The lifetime of the machine is dictated precisely by wear of these friction pairs.

[0008] Drawbacks also include cantilever fastening of the machine shaft in the presence of an uncompensated radial load on the free end of the rotor; nonconstant machine feed during one revolution of the shaft and the impossibility of obtaining uniform feed during parallel integration of several stages; impossibility of creating pressure with one stage in a variant with one piston; reduction of maximum pressure developed by the stage during use of two pistons owing to their weakening associated with the need for mutual overlap within the rotors; limited stroke of the pistons during use of two pistons, which reduces maximum feed and the control limits. Moreover, use of a common sealing synchronizing element (SSE) for two (several) pistons presumes the presence of elas-

tic elements, through which the piston interacts with the SSE, which limits the range of application of the machine.

[0009] A positive-displacement rotary machine is known (RU 2202695), containing a stator; working chambers; rotor installed with the capability of rotation; separator installed with the capability of rotation, in which the geometric axes of rotation of the rotor and separator intersect at an acute angle; input ports and output ports of the working fluid; in which the separator meshes with the rotor through the sealing synchronizing element (SSE) having a through slot through which the rotor passes.

[0010] This positive-displacement rotary machine has a symmetrically loaded SSE, two of its stages during parallel operation can ensure almost uniform feed, but it has increased dimensions (diameter) owing to the groove, which makes rotation of the separator possible. The diameter is additionally increased owing to the need to introduce two channels for the working fluid that bypass this groove for connection of the working chambers and stages. The possibility of concentration of abrasive by centrifugal forces in this groove is also a shortcoming.

[0011] A positive-displacement rotary machine is known (RU 2382884), containing a housing with a sphere-like internal working surface, arbitrarily divided into bypass and pressure parts, a rotor with a working surface of revolution installed in the housing with the capability of rotation, an annular working cavity formed by the working surfaces of the housing and rotor, a C-shaped separator installed in part (along the rotation path of the rotor) of the annular working cavity at an angle to the plane of rotation of the rotor and fastened immobile to the housing, in which the working cavity is divided by the separator into two parts in the bypass part of the housing, and input and output ports of the working fluid are positioned on different sides of this separator, at least one groove being made on the working surface of the rotor mostly along the geometric axis of rotation of the rotor, a piston is installed in each groove of the rotor with the capability of closing off (sealing) the working cavity and executing rotary oscillations in the plane of the groove, the piston being designed in the form of at least part of a disk and there is at least one slot in each piston for passage of the separator and also means for closing off the slots of the piston on the pressure section of the housing.

[0012] In the annular (circular) sphere-like working cavity formed in the housing around the rotor, the working chambers are closed off by the piston and separator during its interaction with the conical surface on the rotor, since the working cavity is divided by the separator into two parts in the bypass part of the housing.

[0013] This positive-displacement rotary machine has reliable synchronization, a symmetric balanced piston, working devices having a high safety factor, almost strictly uniform feed even with one stage.

[0014] However, the maximum pressure withstood by one stage and the lifetime are limited by the wear resistance of the friction pair SSE-piston owing to loading of

the SSE by the pressure drop of the stage. Since the main support surfaces of the SSE are situated within the part of the piston not emerging from the rotor and loading by the pressure drop falls within the part of the SSE situated in the piston slot, the specific pressure on the support surface is somewhat greater than the pressure drop of the stage.

[0015] The resultant of forces acting on the piston from the pressure of the working fluid, which creates torque around the rotor axis, is applied farther from the rotor axis than the resultant of forces developing in the piston support (in the rotor groove). The load arm is therefore greater than the support arm, which increases the specific pressure in the support in comparison with the pressure drop of the stage, which reduces the lifetime of the friction pair piston-rotor groove.

[0016] Moreover the positive-displacement rotary machine does not have a controllable version.

[0017] A positive-displacement rotary machine is known (RU 2376478), containing a housing, the working surface of which is designed in the form of part of a spherical segment, a rotor with a working surface of revolution installed in the housing with the capability of rotation, an annular concentric working cavity, formed by the housing and rotor, a separator, designed in the form of an inclined disk, installed fixed in the housing at an angle to the geometric axis of rotation of the rotor and dividing the working cavity into two parts, at least one groove being made on the working surface of the rotor along its geometric axis of rotation, a piston is installed in the rotor with capability of closing off (sealing) the working cavity and executing rotary oscillations around its geometric axis, which intersects the geometric axis of the rotor, the piston being designed in the form of at least part of a disk, and there is at least one sealed groove in each piston for passage of the separator. In the variant with one piston the input and output ports of the working fluid are adjacent to the point of contact of the ends of the separator with the rotor.

[0018] This positive-displacement rotary machine has reliable synchronization.

[0019] However, the drawbacks of the preceding prior art are inherent to it. Specifically, the maximum pressure withstood by one stage and the lifetime are limited by the wear resistance of the friction pair SSE-piston owing to loading of the SSE by the pressure drop in the stage.

[0020] Similarly, the resultant of forces acting on the piston from the pressure of the working fluid creates a torque around the axis of the rotor, whereas the moment of forces of the support in this direction is minimal owing to the geometry of the rotor. Moreover, the positive-displacement rotary machine has a pulsating feed, which cannot be converted to strictly uniform feed, establishing several parallel stages.

[0021] This positive-displacement rotary machine is the closest prior art.

[0022] The task of the invention is to reduce the load on the friction pairs to increase lifetime and the working

pressure drop on the stage in the PDRM with sphere-like working chamber and piston, which executes rotary oscillations relative to the rotor, in their uncontrollable and controllable version.

[0023] The task of the invention is functionally achieved in that the working chambers in the annular (circular) sphere-like working cavity formed in the housing around the rotor are closed off by the separator and piston, ruling out participation of the conical surface of the rotor. For this purpose either a gap sufficient for passage of the working fluid is left between the ends of the guide part of the separator and rotor (its conical surface or the surface replacing it), or channels are made on the rotor that ensure passage of the working fluid between the parts of the working chamber and/or from the chamber to the input and output ports. The location of the input and output ports is changed accordingly,

[0024] During operation with a relatively incompressible liquid, when the sphere-like cavity of the housing is made on the surface, the ports are situated in the region of maximum slope angle of the separator, in contrast to the location of the ports in the prior art, where they are adjacent to a site of contact of the ends of the separator with the rotor. During operation with a compressible liquid the ports of one of the types (input or output) are reduced and the restriction on their position becomes less strict.

[0025] This change means that in the case of a symmetric variant the resultant of forces and the moments of forces from the pressure of the working fluid on the SSE become equal to zero; the resultant of forces from the pressure of the working fluid on the piston also becomes equal to zero and the total moment of forces from the pressure of the working fluid on the piston mostly acts in the plane passing through the axis of rotation of the rotor (i.e., around the axis perpendicular to the axis of rotation of the rotor). In this plane the arm of forces is significantly smaller than the arm of the support (forces applied close to the axis of the SSE, and the main area of support is concentrated close to the diameter of the piston within the rotor slot), for which reason weakening of the specific load on the friction pair piston-rotor slot occurs, and not an increase, as in the prior art.

[0026] The task of the invention is achieved in that the positive-displacement rotary machine contains a housing;

a rotor, installed in the housing with the capability of rotation;

a separator, installed in the housing, having a guide part with a hole for the rotor;

a piston, installed in the groove of the rotor with the capability of accomplishing rotary oscillations relative to the rotor around an axis that intersects the axis of rotation of the rotor mostly at a right angle, having at least one slot for passage of the guide part of the separator,

a sphere-like working cavity, formed around the rotor, which the guide part of the separator, during interaction of the hole with the rotor, divides into chamber-forming cavities of variable cross section, each of which is divided

by the piston into working chambers, in which in the minimal cross section of the chamber-forming cavity between the end surfaces of the guide part of the separator and rotor there is a passage for the working fluid and/or there is a channel in the rotor that permits the working fluid to bypass the minimal cross section of the chamber-forming cavity; input and output ports of the working fluid.

[0027] The task of the invention is achieved in that the positive-displacement rotary machine contains a housing; a rotor, installed in the housing with capability of rotation; a separator installed in the housing, having a guide part with a hole for the rotor; a piston, installed in the rotor groove with capability of accomplishing rotary oscillations relative to the rotor around an axis that intersects the axis of rotation of the rotor mostly at a right angle, having at least one slot for passage of the guide part of the separator;

a sphere-like working cavity formed around the rotor, which is divided into two parts by the guide part of the separator during interaction of the hole with the rotor, each of which is divided by the piston into working chambers;

input and output ports of the working fluid, in which at least one of the ports is adjacent in angular position to the location of maximum slope of the guide part of the separator.

The task of the invention is achieved in that the positive-displacement rotary machine contains a housing, a rotor installed in the housing with capability of rotation, having a groove mostly along its axis of rotation,

a separator, having a guide part with hole for passage of the rotor, installed in the housing,

a piston, having two slots for passage of the guide part of the separator, installed in the groove of the rotor with the capability of accomplishing rotary oscillations relative to the rotor, during interaction with the guide part of the separator,

a sphere-like working cavity, formed around the rotor, which is divided into two parts by the guide part of the separator, each of which is divided into two working chambers by the piston,

input and output ports of the working fluid

in which channels emerge from each chamber for passage of the working fluid, made in the rotor with the capability of its connection to the input and output ports.

[0028] The task of the invention is achieved in that the input and output ports of the working fluid are situated in the zone of interaction with the rotor and there are channels on the rotor made with the capability of connection of the working chambers with the input and output ports, which permits that pressure to be maintained with one stage during use of one piston.

[0029] The task of the invention is achieved in that the piston contains at least one sealing synchronizing element installed in the slot, through which it interacts with the guide part of the separator.

[0030] The task of the invention is achieved in that the

sealing synchronizing element is installed in the piston with the capability of rotation relative to the axis perpendicular to the axis of the piston.

[0031] The task of the invention is achieved in that the guide part of the separator is installed in the housing at a fixed angle to the axis of rotation of the rotor.

[0032] The task of the invention is achieved in that the separator is installed in the housing with the capability of changing the slope of the guide part to the axis of rotation of the rotor to control machine feed.

[0033] The task of the invention is achieved in that the separator changes the slope of the guide part to the axis of rotation of the rotor, rotating around an axis perpendicular to the axis of rotation of the rotor.

[0034] The task of the invention is achieved in that the separator is made with a shell.

[0035] The task of the invention is achieved in that the separator with at least one stage is supplemented with a shell with a sphere-like cavity.

[0036] The task of the invention is achieved in that the guide part is situated at an angle relative to the shell and changes its slope to the axis of rotation of the rotor by rotation of the shell around an axis passing at an angle to the axis of rotation of the rotor.

[0037] The task of the invention is achieved in that a sleeve is installed in the housing on which the input and output ports of the working fluid are positioned, the machine being equipped with a mechanism to rotate the separator and sleeve.

[0038] The task of the invention is achieved in that the separator changes the slope of the guide part to the axis of rotation of the rotor by rotating around a point - the center of the sphere-like working cavity.

[0039] In this case the loading of the SSE by the pressure in the working fluid is fully symmetric, which significantly reduces the load on the friction pair SSE-piston. The operating conditions of the friction pair piston-rotor are additionally improved. Because of the changed nature of the load (direction, cyclicity), the possibility of hydrodynamic unloading of the piston appears (effective, if the rotational speed of the rotor is not reduced below minimal) and in another variant full hydrostatic unloading of the piston (effective at any speed).

[0040] All this permits an increase in maximum pressure created by the stage during operation with abrasive. Even allowing for the need to use a double number of stages (parallel) to obtain uniform feed, with the same number of stages it is possible to obtain several-fold higher pressure while ensuring similar lifetime or greater lifetime at a pressure equal to the best prior art (RU 2382884). Use of one piston in the stage permits a stronger rotor, piston and SSE to be obtained, which increases reliability and safety margin of the machine. Moreover, in the new configuration it was possible to develop a reliable, controllable machine in the submersible multi-stage variants.

[0041] The nonobviousness of the solution is explained by the presence of a number of modifications and

directions of development of production machines with a sphere-like chamber, separator and piston, installed with the capability of rotary oscillations relative to the rotor, which satisfy individual requirements of the posed task but do not solve the task fully. To solve the task it was necessary to dispense with existing achievements (for example, uniform feed in one stage, multipiston variants), and make a step back to the two-stage variant with one piston in the stage and to alter the location of the ports.

The invention is explained by means of drawings.

[0042]

Figure 1 shows an isometric projection of the stage of a multistage positive-displacement rotary machine (PDRM). The housing part is removed.

Figure 2 shows an isometric projection of the part of the rotor corresponding to one stage of the PDRM.

Figure 3 shows an isometric projection of the piston of the PDRM.

Figure 4 shows an isometric projection of the sealing synchronizing element (SSE).

Figure 5 shows an isometric projection of the separator.

Figure 6 shows an isometric projection of the part of the housing visible in Figure 1.

Figure 7 shows an isometric projection of the part of the housing absent in Figure 1.

Figure 8 shows an isometric projection of a section of a multistage PDRM, consisting of two hydraulically parallel stages press-fit into a tube. Part of the tube is removed for clarity.

Figure 9 shows an isometric projection of a hydraulically unloaded piston combined with SSE.

Figure 10 shows an isometric projection of part of the housing of the stage made with the capability of feed regulation.

Figure 11 shows an isometric projection of the turnable shaft of the separator.

Figure 12 shows an isometric projection of the separator used with the turnable shaft according to Figure 11.

Figure 13 shows an isometric projection of two hydraulically parallel stages on a controllable PDRM

with the turnable shaft of the separator.

Figure 14 shows an isometric projection of two stages of a controllable PDRM with a sphere-like shell of the separator. Nearby parts of the housings are removed.

Figure 15 shows an isometric projection of two stages of a controllable PDRM according to Figure 14. All parts are removed except for the distant parts of the housings, the separator halves with shell and rack.

Figure 16 shows an isometric projection of two stages of a controllable PDRM according to Figure 14. External view with channels for a working fluid.

Figure 17 shows an isometric projection of the turnable separator.

Figure 18 shows an isometric projection of part of the housing with groove for the turnable separator.

Figure 19 shows an isometric projection of a stage using a turnable separator. External view. Rack, channels are visible.

Figure 20 shows an isometric projection of the turnable sleeve.

Figure 21 shows an isometric projection of the scheme of feed control of the PDRM. Two rotor stages with turnable separators, sleeve and rack are shown.

Figure 22 shows an isometric projection of the turnable sleeve with rack and their meshing by means of a tooth and helical groove.

Figure 23 shows an isometric projection of a variant of a turnable separator installed with the capability of rotation around a point.

Figure 24 shows an isometric projection of part of the housing with a groove for the rack operating with the turnable separator according to Figure 23.

Figure 25 shows an isometric projection of the second part of the housing according to Figure 24.

Figure 26 shows an isometric projection of the stage operating with a turnable separator according to Figure 23. Part of the housing without a groove for the rack is removed.

Figure 27 shows an isometric projection of two hydraulically consecutive stages of a PDRM that creates a pressure drop only in parts of the cycle. The

nearby parts of the housing are removed.

Figure 28 shows an isometric projection of part of the housing of the PDRM according to Figure 27.

Figure 29 shows an isometric projection of the external form of the PDRM according to Figure 27.

Figure 30 shows an isometric projection of the external form of the PDRM according to Figure 27 on the opposite side.

Figure 31 shows an isometric projection of two hydraulically consecutive stages of a controllable PDRM in the "above-ground" version. Half of the middle and half of the end part of the housing are cut off.

Figure 32 shows an isometric projection of a piston with grooves to increase the support area.

Figure 33 shows an isometric projection of the rotor used with the piston according to Figure 32.

Description of embodiment

[0043] To simplify the description we will introduce some definitions.

[0044] Closing off is understood to mean sliding contact or the presence of a small gap.

[0045] Sphere-like surface is understood to mean a surface similar to a sphere or part of a sphere, permitting slight deviations from an ideal sphere, related to imprecision of manufacture, the need to ensure working gaps, with the design of seals, gaps to reduce viscous friction, etc.

[0046] Sphere-like cavity is understood to mean a cavity in which at least one of the surfaces bounding it is a sphere-like surface.

[0047] One or more sections of a surface of one part with a working gap from which during operation there is a constant or periodic possibility of finding the surface of the second part will be called a region of interaction of two parts.

[0048] The gap between two parts in which they have the capability of relative movement but leaks of the working fluid through it are absent or within admissible limits for the given device owing to the smallness of the gap or owing to positioning of sealing elements in it will be called working gap.

[0049] We will state that two parts interact with each other, if they have a region of interaction in them.

[0050] One or several sections of the surface of one part along which it interacts with other parts to cut off the volume will be called working surface of the part.

[0051] A chamber-forming surface is a surface bounding a working cavity.

[0052] A working cavity is a bounded volume divided into working chambers by the piston and separator.

[0053] A chamber-forming cavity is a bounded volume in which the piston moves, dividing it into working chambers. Passages for the working fluid will be considered separate elements for convenience of the description.

[0054] Passages of different shape for the working fluid made within or along the surface of a part, for example, holes, grooves, cavities obtained by casting or other methods will be called channels.

[0055] The stage of a PDRM (Figure 1) which can also be used as an individual pump, contains a housing 1 with separator 2, rotor 3 and piston 4. A sealing synchronizing element 5 (SSE) is part of piston 4.

[0056] The chamber-forming surface of rotor 3 (Figure 2) is designed in the form of a surface of revolution and consists of several surfaces concentric to geometric axis 6 of rotation of rotor 3: a central sphere-like surface 7, two identical truncated conical surfaces 8 supported on opposite sides on the central sphere-like surface 7 with their smaller bases. On both sides of the chamber-forming surface along axis 6 of rotor 3 there are cylindrical surfaces 9 concentric to axis 6, which are surfaces of shaft 10 (half-shafts) of rotor 3. The transition between cylindrical surfaces 9 and the large bases of truncated conical surfaces 8 are made along sphere-like surfaces 11, the center of which coincides with the center of the central sphere-like surface 7. The chamber-forming surface of rotor 3 forms a circular groove 12 on rotor 3, the side walls of which are truncated conical surfaces 8, while the bottom is a central sphere-like surface 7.

[0057] A continuous, almost rectangular groove 13 (not considering rounding in the corners) is made along the axis 6 of rotor 3 over its entire chamber-forming surface, sphere-like surface 11 and parts of cylindrical surfaces 9.

[0058] Two bypass channels 14 in the form of grooves are made through each sphere-like surface 11 and the truncated conical surfaces 8 symmetrically relative to groove 13. The angular extent around axis 6 of each of them is $\frac{1}{4}$ of a revolution.

[0059] Piston 4 (Figure 3) has the shape of a flat disk with a sphere-like side surface 15 and flat ends 16. The diameter of the side surface 15 is roughly (with an accuracy within the working gaps and tolerances) equal to the diameter of sphere-like surface 11. The thickness of the disk corresponds to the size of groove 13. A cylindrical through-hole 17 is made parallel to end 16, symmetrically along the diameter in the disk. Two cylindrical holes 18 of larger diameter are made coaxial to it, symmetrically on both sides. Their diameter is slightly greater than the thickness of the disk. The transition 9 between different diameters of holes 17, 18 is made conical. A groove with a sphere-like bottom 21, which bisects the side surface of the disk and forms a through-groove 22, is made through each hole 17 symmetric to axis 20 of hole 17. The diameter of bottom 21 corresponds to the diameter of the central sphere-like surface 7. Bevels 23 between end 16 and the surface of holes 18 are formed by grooves. The geometric axis of symmetry of the disk perpendicular

to end 16 is axis 161 of its rotary oscillations relative to rotor 3.

[0060] The SSE 5 (Figure 4) is designed in the form of a symmetric dumbbell consisting of two coaxial cylinders 24 connected by shaft 25 of smaller diameter. The transition between surface 24 and shaft 25 is made along cone 26. The cylinders 24 are symmetrically bisected by a circular flat groove 27 going beyond their external ends 28. Bottom 29 of groove 27 is sphere-like. The external ends 28 of cylinders 24 bisected by groove 27 are bounded by a sphere-like surface which has a diameter close to the diameter of the sides 15 of piston 4. The sides 30 of groove 27 are flat. For the capability of assembly the SSE 5 in the region of the center of shaft 25 is divided into two parts (not shown), which are connected during assembly by any known method (contact welding, welding through a process hole, threaded or pin connection).

[0061] Separator 2 (Figure 5) is designed in the form of a flat rectangle with rounded corners with hole 31 in the center. The surface of hole 31 is sphere-like. The ends 32 are flat. The central part of separator 2 in the form of a flat ring (bounded by the dash-dot circle in Figure 5) interacts with piston 4 through SSE 5 to close off the volume. We will call it guide part 140 when it is necessary to distinguish it from the rest of the separator part, which serves for its fastening in housing 1. Axis 144 is the axis of rotation of the generatrix of guide part 140. In the event of integrated production of the separator 2 and housing 1, separator 2 can consist merely of the guide part 140. For capability of assembly, separator 2 is made from two identical parts. The joint 33 between them passes approximately through diametrically opposite points of the central hole 31. It proceeds from them at an angle to the radius of hole 31 (in the depicted example the angle equals 30 degrees). Moreover, the surface of joint 33 is made in the form of a symmetric dihedral angle (in the depicted example the angle equals 90 degrees), the vertex 34 of which is oriented opposite the direction of motion of SSE 5 during operation of the PDRM.

[0062] There is a sphere-like cavity 35 within housing 1 (Figures 6 and 7) with its center on axis 6, from which two cylindrical holes 36 coaxial to axis 6 emerge on opposite sides for output of the shaft 10 of rotor 3. Functionally three annular sections can be distinguished on the surface of cavity 35: a symmetric middle section 37 coaxial to axis 6, corresponding to the location of groove 12 on rotor 3, and two end sections 38 corresponding to the location of sphere-like surfaces 11 on rotor 3. For clarity in Figure 6 and Figure 7 the sections 37 and 38 are separated by dash-dot circles. A flat circular groove 39 for installation of separator 2 is made through the center of cavity 35 at an angle to the plane of rotation (it is perpendicular to axis 6) of rotor 3 (in the given example the angle equals 25 degrees) symmetrically relative to the center of cavity 35 along the middle section 37 of the surface of cavity 35. For the possibility of assembly of the machine, housing 1 is made from two parts 40 and 41 (Figure 8), the joint plane 42 between which passes

through axis 6 perpendicular to groove 39 (Figures 6 and 7). On the end sections 38 of the surface of cavity 35, an input port 43 and output port 44 of the working fluid are positioned in each of the parts 40 and 41 of housing 1, symmetrically relative to the plane of rotation of rotor 3, passing through the center of cavity 35, symmetrically relative to joint plane 42 and symmetrically relative to the plane passing through axis 6 perpendicular to the joint plane 42. Each of them has an extent of $\frac{1}{4}$ revolution around axis 6. In the direction along axis 6, ports 43 and 44 are separated from the center of cavity 35 and positioned on the end of sections 38 of cavity 35, i.e., outside the zone of location of circular grooves 12. For this reason, input ports 43 and output ports 44 of the working fluid can communicate with the working chambers only via bypass channels 14. Concerning input port 43/output port 44 we can state that it is in contact on both sides with a plane passing through axis 6 of rotation of rotor 3 perpendicular to the plane passing through axis 6 and axis 144 of rotation of the guide part 140 of separator 2.

[0063] Annular working cavity 45, which separator 2 divides into two identical chamber-forming cavities 46 of variable cross section with guide part 140, is formed by the central sphere-like surface 7 (Figure 1), two truncated conical surfaces 8 and the middle section 37 of the surface of the sphere-like cavity 35. Piston 4 divides each of the chamber-forming cavities 46 into two working chambers 47 of variable volume. According to the angular position around axis 6, input port 43 and output port 44 are roughly in the center between the maximal and minimal cross sections of the chamber-forming cavity 46 (cross sectional planes containing axis 6 are meant). This means that in the area of minimal cross section and in the area of maximal cross section of the chamber-forming cavity 46 and the area adjacent to it there are no input ports 43 or output ports 44. Passing through the area of chamber-forming cavity 46 adjacent to its minimal and maximal cross sections, piston 4 with its parts emerging from rotor 3 creates the pressure drop of the stage. In the closest prior art, if one piston 4 is used, at the locations adjacent on both sides of the minimal cross section of the chamber-forming cavity 46, input ports 43 and output ports 44 of the working fluid are located and these locations are not used to create the pressure drop.

[0064] The following mostly interact with each other to cut off working chambers 47: sphere-like surface 11 of rotor 3 with end sections 38 of the surface of sphere-like cavity 35, the surface of the central hole 31 of separator 2 with the central sphere-like surface 7 of rotor 3, the side surface 15 of piston 4 and the external end 28 of the SSE 5 with the surface of the sphere-like cavity 35 of the housing 1, end 6 of piston 4 with the surface of groove 13 of rotor 3, side surface 30 of groove 27 of SSE 5 with the end 32 of the guide part 140 of separator 2, side surface of cylinder 24 of SSE 5 with the surface of hole 18 in piston 4, the cone 26 of SSE 5 with the conical transition 19 in piston 4. The truncated conical surface 8 of rotor 3 does not interact with other surfaces to cut off working

chambers 47, for which reason there are no strict requirements on it in terms of quality and shape (in contrast to the prior art). On the contrary, there is a large gap (passage 143 for working fluid) between it and end 32 of the guide part 140 of separator 2.

[0065] More general requirements on input ports 43 and output ports 44 consist of the fact that they are located in the area of interaction of housing 1 with rotor 3, communicating with chambers 47 through bypass channels 14 and the angular extent of input port 43, output port 44 and bypass channel 14 individually at the locations of intersection with ports 43 and 44 can vary but their sum for each chamber-forming cavity 46 for the incompressible working fluid should amount to roughly one revolution and can be less than a revolution for a compressible working fluid.

[0066] Since the sum of the angular extents of input port 43, output port 44 and the two bypass channels 14 pertaining to each chamber-forming cavity 46 is roughly equal to one revolution, rotor 3 has the capability of almost complete closure of each of the ports 43, 44. An exception is the case of a high-speed PDRM, in which closure of ports 43, 44 by rotor 3 is fairly incomplete (for example, 95%).

[0067] The input ports 43 of different chamber-forming cavities 46 are symmetric relative to the center of cavity 35. Output ports 44 of different chamber-forming cavities 46 are likewise symmetric relative to the center of cavity 35.

[0068] External housing 1 is made in the form of a cylinder. Along the external surface of housing 1 the input ports 43 of the different chamber-forming cavities 46 are connected by channel 48, bypassing cavity 35. A similar channel 49 (Figure 8) along the external side surface of housing 1 connects their output ports 44. Both channels 48, 49 are identical to each other and axisymmetric. Channel 48 / 49 begins and ends with blind holes 50/51 (Figure 1, Figure 8), going past cavity 35 parallel to the joint plane 42 perpendicular to axis 6. Input ports 43 / output ports 44 lead into them from cavity 35. Relative to housing 1, channels 48 and 49 have mostly a diagonal (helical) direction. The middle of channel 48 / 49 falls at joint 42.

[0069] On one end 52 (Figures 6, 7 and 8) on housing 1 there is a cylindrical diameter reduction 53 coaxial to its side surface, on which thread 54 is made. From holes 50 and 51, close to end 52, there are two holes 55 (for connection relative to input pressure) and 56 (for connection relative to output pressure) that emerge along axis 6 on end 52. At the output on end 52 their diameter is increased. Holes 55 and 56 serve for hydraulic parallel connection of two adjacent stages. On the opposite end 57 there are two similar holes 55 on end 57. They serve for hydraulically consecutive connection of two adjacent hydraulically consecutive stages or for connection with the input / output of the PDRM. A spacer 58 (Figure 8) to control the distance between neighboring stages is screwed on during assembly of the stage along thread

54 on housing 1. To prevent hydraulic communication between holes 55 and 56 in the gap between hydraulically parallel stages, holes 55 and 56 of adjacent stages are connected by transitional sleeve 59 (Figure 1) inserted in them. Sleeve 59 also serves as a pin during assembly. Two or more holes 55 / 56 (and not one) are made to increase the passage cross section.

[0070] When more than two hydraulically parallel operating stages are installed, holes 55 and 46 are made in the nonextreme stages on each end 52 and 57 and on the extreme ends of the extreme stages only holes 55 or 56 are made. In the absence of hydraulically parallel stages (which is used very rarely), only holes 55 or 56 are made on each end 52 and 57 of the stage. On ends 52 / 57 in the case the absence of one of the types of holes 55 or 56, blind shallow holes 60 are made instead (Figure 8) for pins. In two adjacent hydraulically parallel stages the location of channels 48 / 49 and separators 2 is a mirror image relative to the plane passing between the stages in the area of thread 54 perpendicular with axis 6 and the location of holes 55 on the extreme end 52 of the first stage 61 is centrally symmetric to holes 56 on the extreme end 57 of the second stage 62.

[0071] The assembly of several stages on one shaft is press-fit into tube 63 (the usual element for assembly of submersible pumps). Internal thread for the nuts that compress the stages (not shown) is made on the ends of the tube.

[0072] Rotor 3 of a multistage PDRM is designed common (integral) for several stages. In this case the stages of rotor 3 of two adjacent stages of the PDRM are turned around the axis 6 by $\frac{1}{4}$ revolution. The separators 2 of the different stages are parallel. Pairs of parallel-connected stages are connected hydraulically in series.

[0073] We will present some simple modifications to the described design, which can also be used in the variants described below.

[0074] To simplify the design, the sphere-like surface 11 of rotor 3 can be absent and the truncated conical surface 8 can grade into cylindrical surface 9. Its diameter (diameter of shaft 10) can be increased. The bypass channels 14 are made on the surface 9 or within shaft 10 with opening onto cylindrical surface 9. Input ports 43 and output ports 44 are then made on the surface of holes 36 for the output of shaft 10. The surface of hole 36 should interact with the surface 9 of rotor 3 in this case.

[0075] To increase the rigidity, the working part of ends 32 (Figure 5) of separator 2 can have a conical shape of the surface, tapering toward the central hole 31. Groove 26 (Figure 4) on SSE 5 then also has mating conical side surfaces 30. Separator 2 can also have small deviations from the plane or from the rotational form (applications to improve the characteristics of PDRM by bending the separator are known).

[0076] To strengthen rotor 3, piston 4 and SSE 5, piston 4 need not be flat but can have a thickening in the center. Piston 4 can be equipped with a shaft coaxial to the geometric axis 161. It can consist of two half-shafts. For its

strengthening it is simplest to use an inseparable connection made during assembly, for example, welding.

[0077] To rule out gaps between piston 4 and the surface of sphere-like cavity 35, piston 4 can consist of two (several) parts. Depending on the required pressure, the joint can pass through the middle of piston 4 perpendicular to axis 20 or have a more complex shape.

[0078] To simplify assembly SSE 5 can consist of two individual halves (one can then speak of two SSE 5), but their mutual fastening reduces the load on the friction pairs, improving the characteristics of the machine.

[0079] Instead of using spacer 58, control spacers can be used or the length of the stage simply adjusted / made precisely. The transitional sleeves 59 in these cases are also unnecessary.

[0080] To reinforce the surface of the guide part 140 of separator 2 operating against end 32 projections 64 (Figure 9) can be made as friction pairs on the side of one or two cylinders 24 of the SSE 5, adjacent to groove 27 and widening its side surfaces 30. Bevels 23 on piston 4 must be increased in this case.

[0081] For hydrostatic unloading of piston 4 (Figure 9) two types of grooves are made on its ends 16. A symmetric groove 65 is made on one side of axis 20 along the perimeter of the section of the surface that does not emerge from groove 13 during rotation of piston 4. If the end 16 of piston 4 is conventionally divided into a central circle of maximum diameter, which does not bisect slot 22 and two semirings adjacent to it, then this circle does not emerge from groove 13 and the center (in terms of angle) of the semirings away from slots 22 of piston 4. For this reason, groove 65 consists of an arc along the side 15 symmetric relative to its two almost radial sections, two symmetric arcs along the perimeter of the circle (bottom 21) and a straight section along axis 20. On the other side of axis 20 a groove 65 symmetric to it is made. Along the perimeter of the symmetric sections of the piston 4 emerging from groove 13 (they are adjacent to slots 22), grooves 26 opened toward slots 22 are made. This type of system of grooves 65 and 66 is made on the other end 16. The grooves 65 are connected by holes 67 to grooves 66 on the other side of piston 4.

[0082] Piston 4 can be made from two parts 68, the joint between which is made along the plane of symmetry of piston 4 parallel to its ends 16. The parts are fixed relative to each other by pins-screws 69 located along the perimeter of the piston 4, or by welding.

[0083] For the possibility of changing the slope angle of guide part 140 of separator 2 relative to the plane of rotation of rotor 3 (one can speak of the angle of slope to axis 6, but feed of the PDRM is proportional to the angle of inclination of the separator 2 from the plane of rotation of rotor 3), groove 39 is not made. There is a through-hole 70 on housing 1 (Figure 10) through the center of cavity 35 perpendicular to axis 6 and perpendicular to plane 42 of the joint. Coaxial to it there are blind holes of larger diameter 71 and 72 (Figure 13), respectively, on the inside and outside of each part 40 and 41.

The transition 73 between holes 70 and 71 and thus the transition between holes 70 and 72 is sphere-like. A part (turnable half-shaft 75) is situated in holes 71, 70 (Figure 13) in the form of cylinder 76 (Figure 11), terminating with a concave cap 77 of large diameter. The concave surface 78 of cap 77 is a continuation of the surface of cavity 35. On the side of hole 72 convex cap 79 having a central hole for cylinder 76 is press-fit onto cylinder 76 during assembly. To improve the press-fit conditions, the hole on cap 79 is lengthened by a cylindrical projection, which enters hole 70. There is a blind rectangular groove 80 on surface 78 for the press-fit of separator 2. Groove 80 in the center has a recess that enters cylinder 76. Caps 79 have teeth 82 on part of the side cylindrical surface 81 (in the given example at an angle of 60 degrees).

[0084] Separator 2 (Figure 12) is made in the form of a central guide part 140 in the form of a flat ring with sphere-like outside surface 83, ends 32 and central hole 31. On the diametrically opposite sides of the ring there are projections 84 for press-fitting into groove 80. For the possibility of assembly the separator 2 consists of two identical parts 85, the joint between which emerges in the center of projections 84. When press-fitted into groove 80, the projections hold together parts 85. After assembly, the separator together with the two turnable half-shafts 75 has the capability of rotating relative to housing 1 around axis 97 (Figure 13) perpendicular to axis 6. In the given example the angle of its possible deviation from the plane of rotation of the rotor is from -25 to +25 degrees. The size of this angle is only limited by the shape of the rotor 3.

[0085] Housing 1 (Figure 10) of the stages of such a controllable PDRM is made with a cavity 35 without reduction 53 and spacer 58. The length of housing 1 of stages 61 and 62 (Figure 13) is adjusted according to the distance between stages 61 and 62 on the common rotor 3 or is regulated by control spacers (not shown). Channels 48 and 49 of stages 61 and 62 are made identical (and not as mirror images, as in the proceeding example), separators 2 are set parallel. Rotors 3 of hydraulically parallel stages 61, 62 are turned by $\frac{1}{4}$ revolution. Holes 55/56 (Figures 10 and 13) for connection of holes 50/51 of hydraulically parallel stages 61 and 62 are made diagonal, while holes 55 and 56 on the outer ends 52 and 57 are on one side of rotor 3 (and not symmetric to the axis, as in the preceding example).

[0086] Two grooves 86 parallel to axis 6 are made on the outside of housings 1 of stages 61, 62 (Figure 13). Grooves 86 brush against the side of hole 72 by the dimension of the teeth. Racks 87 with teeth 88 on separate sections are positioned tightly in grooves 86. In the assembly the racks 87 mesh with the convex cap 79 of turnable half-shaft 75. During synchronous displacement of two racks 87 all turnable half-shafts 75 and separators 2 of all stages of the PDRM are turned synchronously in one direction. Two (and not one) racks 87 are used to take up part of the load from separator 2. Beyond the stages of the PDRM or in intermediate locations racks

87 are connected to the piston pressure regulator or to another control drive. Piston 4, SSE 5 and rotor 3 do not differ essentially from the PDRM according to Figure 1. Slight differences could occur in the length of the stage (without sleeve 58 it is shorter), thickness of the piston 4 (piston 4 can be slightly thinner, since separator 2 in this variant is less strong), etc. The large control angle makes the machine reversible, i.e., the direction of motion of the working fluid can be changed to the opposite direction by changing the angle of the separator. The maximum pressure drop for the stage in this version is limited by the strength of separator 2.

[0087] Another version of separator 2 (Figure 14) permits an increase in the maximum pressure of the stage of the PDRM. For this purpose the central guide part 140 (Figure 15) of separator 2 in the form of a flat ring with a central hole 31 and ends 32 is enclosed in shell 89 with a sphere-like inside surface 90, i.e., the slope angle of the guide part 140 is fixed relative to sleeve 89 or separator 2 is made integral with it. This version increases the rigidity of separator 2. The external surface 91 (Figure 14) of shell 89 is concentric to internal surface 90 (Figure 15) and, for convenience, sphere-like. There is a central through-hole 92 in shell 89 that permits passage of shaft 10 (Figure 14) of rotor 3 with different admissible slope angles of separator 2 to the plane of rotation of rotor 3. In the given example hole 92 passes through shaft 10 at slope angles of the guide part 140 of separator 2 from 0 to 25 degrees. The role of the sphere-like cavity 35 in terms of formation of the chamber-forming cavities 46 in this version is fulfilled by the sphere-like cavity 93 formed within shell 89. For the possibility of assembly of the machine, separator 2, supplemented by shell 89, is made from two parts, the joint 94 (Figure 15) between which passes approximately through the center of separator 2 along its plane of rotation. For fastening of the two parts of separator 2 to each other, there is a flange 95 on the shell of the separator along joint 94. Fastening is accomplished with pins-screws (not shown), for which holes 109 are made on flanges 95. For meshing of the two semirings of the guide part 140 of separator 2 at the locations of joint 94 there is a groove on them for the pin or key. There is a circular groove 96 for flanges 95 of shell 89 on joint 42 of parts 40 (absent in Figure 15) and 41 of housing 1 along the perimeter of cavity 35. The input ports 43 and output ports 44 remain on the surface of cavity 35 of housing 1, which in this case can have a different shape, for example, the shape of the surface of revolution relative to axis 97 of turning of separator 2. However, it is more convenient to make it sphere-like. For passage of the working fluid through shell 89 to input ports 43 and output ports 44 situated on the housing 1, there are passages 98 on shell 89 of separator 2 symmetric relative to the rotational plane. They are made in the form of one rhomboid large hole 99 and several small holes 100. The large hole 99 is made on the section of shell 89, which is opposite input ports 43 / output ports 44 in any admissible angular position of separator 2, the

small holes 100 are made on the sections of the shell 89, which are opposite input ports 43 / output ports 44 not at any admissible angular position, i.e., there are positions of separator 2 in which the small holes 100 cannot communicate with the input ports 43 or output ports 44. This version of the input / output passages 98 permits elimination of the effect of the angular position of separator 2 for the bypass phases of the machine. The general shape of passage 98 (with all its holes 99, 100) is similar to a trapezium. Passages 98 are positioned symmetric relative to shell 89, but not symmetric relative to guide part 140 of separator 2, since it is positioned at a slope to the plane of symmetry of shell 89. The term small hole 100 is a qualitative one, since the optimal size depends on the viscosity of the working fluid, the percentage of leaks in the machine feed and is determined for each specific use condition. The important factor is individuality of such holes 100, i.e., that they do not merge with other holes 100. The smaller the size of holes 100, the more precision in observation of optimal bypass phases of the working fluid, but the larger the percentage of hydraulic losses. The larger the size of the holes 100, the lower the accuracy of observation of optimal bypass phases of the working fluid, but the lower the percentage of hydraulic losses in them. For greater rigidity of separator 2, large hole 99 can also be replaced with a set of small holes, although this somewhat increases the hydraulic resistance. Small holes can also be located on other locations of shell 89 to equalize the pressure inside and outside shell 89. This permits a reduction in load on shell 89 from the pressure drop of the working fluid and thus reduces its required thickness and the weight and dimensions of the machine accordingly. The pressure drop in this case is taken up by housing 1, which is designed for this in any case.

[0088] The input ports 43 and output ports 44, as in the preceding example, are located in the region 38 of interaction of housing 1 with rotor 3. However housing 1 interacts with rotor 3 in this variant through an intermediate part - shell 89 of separator 2, which seals the contact of housing 1 with rotor 3 but owing to passages 98 passes the working fluid through in the direction between channels 14 (Figures 2 and 14) of the rotor and input ports 43 / output ports 44 located on housing 1. This means the perforated shell 89 prevents passage of working fluid along the gap between housing 1 and rotor 3 and passes it through in the transverse direction. To limit the degrees of freedom of separator 2 in cavity 35, there are two half-shafts 101 on it (Figure 14) in the form of coaxial cylindrical projections, the geometric axis of which passes through the center of shell 89 along the rotational axis 97 (perpendicular to the plane of rotation) of separator 2. There are cylindrical recesses 102 (Figure 15) for half-shaft 101 on parts 41, 40 (not shown in Figure 15 since its internal part is a mirror image of part 40) of housing 1.

[0089] Teeth 82 are made on the cylindrical surface of flanges 95 to control the angle of separator 2 (guide part 140).

[0090] The slope of separator 2 is controlled with rack

87 situated in the groove 86 of housing 1 located at the joint of parts 40 and 41 and matching the size of teeth 82 of groove 96 of stages 61, 62.

[0091] Supply of working fluid is accomplished by feed channels 103 (Figure 16) and discharge channels 104 that run along the surface of housing 1 along axis 6 relative to stages 61, 62. Symmetrically on both sides of groove 86 there are two discharge channels 104 and symmetrically from the diametrically opposite line of joint 42 there are two feed channels 103. In essence, this is one channel 103 but for symmetry of press-fitting into tube 63 (shown previously in Figure 8) a stiffness rib 105 is left in it through the center. Passages 106 emerge between channels 103 and 104 on parts 40 and 41 from the input ports 43 and output ports 44 of the working fluid and are connected to channels 103 and 104, respectively.

[0092] Along joint 42 diametrically opposite groove 86 a cylindrical hole 107 runs for the spacer of the tube, hydraulically connecting the input of the PDRM with the output for supply of low / high pressure for axial unloading of rotor 3.

[0093] For mutual orientation of the adjacent housings 1 of the stages of the PDRM according to the angle relative to axis 6, there are holes 108 on ends 52, 57 for the pins. Similar holes 108 for fixation of the position of parts 40, 41 relative to each other are present on the joint plane 42 (Figure 15). Channels 103 / 104 (Figure 16) of the hydraulically parallel stages are connected and at the transition to the next hydraulically consecutive stage channel 103 of the present stage terminates and channel 104 of the present stage grades into channel 103 of the next stage. For this purpose, in the next group of hydraulically parallel stages the passages 106 emerge in opposite directions, owing to which channels 103 and 104 change. And in the next group after them the passages 106 are made as in the present stages 61, 62, and so on.

[0094] The shape of the external surface 91 and the surface of cavity 35 of this variant need not be sphere-like. These surfaces can be any surfaces of revolution relative to axis 97, for example, cylinders. But a sphere-like version permits a reduction in size and weight.

[0095] Another method for changing the slope angle of the guide part 140 of separator 2 (Figure 17) consists of the fact that shell 89 of the separator 2 is made in the form of a ring 110. The internal surface 90 of ring 110 is bounded by a sphere-like surface similar (with an accuracy within the tolerance) in diameter to the diameter of cavity 35. The external surface 91 is also sphere-like and concentric to the internal surface 90, the ends 36 are flat. The guide part 140 of separator 2 is situated in the ring 110 at an angle to it, i.e., it is installed at a fixed angle, for example, with a groove, or is made integral. This means that central hole 31 is concentric to the inside surface 90 and ends 32 (or the plane) of the guide part 140 of separator 2 are positioned at an angle (in the given example 21 degrees) to the ends 136 of ring 110. Essentially the section of housing 1 - the sloped ring 110 to-

gether with the guide part 140 of separator 2 installed in it, is isolated in a separate part - turnable separator 111 (used further in Figures 21 and 26). A groove 112 is made here in housing 1 (Figure 18), passing symmetrically through the center of cavity 35 at an angle (in the given example 21 degrees) to the plane of rotation of rotor 3 (in other words, the axis of rotation of its generatrix passes through at an angle to axis 6). It is bounded by a sphere-like side surface 113 concentric to cavity 35 and two ends 14 in the form of flat rings. Groove 112 is made symmetric relative to the joint plane 42.

[0096] For the possibility of assembly, the turnable separator 111 (Figure 17) is made from two parts 115 or 116. The joint 117 between them for convenience of passage passes right through the entire part roughly through the center of the guide part 140 of separator 2 parallel to the plane of symmetry of turnable separator 111 in the form of a dihedral angle 118 and then on one side of the plane of symmetry symmetric to the plane of guide part 140 of separator 2 on both sides of the body of the guide part 140 along ring 110, forming rectangular projections 119 in it at roughly diametrically opposite locations of part 115 and mating grooves for it on part 116. For fixation of parts 115 and 116 to each other, holes 121 for pins are made at the contact of the projections 119 and grooves. On the outside surface 91 of part 115 teeth 122 are made on the section adjacent to joint 117 with an angular extent of roughly 100 degrees around the axis of symmetry of ring 110.

[0097] Along the outside of housing 1 (Figure 18) along the surface of one of its parts - part 40, a groove 86 is made along axis 6 with a cross section in the form of a ring sector. Groove 86 matches the size of tooth 122 of grooves 112 at the site of maximum slope. Rack 187 (Figure 19) is positioned in groove 86, having a cross section reciprocal to the cross section of groove 86 in the form of a ring sector. On its individual parts on the inside cylindrical surface teeth 123 are made for interaction with teeth 122. In the given example teeth 123 are made at an angle of around 45 degrees to axis 6. The direction of displacement of rack 87 and groove 86 partially coincides with the direction of rotation of ring 110, which improves the conditions of meshing.

[0098] During rotation of turnable separator 111 the guide part 140 of separator 2 changes the slope angle to the plane of rotation of rotor 3, changing feed of the PDRM, but in this case an adverse effect occurs - the points of maximum slope of guide part 140 of separator 2 are rotated relative to axis 6, with the angular position of which the position of input port 43 and output port 44 of the working fluid are associated. To compensate for this effect the input ports 43 and output ports 44 are made on the turnable sleeve 124 (Figure 20). The turnable sleeve 124 has the shape of a tube segment with concentric cylindrical inside and outside surface. The diameter of the inside surface is similar to the diameter of surface 9. They interact with each other. Two input ports 43 and two output ports 44 are made on it symmetrically.

The input ports 43 are axisymmetric to the output port 44 and the pair of ports 43, 44 is centrosymmetric relative to the center of sleeve 124 of the other pair of ports 43, 44. The angular extent of each port 43, 44 in the given example is $\frac{1}{4}$ revolution around the axis of sleeve 124. In the plane of symmetry of sleeve 124 perpendicular to its axis, concentric to sleeve 124, a projection 125 is positioned in the form of a flat ring sector with teeth 126 on the outside cylindrical surface (in other words, sector of a pinion). On individual sections of rack 87 (Figure 21) between sections on which teeth 123 are made, teeth 127 are made reciprocal to teeth 126. They are made at a smaller angle to rack 87 than teeth 123. The ratio between angles of teeth 123 and teeth 126 is calculated from the condition that the turnable sleeve 124 must rotate with rack 87 relative to axis 6 twice as slowly as the turnable separator 111 rotates with rack 87 in groove 112. For the possibility of assembly on rotor 3 sleeve 124 (Figure 20) is made from two parts. The joint 120 between them is symmetric relative to the plane of symmetry of the sleeve and passes through the internal surface of sleeve 124 in its diametrically opposite locations away from ports 43, 44 along the radius then at a right angle to it and then again at a right angle in the previous direction, forming steps. The parts of sleeve 124 are connected to each other with pins, for which radial holes are made in the step of joint 120. The rigidity of the sleeve 24 is ensured by the thickness of its walls.

[0099] Half-shafts 10 (Figure 21) of rotor 3 are made of larger diameter than in the PDRM according to Figure 1, since the channels 14 for passage of the working fluid, beginning on the truncated conical surfaces 8, are made within rotor 3 and emerge outside in the form of ports 128 on the cylindrical surface 9. The angular extent of the ports in this example is $\frac{1}{4}$ of a revolution around axis 6. In the middle of port 128 a stiffness rib 129 is left. The feed channels 103 and the discharge channels 104 (Figure 19) of the working fluid are made on the outside surface of housing 1 in the axial direction. In the depicted stages, two channels 103 are in contact with grooves 86 and two channels 104 are situated on the opposite side of housing 1 and are divided by stiffness rib 105. In the hydraulically consecutive stage following them, channels 103 and 104 change places. A hole 107 passes within the stiffness rib 105 through all stages of the PDRM for communication of the region of the input of the PDRM with the region of the output of the PDRM. The pressure necessary for hydraulic axial unloading of the common rotor 3 and to drive the control system of rack 87 (feed of the PDRM) is supplied through it from one region to the other.

[0100] There is a cylindrical cavity 130 for sleeve 124 and housing 1 in holes 36 (Figure 18) having a diameter close to the diameter of the outside surface of sleeve 124. Passages 131 emerge on its surface for the working fluid from channels 103 and 104 (Figure 19) in the area where ports 43 and 44 are positioned, respectively. The passages 131 emerge on the outside surface of housing

1 between channels 103 and 104 and have an output either in channel 103 or channel 104, depending on the position of the stage in the PDRM and the position of passage 131 on it. The outside surface of sleeve 124 interacts with the surface of cavity 130. In the center of cavity 130 there is a flat groove 132 for projection 125. The angular extent of groove 132 is larger than the angular extent of projection 125 by the control angle (in the given example by 34 degrees).

[0101] At the sites of contact of the hydraulically parallel stages, the corresponding channels of the different stages communicate with each other and at the locations of contact of hydraulically consecutive stages only channel 104 communicates for the output pressure of one stage with channel 103 for the input pressure of the next stage. As in the example according to Figure 16, channels 103 and 104 necessary for contact of the hydraulically consecutive stages are opposite each other.

[0102] As in the preceding variant, it can be assumed that input ports 43 and output ports 44 are situated on housing 1 in the region of its interaction with rotor 3, but they interact through an intermediate part - sleeve 124, which seals their contact. But in addition to the preceding variant, a sleeve 124 actively shifts the boundary of input ports 43 and output ports 44.

[0103] Another method for control of sleeve 124 (Figure 22) is to make a helical groove 133 on the sleeve 124 in the gap between ports 43, 44 instead of projection 125. A high tooth 134 is then made on rack 87 instead of teeth 127 for interaction with the helical groove 133. A through groove running along axis 6 within groove 86 on the length of cavity 130 is made on housing 1 instead of groove 132. Tooth 134 has two side surfaces reciprocal to helical groove 133 and two side surfaces reciprocal to the groove in housing 1.

[0104] Making the surface of the ends 136 of ring 110 and the mating ends 14 of groove 112 conical is one of the simple modifications for conveniently making groove 112 by electroerosion. Instead of a sphere-like external surface 91 of ring 110 a different, for example, cylindrical surface can be used. The position of the turnable separator 111 in the turnable sleeve 124 can be controlled by the shaft with the pinions on it and not by rack 87. Since sleeve 124 rotates by an angle less than the angular dimension of ports 43, 44, part of the ports 43, 44 of smaller angular size can be made on housing 1, as in the example according to Figure 1.

[0105] In the machine variant according to Figure 13 the pressure drop is limited by the strength of the separator 2, and in the machine according to Figure 14 the control angle is limited, and in the machine according to Figure 19 an extra part appears - bypass sleeve 124. The next variant of the machine (Figure 26) is devoid of these shortcomings. For this purpose, the central guide part 140 of separator 2 (Figure 23) in the form of a flat ring with a central hole 31 and ends 32 is incorporated in shell 89 with a sphere-like inside surface 90 and a sphere-like outside surface 91 concentric to it. There is

a circular central through-hole 92 in shell 89 that permits passage of shaft 10 of rotor 3 at zero and maximum admissible slope angle of the guide part 140 of separator 2 to the plane of rotation of rotor 3. In the given example hole 92 passes through shaft 10 at slope angles of the guide part 140 from 0 to 25 degrees. The role of the sphere-like working cavity 35, in terms of formation of chamber-forming cavities 46, in this version is fulfilled by the sphere-like cavity 93 formed within shell 89.

[0106] To control the angular position of the guide part 140 of this turnable separator 111, there are several projections 135 on the surface of shell 89. Their minimal number is two. In the given example three projections 135 are made. Each projection 135 is made in the form of a cylinder oriented along the radius of shell 89. The projections 135 are separated along the ring of separator 2 by roughly angles of 90 degrees and are slightly separated along the axis 137 of shell 89. On the surface of shell 89 teeth 139 (grooves) are made, the slope of which to axis 137 varies (as in a helical pinion, only the slope of the teeth 138 smoothly changes from tooth to tooth).

[0107] For the possibility of assembly of the machine the separator 2 supplemented by shell 89 is made from two parts, the joint 117 between which passes roughly through the center of the guide part 140 of the separator 2 and consistent rectangular projections 119 along the plane of separator 2 and the grooves reciprocal to them. Two dihedral angles 118 are made on one of the projections 119 in the center of separator 2 with vertices directed to opposite sides in the direction along the plane of separator 2. The direction of the generatrix of joint 117 deviates slightly from the plane of the guide part 140 of separator 2, for which reason each of the vertices of the dihedral angles 119 pertains to one of the diametrically opposite parts of the guide part 140 of separator 2 so that the angle of the vertex is directed opposite the direction of movement of piston 4. For fastening of the two parts of separator 2 to each other, there are holes 121 for pins at the contacts of the planes of projections 119 and the grooves.

[0108] There is a sphere-like cavity 35 in housing 1 (Figures 24, 25) for positioning of shell 89. There are three (according to the number of projections 135) curved guide grooves 139 on the surface of cavity 35. There are input ports 43 and output ports 44 of the working fluid on the surface of these holes 36 of housing 1. Their angular extent is roughly $\frac{1}{4}$ revolution. On the outside surface of housing 1 there is a groove 86 for rack 87, which runs along axis 6. On both sides relative to groove 86 channels 103, 104 are symmetrically positioned. There is a stiffness rib 105 in the middle of each. For the possibility of assembly, housing 1 consists of two parts 40 and 41. Joint plane 42 between them passes through stiffness rib 105. Groove 86 is in the center of part 40. The input ports 43 and output ports 44 are positioned symmetrically on parts 40, 41 and connected by passages 96 to channels 103 and 104 respectively.

[0109] The guide part 140 of separator 2 (Figures 23

to 26) varies its slope to the plane of rotation of rotor 3 during rotation of the separator 2 around a point - the center of cavity 35. There is no fixed axis of rotation in it. Having an additional degree of freedom, it simultaneously executes two movements - slope (as in the machines according to Figures 10-13 and 14) and rotation around the axis of symmetry of shell 89 (as in the machine according to Figures 17-22). It is sloped from -25 degrees through zero back to -25 degrees as hole 92 permits, but in so doing it manages to rotate around axis 6 as a result of which the negative slope of -25 degrees becomes positive of +25 degrees. As a result, it can change its slope in the given example from an angle of -25 to an angle of +25 degrees. The control angle is thus doubled. The guide grooves 139 can be plotted by tracing the path of the projections 135 during simultaneous sloping and rotation of separator 2. Their shape depends on the position of projections 135.

[0110] To reduce the load on the friction pairs the projections 135 can have a shape reciprocal to grooves 139 (it is easy to produce by turning projection 135 with groove 139), or they can be installed with the capability of rotation or for transmission of forces an intermediate element can be used, for example, a sleeve placed on cylindrical projections 135. The projections 135 can be made on the surface of cavity 35 and the guide grooves 139 on shell 89. There can be many projections and grooves. The space in hole 92 free from shaft 10 and rotor 3 can be filled with a separate part having the shape of a sphere-like circle with a radial hole for the shaft offset from the center. It makes sense to use this part to seal the working cavity for large control angles, for which surface 11 of rotor 3 does not cover holes 92. To prevent its interaction with shaft 10, there is a circular projection around the hole in the part and in the housing - a circular groove for it positioned at the contact between surface 11 and hole 36.

[0111] To reduce internal overflows, it is possible to use in each stage 61, 62 only part of the working cycle to create a pressure drop, having maximum feed (Figure 27). For this purpose it is possible to widen the input ports 43 and/or output ports 44 (Figure 28) according to the angular size and/or to shift / extend them to section 37 of housing 1, i.e., in the region of working cavity 45. In the direction along axis 6 the input ports 43 and output ports 44 can reach the groove 39 for separator 2. Since the ports 43, 44 are larger, for rigidity of housing 1 a stiffness rib is left in the middle of ports 43, 44. The load of the piston 4 and SSE 5 in this case is similar to the load in the preceding variants, except that in part of the cycle the pressure drop of stage 61, 62 almost completely disappears because of lengthening of the connection of working chambers 47 with input ports 43 and output ports 44. To maintain pressure with the machine, two or more consecutive stages 61, 62 are installed which maintain the pressure - each in its own section of the cycle, possibly with a slight overlap. Thus, for example, if the pressure drop in the entire cycle is ensured with two consec-

utive stages 61, 62, then at roughly $\frac{1}{2}$ of the cycle the working chamber 47 of the stage is connected simultaneously to both the input port 43 and output port 44 and if it is ensured with three, then roughly $\frac{1}{3}$ of the cycle, etc. The stage 62 that creates the pressure drop pumps the working fluid through the working cavities 46, which do not create at this point the pressure of the consecutive stages 61. The more consecutive stages 61, 62 are installed, the more uniform feed of the machine can be. Channels 14 on rotor 2 in this variant are used to a greater extent to ensure passage 143 than as a means for connection of input ports 43 and output ports 44 to working chambers 47. The passage 143 is ensured by channels 14 and not by a common shift in the truncated conical surfaces 8 into the body of rotor 3, since it is possible to retain a large area of the support surface for the piston 4 in groove 13, since the channels 14 do not reach groove 13. In another variant, instead of surface 8 in channels 14, a surface that is not a surface of rotation around axis 6 is made.

[0112] Overall the machine according to Figure 27 is similar to the machine according to Figure 1. The differences consist of the widened channels 14 in terms of angular size, the widened input ports 43 and output ports 44 in terms of size (mostly along axis 6) and a change in the system of channels 48, 49 that connect stages 61, 62 (owing to a transition from parallel connection to series connection). To simplify the description the control system of the distances between stages 61, 62 is also not taken up. The machine according to Figure 27 can be used in all the previously described controllable variants for the machine according to Figure 1, since the switch from the machine according to the Figure 1 to the machine according to Figure 27 consists of increasing the input ports 43 output ports 44 and channels 14 (instead of channels 14 a large gap between parts can be used - passage 143).

[0113] For the possibility of assembly of the machine housing 1 (Figures 29, 30) is made of two parts 40 and 41, the joint plane 42 between which passes through axis 6 perpendicular to groove 39. The external housing 1 of the machine according to Figure 27 is made in the form of a cylinder. Channels pass along the external surface of the housing 1 of the group of two stages 61, 62: 147-154. Their location is nonsymmetric. On one side of the housing channels 147-149 and straight channels 150-151 pass along parts 40 and on the other side of the housing 1 c-shaped channels 152-154 pass along parts 41, bypassing the sphere-like cavities 35. Channel 147 (Figure 29) connects the input port 43 on part 40 of stage 61 to the input of the machine or to the preceding stages. Channel 148 connects the output port 44 on part 40 of stage 61 to the closest input port 43 on part 40 of stage 62. Channel 149 connects the output port 44 on part 40 of stage 62 to the output of the machine or to the subsequent stages. A place remains on the surface of parts 40, which is used for positioning of channels 150 and 151, which run parallel to axis 6. They can be used for a

parallel connection of other stages, to increase the throughput capacity of the main channels or to supply pressure for hydraulic unloading of rotor 3. Channel 152 (Figure 30) connects the input port 43 on part 41 of stage 61 to the input of the machine or to the preceding stages. Channel 153 connects the output port 44 on part 41 of stage 61 with the input port 43 distant from it on part 41 of stage 62. Channel 154 connects the output port 44 on part 41 of stage 62 to the output of the machine or to subsequent stages.

[0114] An example of a machine according to Figure 27 in an above-ground controllable version is shown in Figure 31 to illustrate different possibilities of using the machine types according to Figure 1 and Figure 27. A smaller number of stages is usually required for it and smaller input and output connectors of the machine. For this reason, use of the external tube as a common housing of the machine is less expedient and transverse division of the housing into parts is preferable.

[0115] Housing 1 consists of three parts similar in shape to cylinders: middle part 155 and two symmetric end parts 156. The joints between them pass through the centers of stages 61 and 62 (through the centers of cavities 35). For mutual fastening there are flanges on the joints. The fastenings (holes, bolts) are not shown. Symmetrically, in the ends of the middle part 155 sphere-like cavities 35 remain on each half, which are connected by a hole 36 coaxial to them for shaft 10 of rotor 3. Channels 148, 152 and 154 are made from the ends of the middle part 155 through the surface of sphere-like cavity 35.

[0116] Half of sphere-like cavity 35 is made on the end of the end part 156, from which a through-hole 36 for shaft 10 of rotor 3 emerges symmetrically. On the other hand, a bore is made for the roller bearing 160. Channels 147, 153 on stage 61 and channels 149, 154 on stage 62 are made through the surface of the sphere-like cavity 35. Their purpose coincides with the preceding example. All channels are terminated with holes 157 for connection of main lines (flexible high-pressure hoses or tubes), which connect two sections of the internal channel 153 situated in different end parts 156 and the machine is connected to the external load this way.

[0117] Separator 2 is made similarly to the separator of the machine according to Figure 14 - with sphere-like shell 89. It has a sphere-like internal surface 90 and for convenience of design a sphere-like external surface 91. Slight differences are present in fastening of the two parts of the separator 2 to each other. The joint between them passes symmetrically through the center of shell 89, but on one part there is a cylindrical reduction and on the other part a cylindrical projection enclosing it. During assembly the reduction enters the projection and the parts are fixed to each other with pins (not shown). The input ports 43 and output ports 44, for reduction of the hydraulic resistance, are made on shell 89. This is associated with the fact that when two stages are connected in series, pressure surges are usually higher than during parallel

connection (this is the payment for a reduction of internal backflows, friction and wear) and the deviation of ports 43, 44 during rotation of separator 2 from their optimal position is less (owing to the greater angular extent on the sphere). But it is also possible to use positioning of ports 43, 44 when passages 98 are used according to Figure 14.

[0118] For the possibility of assembly in housing 1, rotors 3 on the individual stages 61, 62 are made separately. There is a connection of the shaft-sleeve type between them.

[0119] Another difference is that the half-shafts 101 of separator 2 emerge from housing 1 through sealed holes 158 and have flat spots (slits) 159 on the ends for contact with the external device that controls machine feed.

[0120] To reduce the load on the friction pair piston 4-groove 13 of rotor 3 (Figure 32), flat grooves 141 are made on piston 4 parallel to its end 16. Each groove 141 passes through the side surface 15 of piston 4 without entering slots 22. During use of SSE 5 grooves 141 do not enter hole 17, 18 for SSE 5. In this example it can be stated that the piston is assembled from several disks connected in the region of axis 20 of SSE 5.

[0121] In this case on rotor 3 (Figure 33) groove 13 for piston 4 is made in the form of several parallel grooves 145 connected in the middle of groove 13. Between adjacent grooves 145 projections 142 are left. The thickness of projection 142 corresponds to the dimension of groove 141. During rotations of piston 4 in groove 13 of rotor 3, the projections 142 do not fully close the grooves 141, leaving a space close to axis 20 for passage of the working fluid cut off into groove 141.

[0122] In the given example one groove 141 is made on each side of the axis of SSE 5. But it is possible to also use a larger number of grooves 141. A projection 142 in groove 13 of rotor 3 corresponds to each groove 141 here.

[0123] The grooves 145 need not be flat, for example, they can be conical with the axis of the cone along the geometric axis 161 of the rotary oscillations of piston 4. This means the surfaces of grooves 145 can be surfaces of revolution around the geometric axis 161 of piston 4. A mating surface is then made on projection 142.

[0124] Such a piston 4 can also be used in other PDRM from the mentioned prior art since addition of grooves 141 does not affect the method or operating characteristics of the PDRM and only reinforces support of the piston.

[0125] The machine according to Figure 1 operates as follows. A circular working cavity 45, which the guide part 140 of the separator 2 divides into two parts 46 of variable cross section, each of which is divided by piston 4 into two working chambers 47, is formed in the sphere-like cavity 35 of housing 1 between housing 1 and rotor 3 around rotor 3. During rotation of rotor 3, the angle between piston 4 and the guide part 140 of separator 2 periodically changes. For this reason, the volume of the working chambers 47 periodically changes. When two

chambers 47 positioned centrally symmetric to the center of cavity 35 increase their volume, two other working chambers 47 reduce their volume. During the increase in volume of chambers 47, the channels 14 running from them are situated in the overlap with input ports 43 (Figures 6 and 7) situated on housing 1 beyond the working cavity 45 in the area of interaction of housing 1 with rotor 3. The working fluid from input ports 43 enters through channels 14 the working chambers 47. During a reduction in volume of chambers 47, channels 14 running from them are in the overlap with the output ports 44 located on housing 1 beyond working cavity 45 in the area of interaction of housing 1 with rotor 3. The working fluid from working chambers 47 emerges through channels 14 into output ports 44. The input ports 43 / output ports 44 are connected to the input / output of the machine or to the output /input of subsequent stages by channels 48, 49 and holes 50, 51, 55, 56. Channels 14 together with the passage (large gap) 143 ensure continuity of the parts of the chamber 47 located on different sides of its minimal cross section.

[0126] In symmetric chambers 47 and centrally symmetric positioning of the input ports 43 and output ports 44 of different chambers 47 the load on the SSE 5 from the pressure drop of working fluid is symmetric and the sum of these forces and moments of forces equals zero. SSE 5 participates in transmission of the moment of forces from separator 2 required to maintain and synchronize the rotary oscillations of piston 4 with rotation of rotor 3. The specific pressures in the friction pairs are then proportional to the square of the maximum linear velocity of piston 4. Thus, during operation at 3000 rpm of a machine with a steel piston 46 mm in diameter, the specific pressure associated with inertial loads on the friction pairs separator 2-SSE 5-piston 4 is about 4 kg/cm². The small moment (especially during use of hydraulic unloading of piston 4) is required to compensate for friction forces of piston 4.

[0127] The machine according to Figures 10-13 operates similarly. The difference consists of the fact that with the mechanism for changing the slope angle of separator 2 (more precisely its guide part 140) it is possible to control feed of the machine by changing the geometry of the machine. This means that at constant revolutions of rotor 3, by changing the angle of separator 2 it is possible to smoothly change feed of the machine for maximum feed in one direction to maximum feed in the other direction. During displacement with the external device, for example, piston regulator, of rack 87 along axis 6 of rotor 3, through teeth 88 and 82, cap 79 of the turnable half-shaft 75 is made to rotate and the guide part 140 of separator 2 rigidly connected to it rotates, changing its slope angle to the axis 6 of rotation of rotor 3. The limits of the periodic changes in dimensions of chambers 47 change here and consequently feed in the machine changes. At an angle between the guide part 140 or separator 2 and the axis 6 of rotation of rotor 3 equal to 90 degrees the theoretical feed of the machine (during operation on an incompress-

ible liquid) becomes equal to zero, since the maximum volume of chambers 47 becomes equal to the minimal volume. With a further change in slope angle of separator 2, the machine begins to supply working fluid in the opposite direction, since during an increase in volume of chambers 47 they will be connected by channels 14 to output ports 44 and during a reduction in volume of chambers 47 they will be connected by channels 14 to input ports 43. This means the input ports 43 and output ports 44 functionally change places.

[0128] The machine according to Figures 14-16 operates similarly to the machine according to Figures 10-13. The difference is that with rack 87, through teeth 88 and 82, shell 89 of separator 2 is made to rotate and the guide part 140 of separator 2 rigidly connected to it rotates, changing its angle of slope to axis 6 of rotation of rotor 3. The maximum pressure drop at one stage here can be greater and the control range of feed less, for example, from zero to maximum feed. Another difference is that the working fluid between channels 14 and input ports 43 / output ports 44 passes through ports 98 in shell 89 of separator 2.

[0129] The machine according to Figures 17-22 operates similarly to the machine according to Figures 10-13. The difference consists of the method for changing the slope angle of the guide part 140 of separator 2. The guide part 140 of separator 2 changes its slope to axis 6 with rotation of rotors 3 by rotation of shell 89 of separator 2 made in the form of a ring 110 in circular groove 112, the axis of rotation of the generatrix of which is sloped to the axis 6 of rotation of rotor 3. The guide part 140 of separator 2 is also sloped to the axis 137 of rotation of the generatrix of shell 89. Reciprocating motion of rack 87 is transferred to rotation of ring 110 via teeth 123 and 122. With this method of changing the angle a parasitic phenomenon develops - shifting of the optimal position of input ports 43 and output ports 44 relative to the plane of the slope of guide part 140 of separator 2. Shifting is compensated by rotation of the bypass sleeve 124 around axis 6. For this purpose rack 87, also meshes with sleeve 124 via teeth 126 and 127 or via tooth 134 and groove 133. A different gear ratio is used in this case. The other difference consists of the fact that the input ports 43 and output ports 44 are positioned in the region of half-shaft 10 to simplify the geometry of sleeve 124 and the channels 14 are made within rotor 3 and not in the form of open grooves, as in other variants.

[0130] The machine according to Figures 23-26 operates similarly to the machine according to Figures 10-13. The difference consists of the method for changing the slope angle of the guide part 140 of separator 2. The guide part 140 of separator 2 changes its slope to axis 6 of rotation of rotor 3 by complex turning of shell 89 of separator 2 around the center of cavity 35. The guide part 140 of separator 2 is sloped to the axis 137 of shell 89 here. The reciprocating movement of rack 87 via teeth 123 and 138 is converted to turning of shell 89, which changes the slope angle of guide part 140 but does not

rotate the plane of slope around axis 6. The nature of this movement is determined by the displacement of projections 135 in guide grooves 139. In this method for changing the angle the optimal positions of input ports 43 and output ports 44 remain at their locations. The other difference consists of the fact that the input ports 43 and output ports 44 are located in the region of the half-shafts 10 and the channels 14 are made within rotor 3 and not in the form of open grooves, as in other variants.

[0131] The machine according to Figure 27 operates as follows. A circular working cavity 45, which the guide part 140 of separator 2 divides into two parts 46 of variable cross section, each of which is divided by piston 4 into two working chambers 47, is formed in the sphere-like cavity 35 of the housing 1 between the housing 1 and rotor 3 around rotor 3. During rotation of rotor 3 the angle between piston 4 and guide part 140 of separator 2 changes periodically. For this reason, the volume of working chambers 47 changes periodically. When two chambers 47 positioned centrally symmetric to the center of cavity 35 increase their volume, the two other working chambers 47 reduce their volume. During a rapid increase in volume of chambers 47 they directly and through channels 14 overlap input port 43 located on housing 1. The working fluid from input port 43 enters working chambers 47. During a rapid reduction in volume of chambers 47 they directly and through channels 14 overlap output ports 44 located on housing 1. In the phase of the cycle when the rate of change in volume of the chambers is lower, pistons 4 enter the zone of ports 43, 44 and no longer create a pressure drop of the stage but also do not prevent passage of the working fluid through the given stage by the pressure drop created at this point by the other consecutive stage, in which the phase is shifted. In symmetric chambers 47 and with centrally symmetric location of the input port 43 and output port 44 of different chambers 47, the load on SSE 5 from the pressure drop of the working fluid is symmetric and the sum of these forces and moments of forces equals zero. SSE 5 participates in transferring the moment of forces from the separator 2 required to maintain and synchronize the rotor oscillations of piston 4 with rotation of rotor 3. In this machine piston 4 and SSE 5 are loaded for only part of the cycle and consequently their wear is less than in the machine according to Figure 1. The lubrication conditions are also better. However, a shortcoming is the large pulsation of the feed.

[0132] The machine according to Figure 31 operates similarly to the machine according to Figure 27. The difference is the possibility of controlling feed by changing the slope angle of the guide part of the separator relative to axis 97. The angle changes by simultaneous turning of half-shafts 101 by an external control device.

Claims

1. Positive-displacement rotary machine containing

- a housing;
 a rotor installed in the housing with the capability of rotation;
 a separator installed in the housing, having a guide part with a hole for the rotor;
 a piston installed in the groove of the rotor with the capability of making rotary oscillations relative to the rotor around an axis that intersects the axis of rotation of the rotor preferably at a right angle, having at least one slot into which the guide part of the separator enters;
 a sphere-like working cavity formed around the rotor, which the guide part of the separator, by interaction of the hole with the rotor, divides into chamber-forming cavities of variable cross section, each of which is divided by the piston into working chambers, in which at minimal cross section of the chamber-forming cavity there is a passage for the working fluid and/or there is a channel in the rotor that permits the working fluid to bypass the minimal cross section of the chamber-forming cavity;
 input and output ports of the working fluid.
2. Machine according to Claim 1, in which channels made in the rotor emerge from each chamber for passage of the working fluid with the possibility of its connection to the input and output ports.
 3. Machine according to Claim 1, in which in the middle between maximum and minimum cross section of the chamber-forming cavity, according to the angular position around the axis of rotation of the rotor, there is at least one input port or output port.
 4. Machine according to Claim 1, in which the piston contains at least one sealing synchronizing element installed in the slot, through which the piston interacts with the guide part of the separator.
 5. Machine according to Claim 4, in which a sealing synchronizing element is installed in the piston with the capability of turning relative to an axis perpendicular to the axis of the piston.
 6. Machine according to Claim 1, in which the guide part of the separator is installed in the housing at a fixed angle to the axis of rotation of the rotor.
 7. Machine according to Claim 1, in which the separator is installed in the housing with the capability of changing the slope of the guide part to the axis of rotation of the rotor to control feed of the machine.
 8. Machine according to Claim 7, in which the separator changes the slope of the guide part to the axis of rotation of the rotor, by turning around an axis perpendicular to the axis of rotation of the rotor.
 9. Machine according to Claim 7, in which the separator is supplemented by a shell with a sphere-like cavity in which its guide part is situated.
 10. Machine according to Claim 9, in which the guide part is situated at an angle relative to the shell and changes its slope to the axis of rotation of the rotor by turning of the shell around an axis passing at an angle to the axis of rotation of the rotor.
 11. Machine according to Claim 10, in which a sleeve is installed in the housing, on which input and output ports of the working fluid are positioned, the machine being equipped with a mechanism for turning of the separator and sleeve.
 12. Machine according to Claim 7, in which the separator changes the slope of the guide part to the axis of rotation of the rotor, by turning around a point - the center of the sphere-like working cavity.

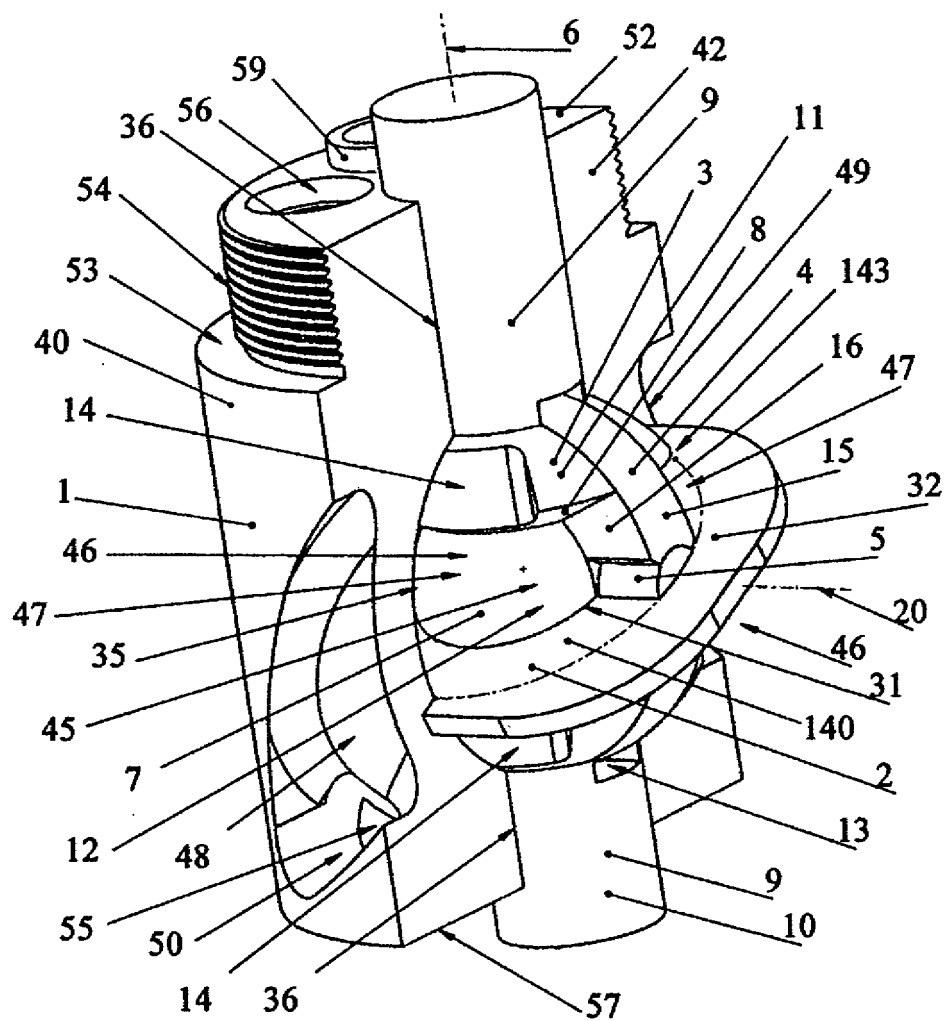


FIG.1

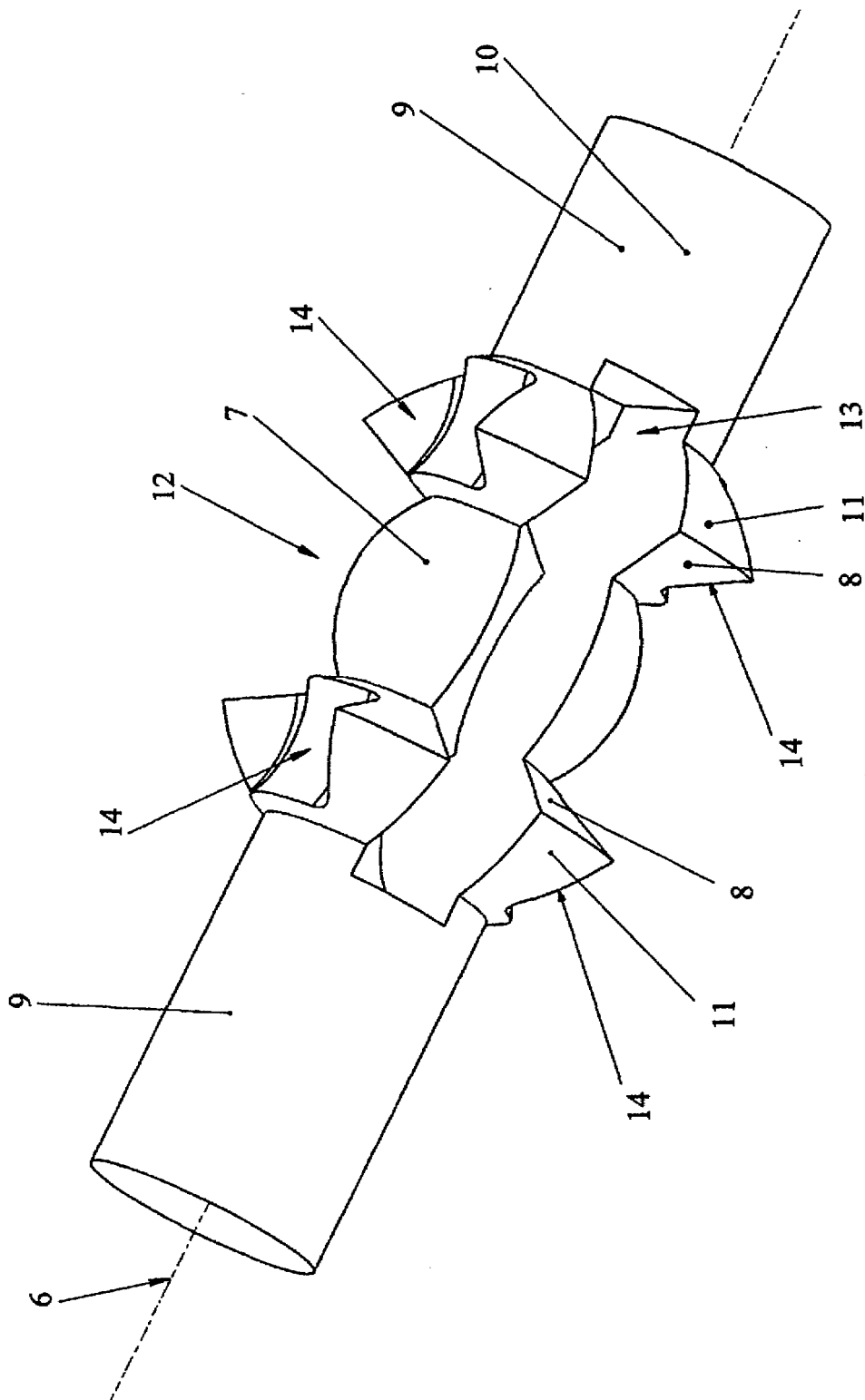


FIG.2

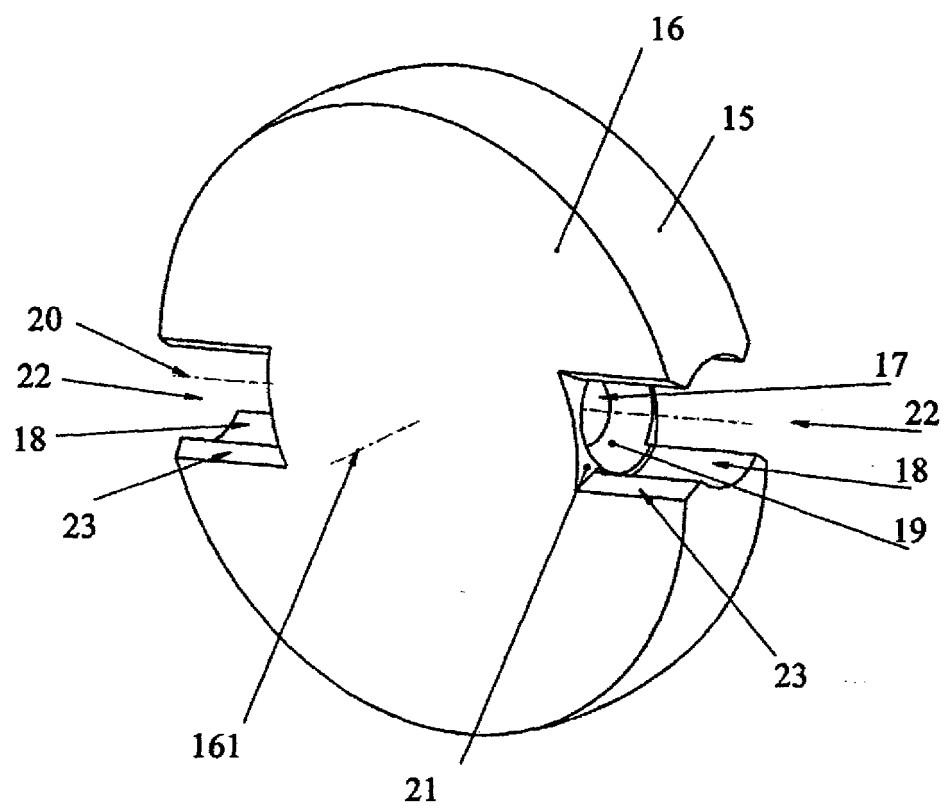


FIG.3

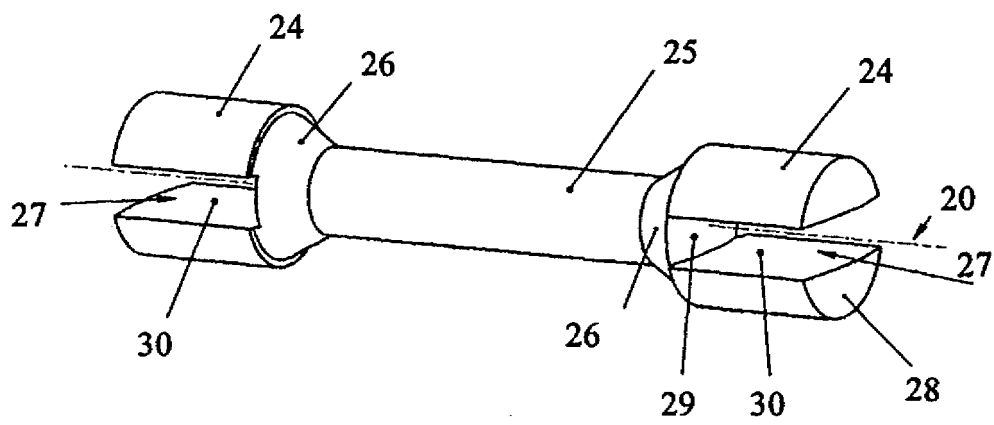


FIG.4

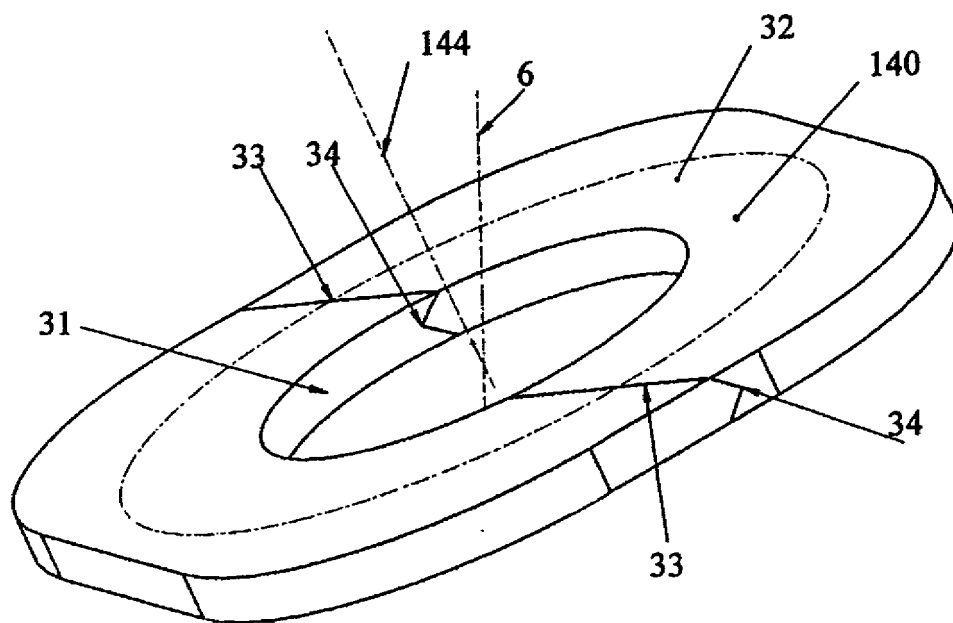


FIG.5

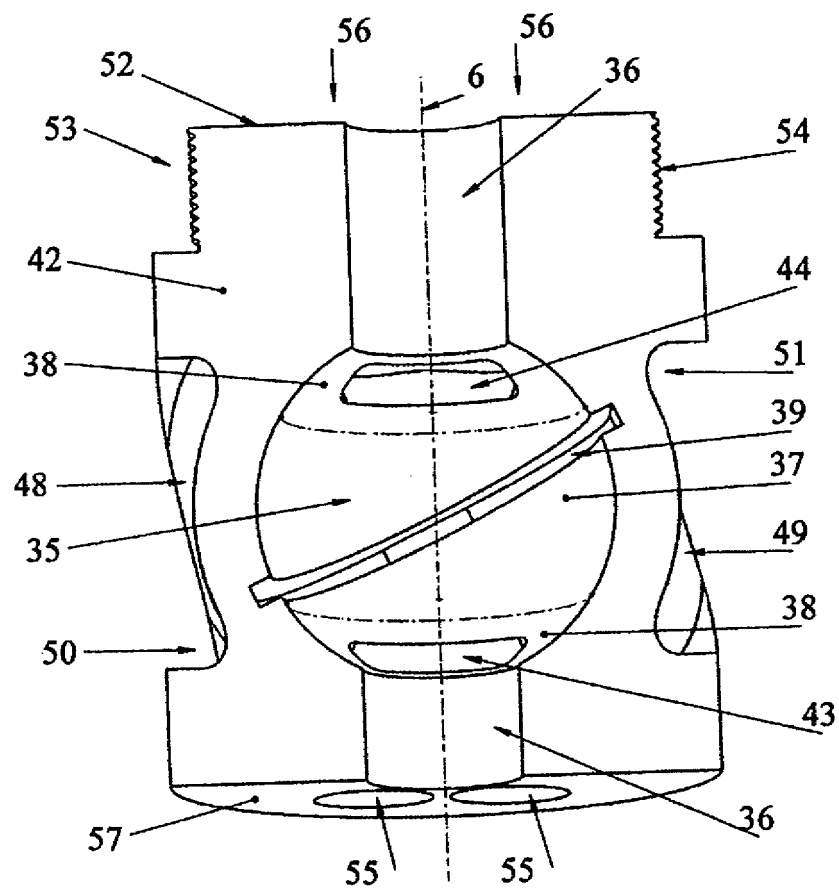


FIG.6

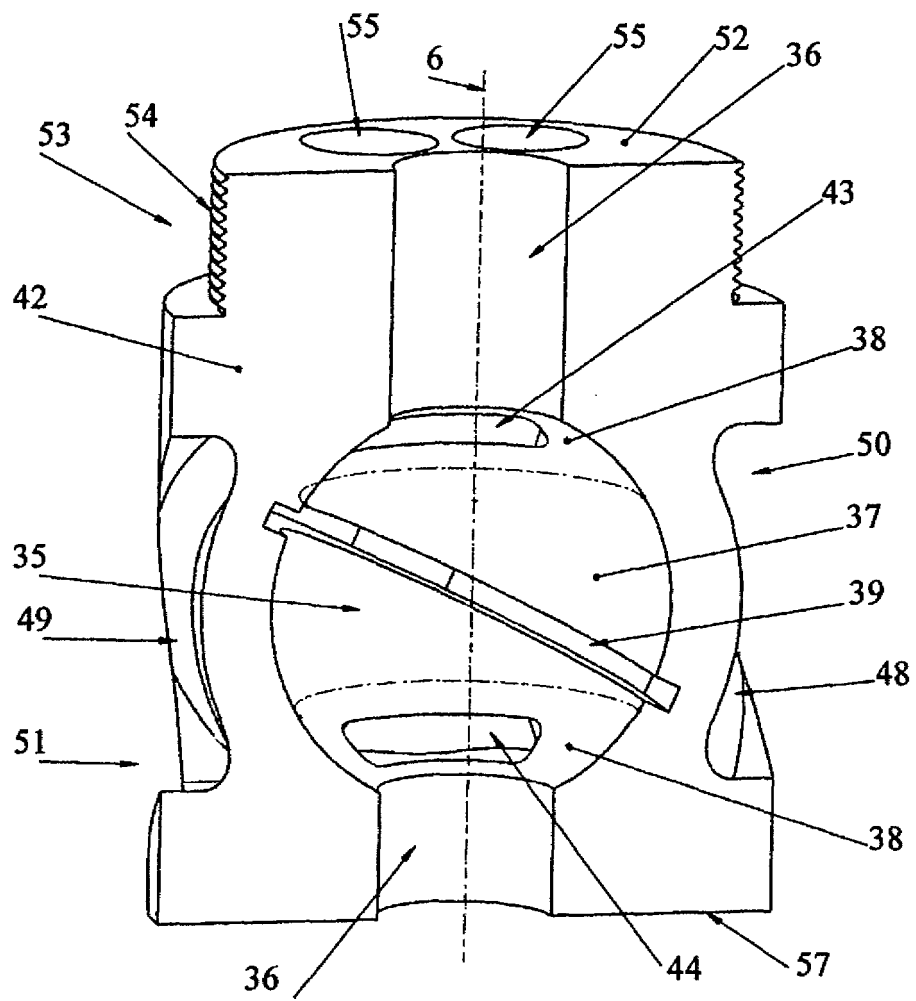


FIG.7

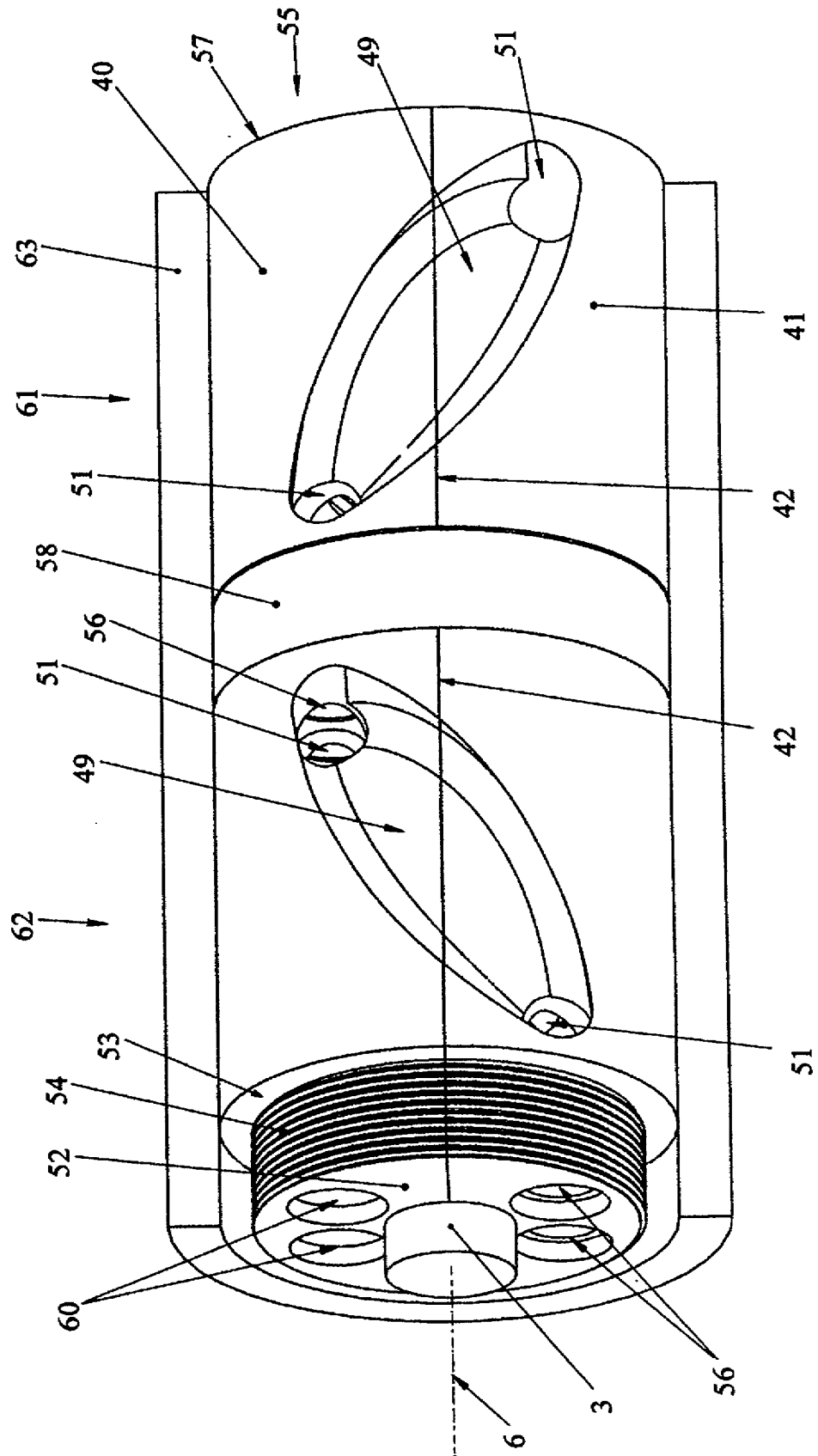


FIG. 8

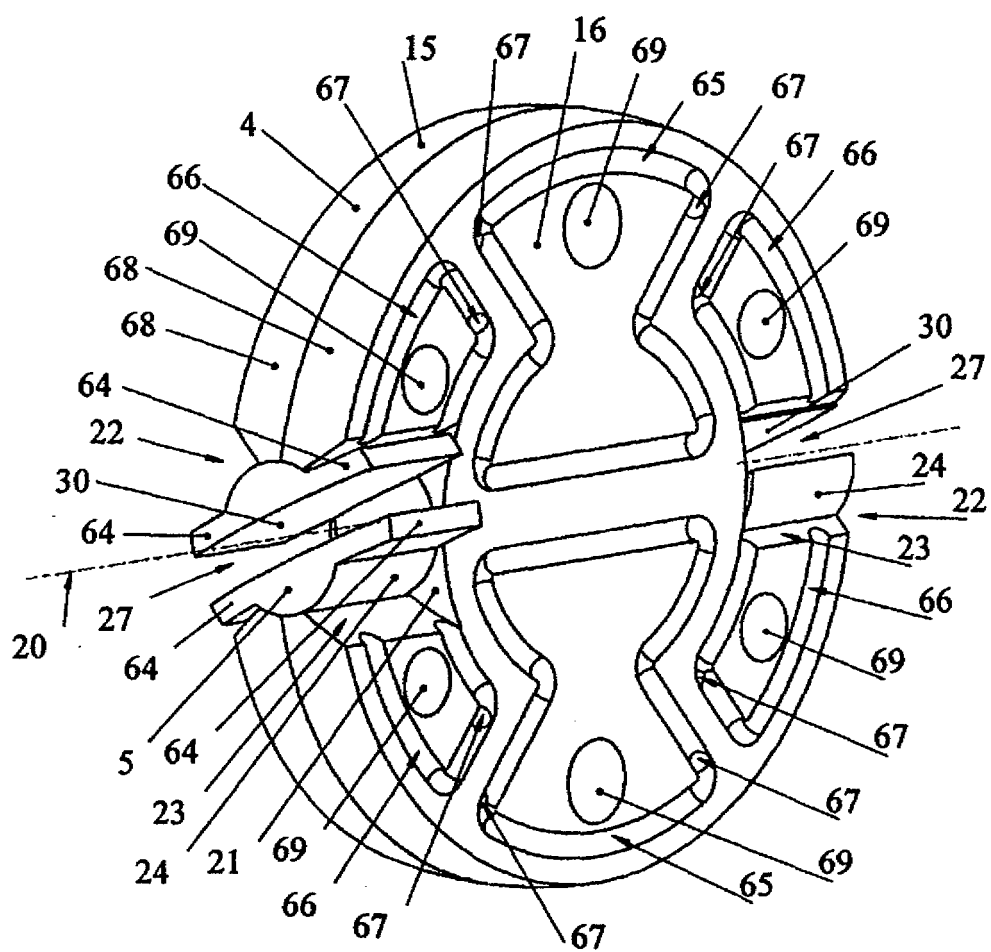


FIG.9

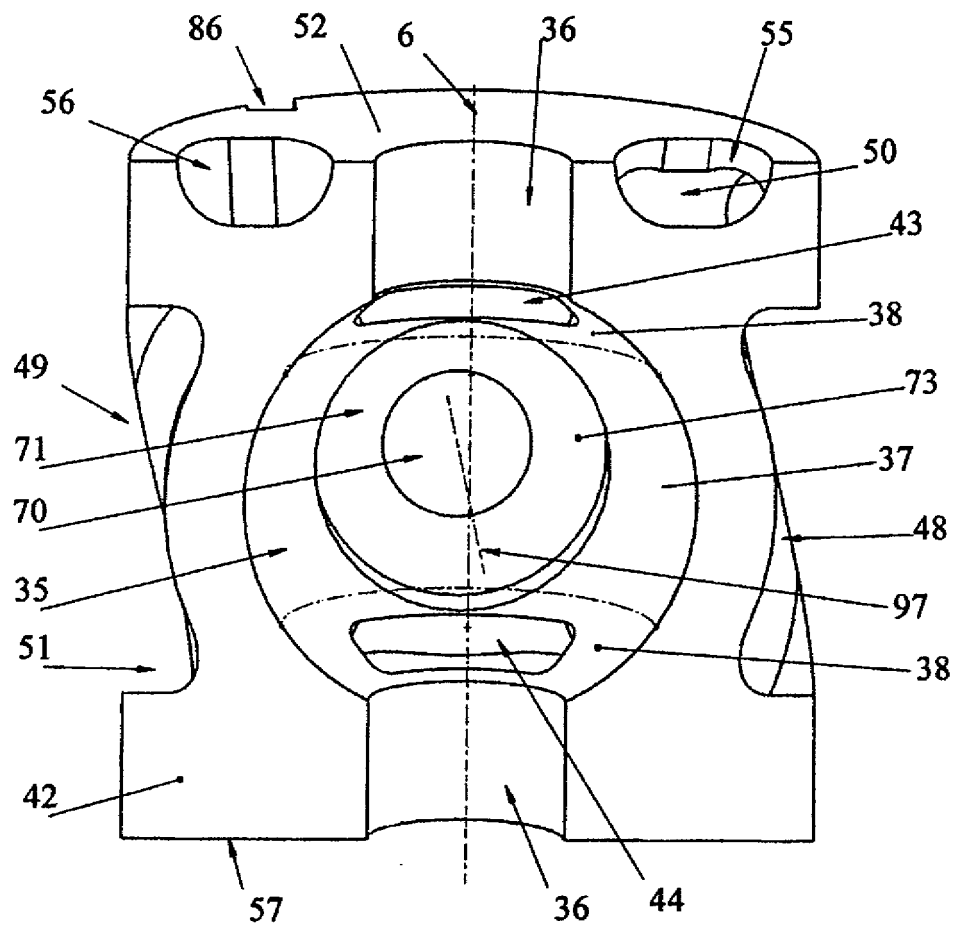


FIG.10

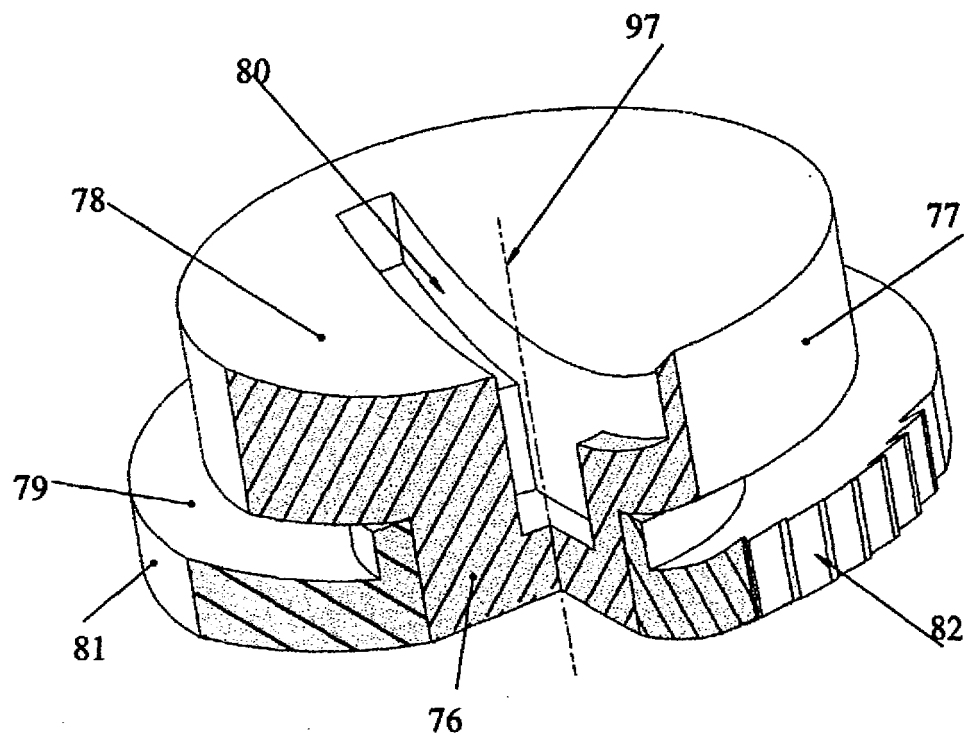


FIG.11

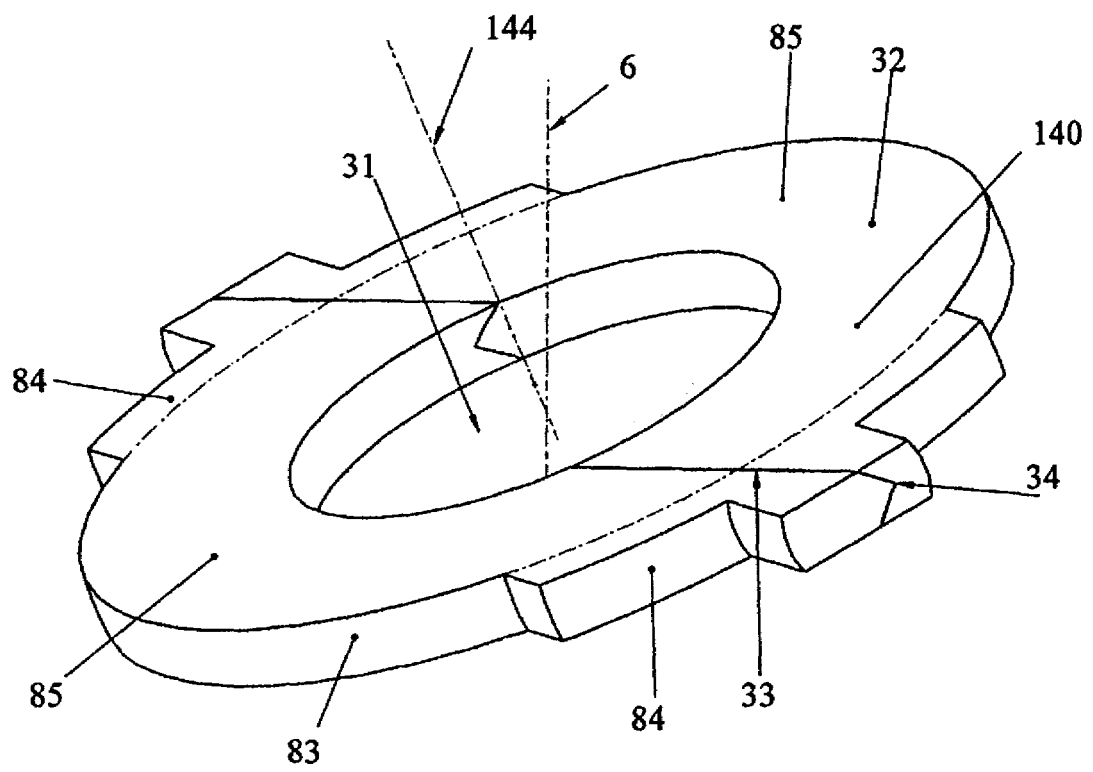


FIG.12

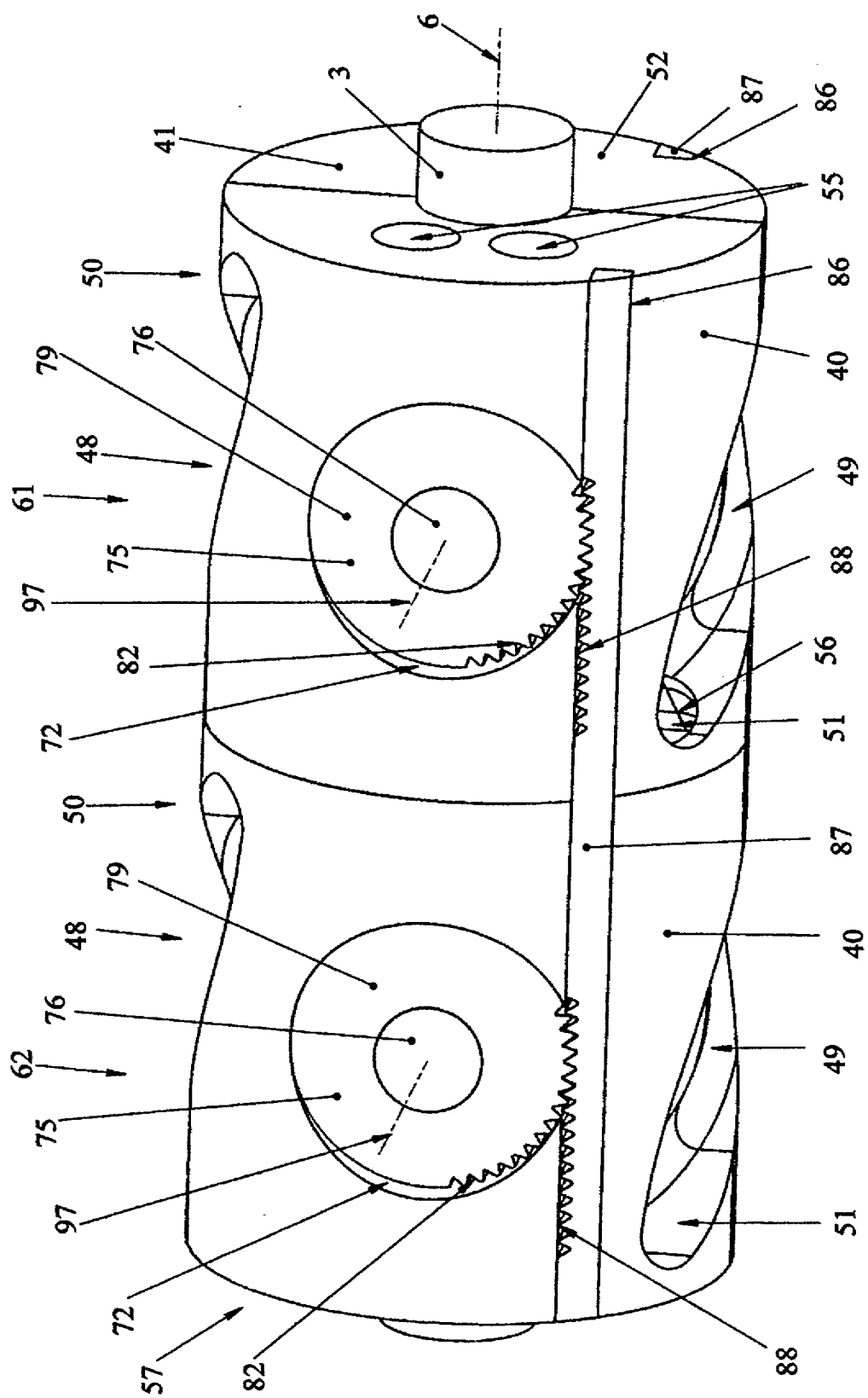


FIG.13

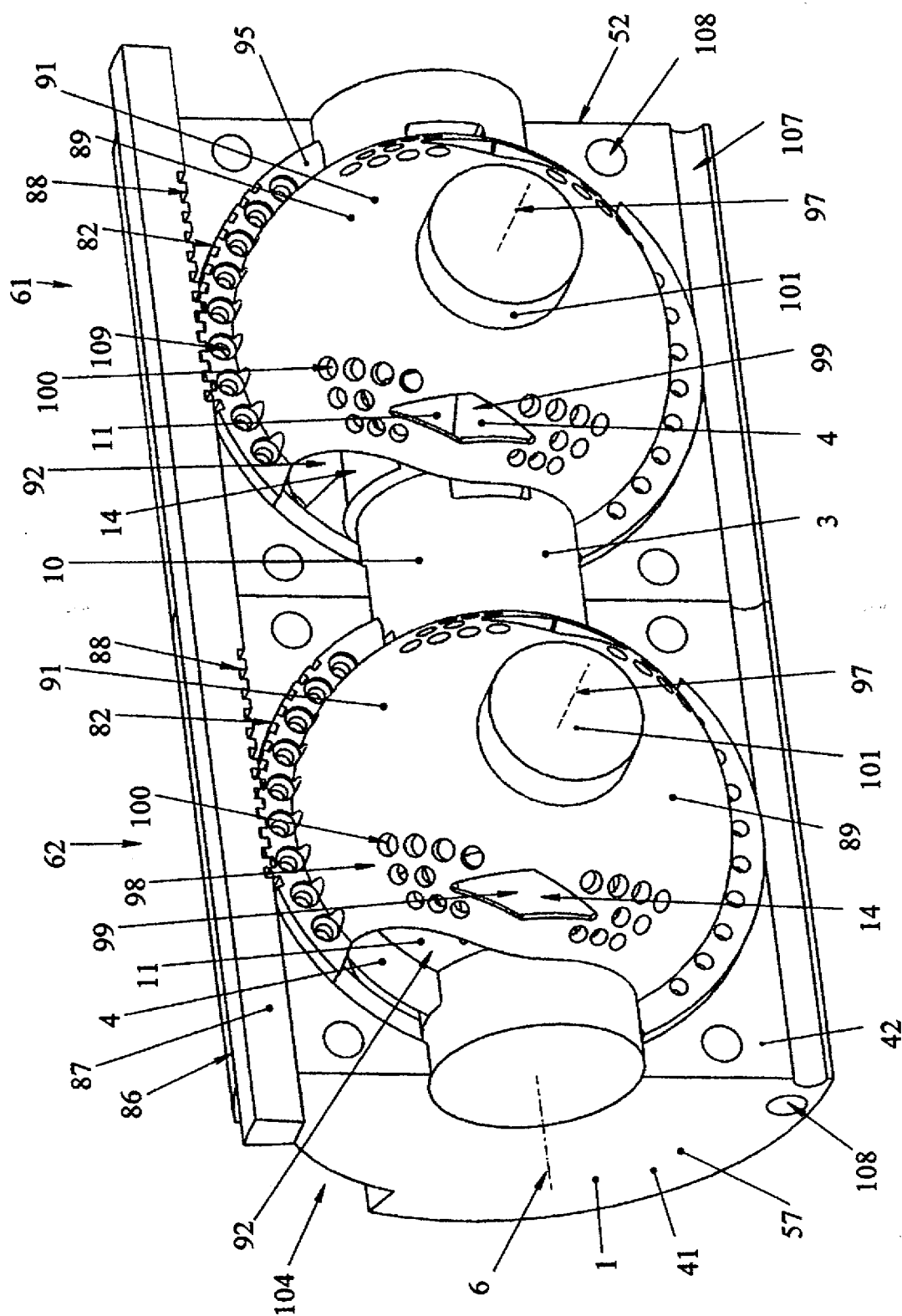


FIG.14

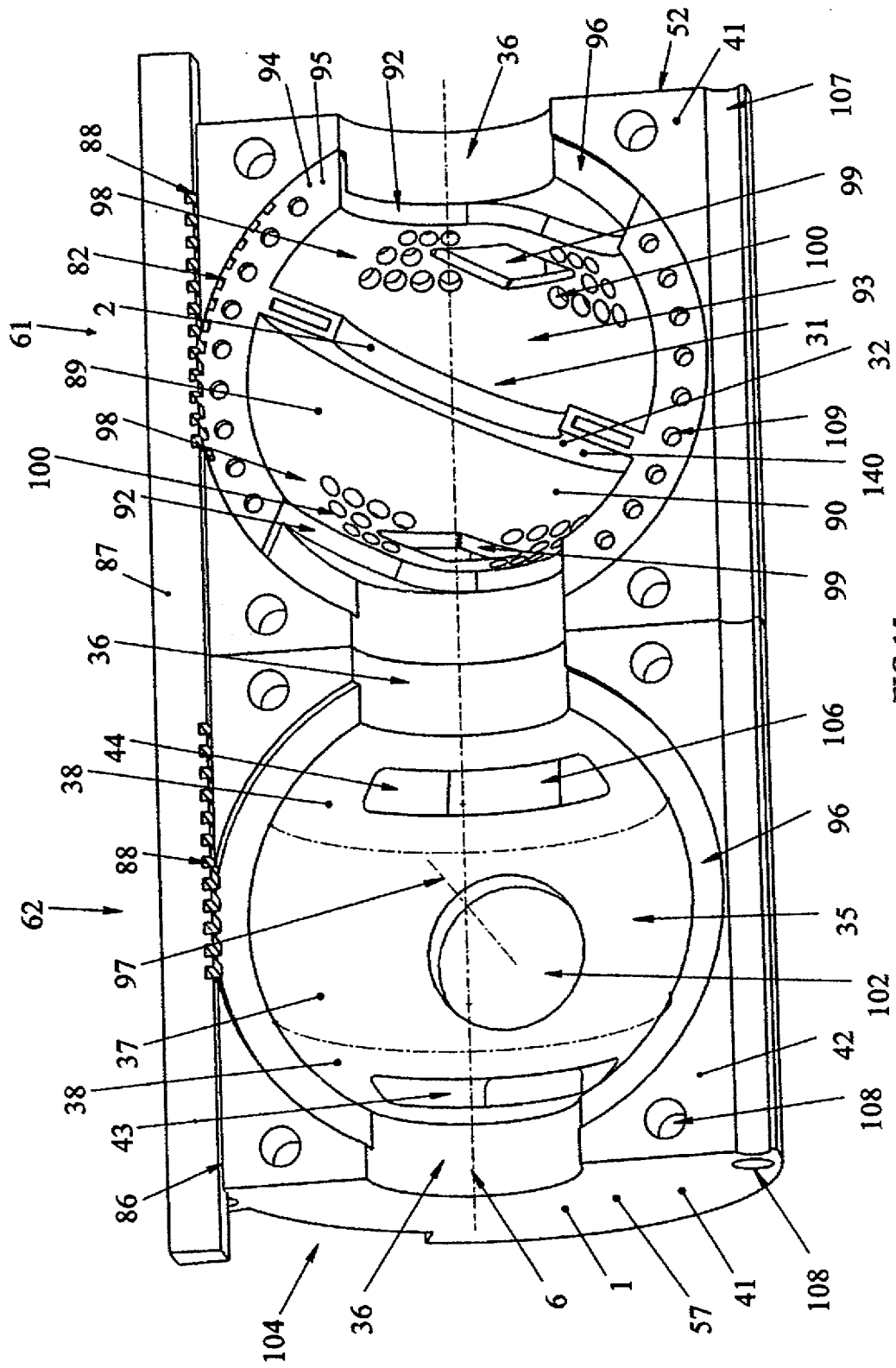


FIG.15

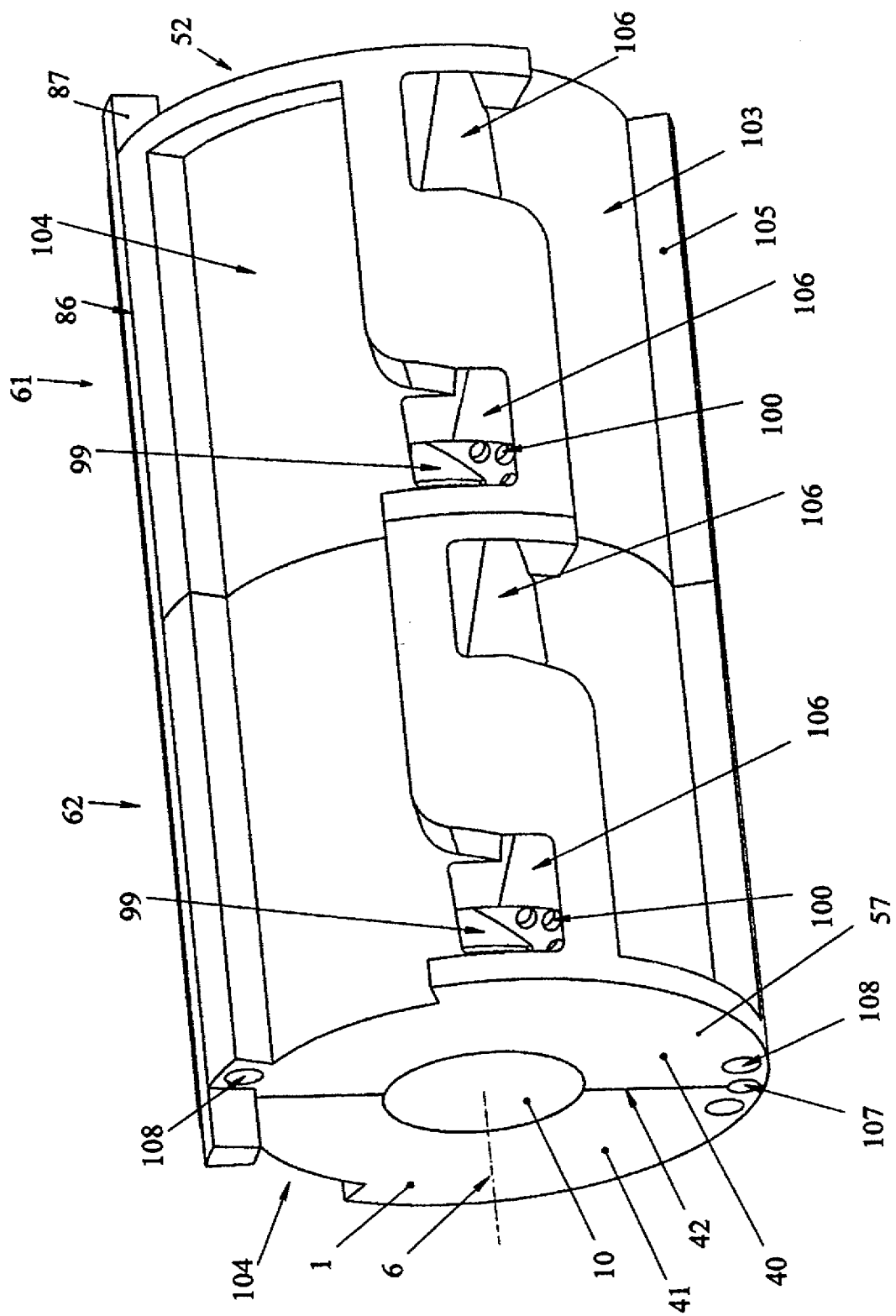


FIG.16

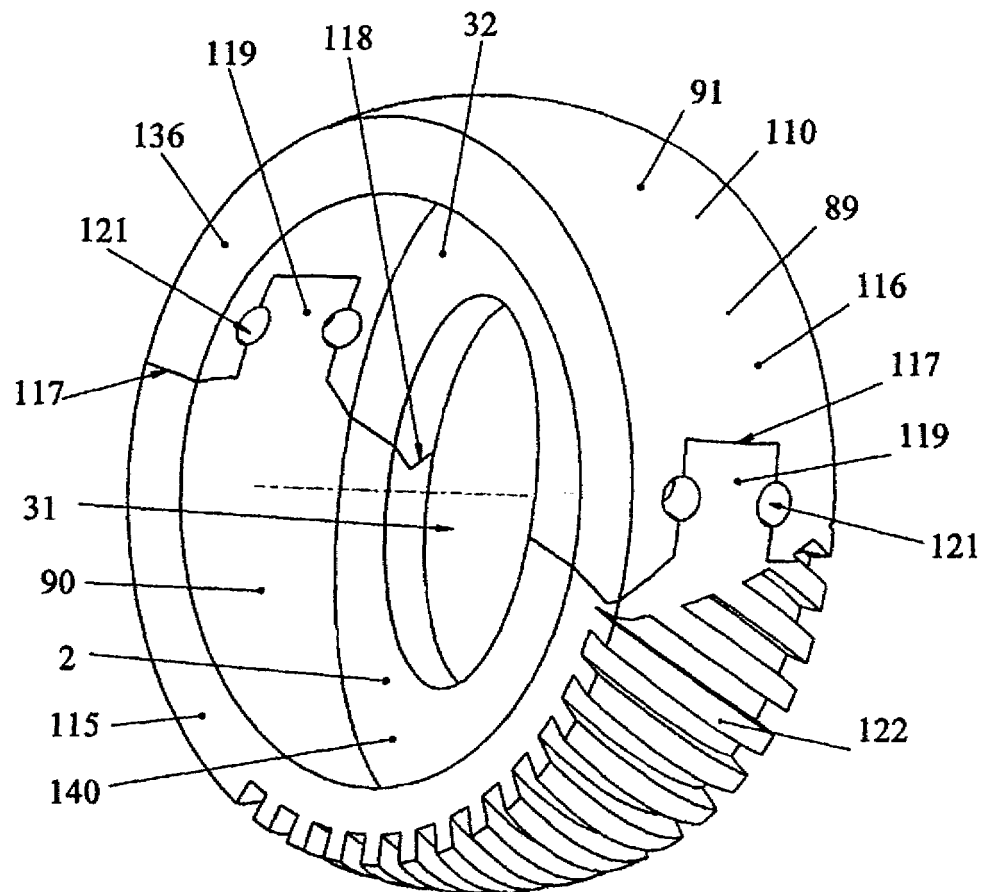


FIG.17

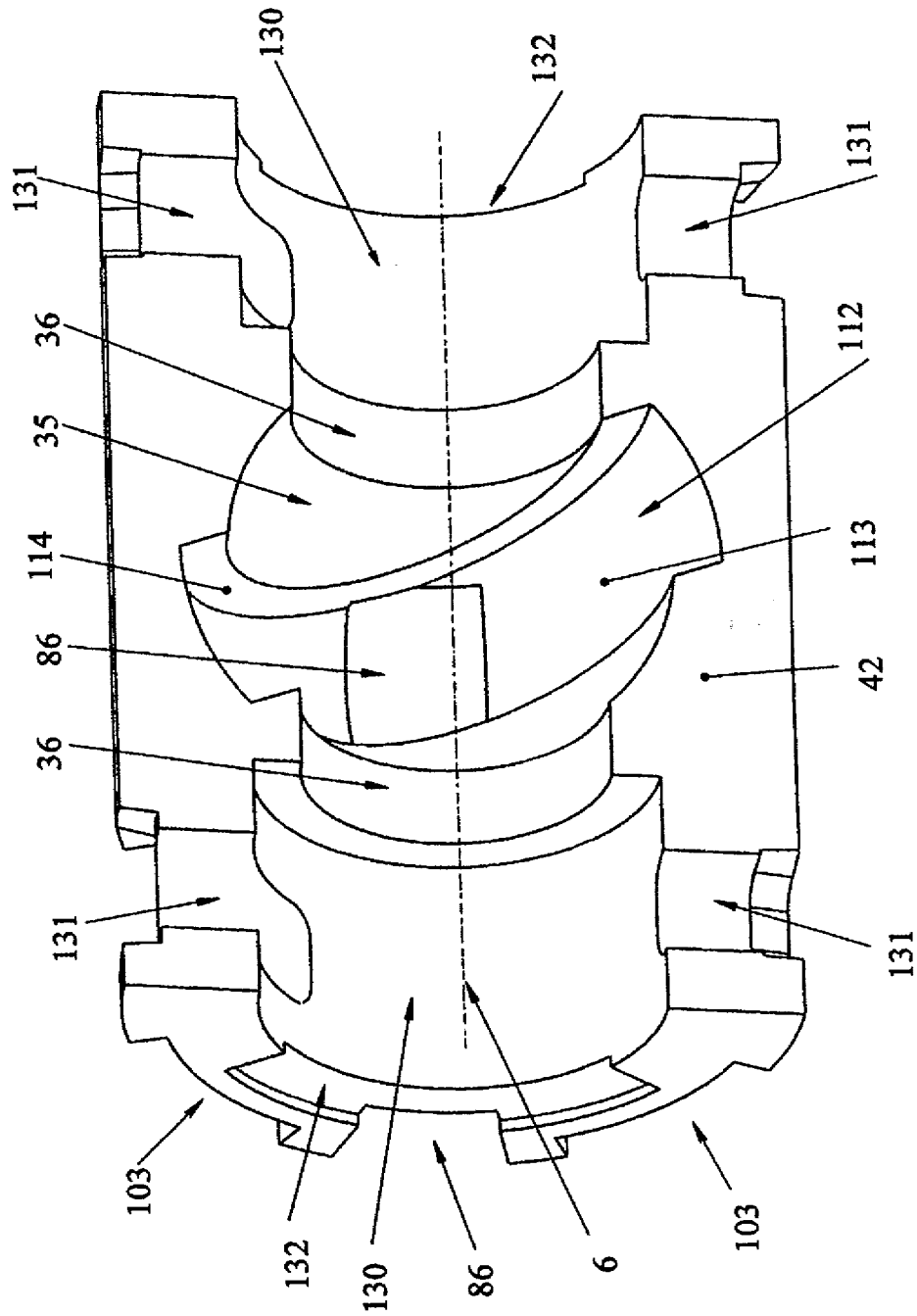


FIG.18

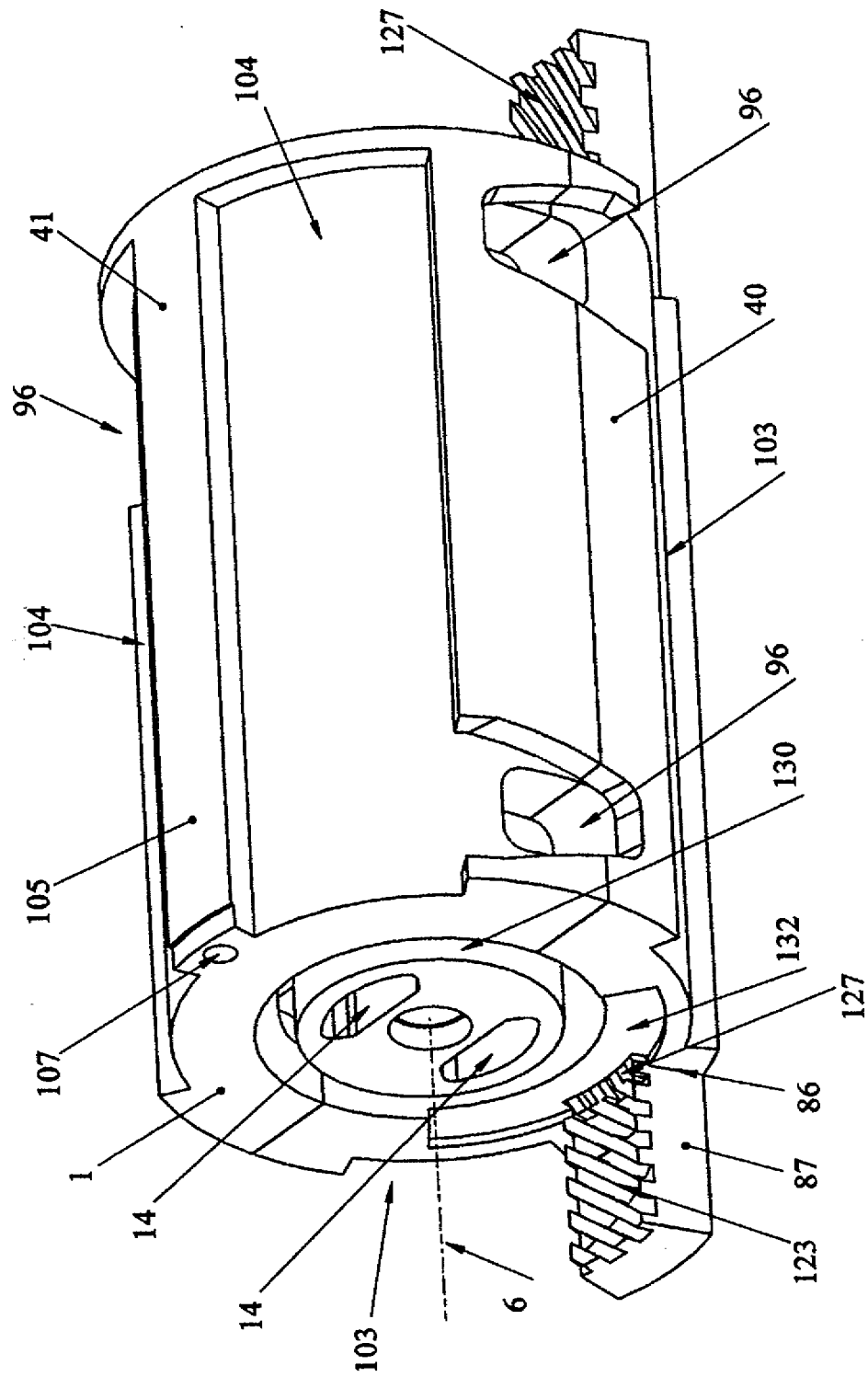


FIG.19

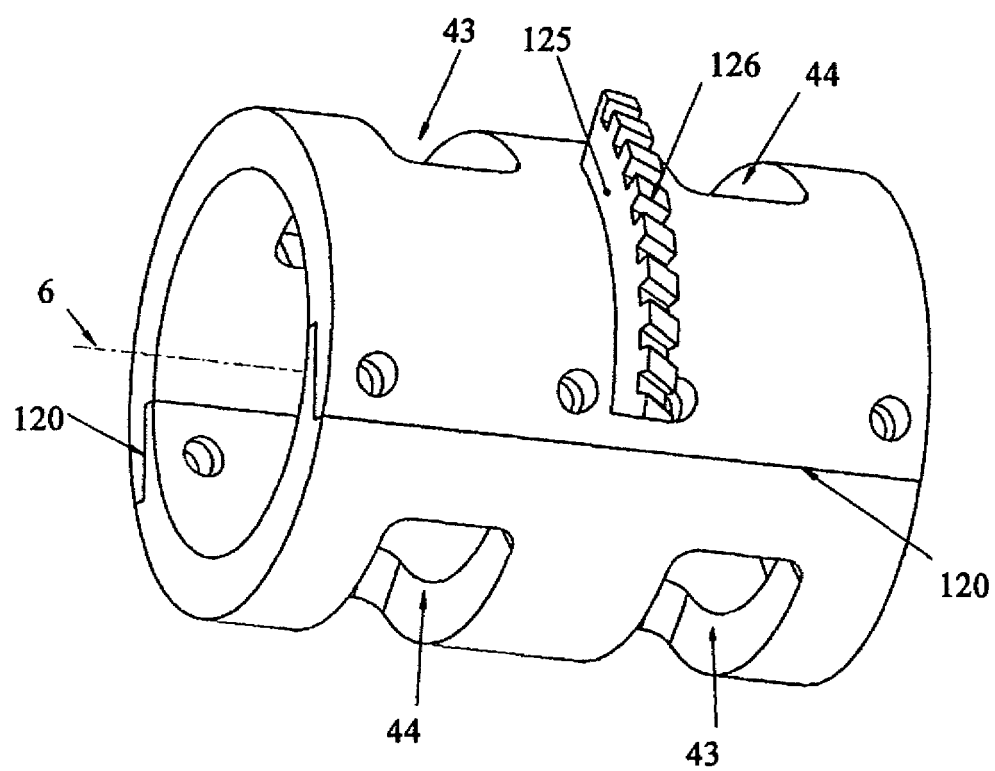


FIG.20

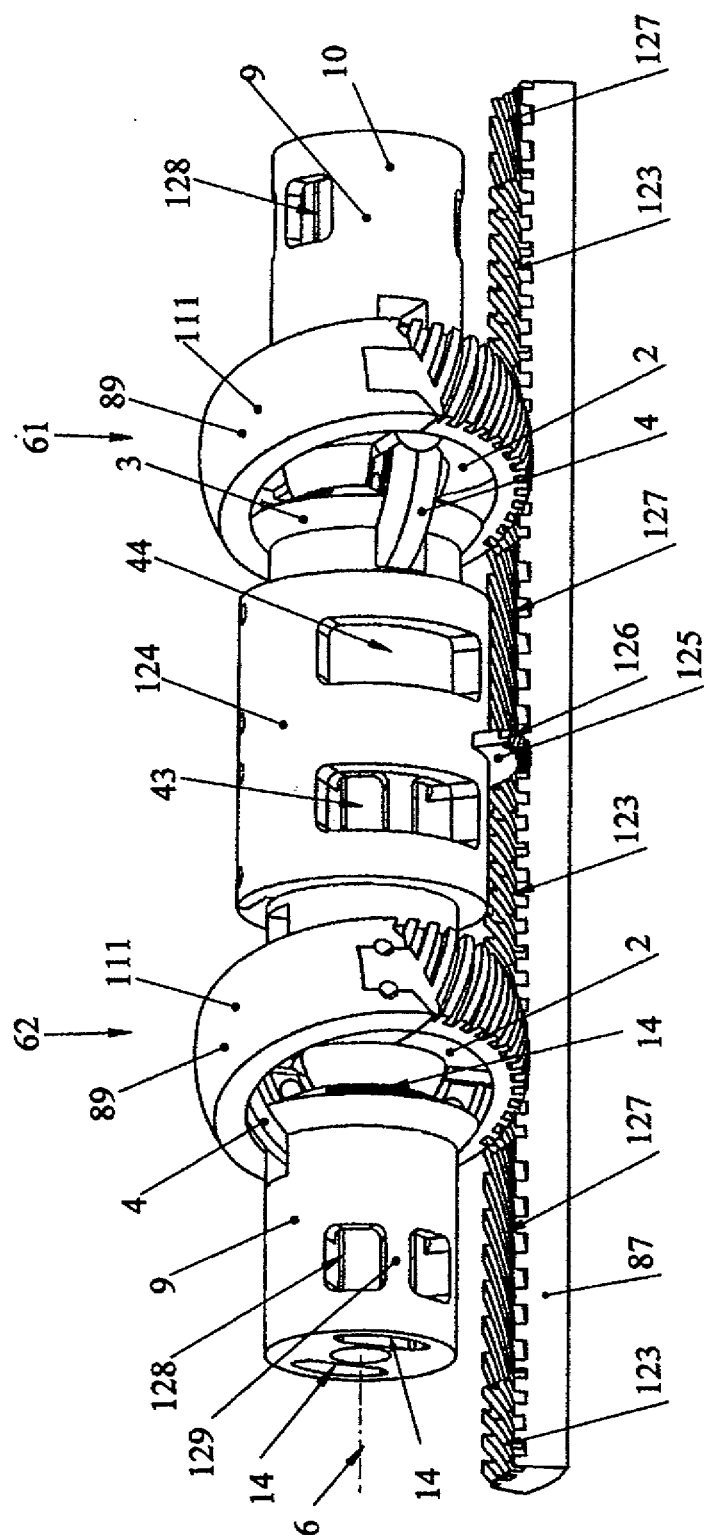


FIG. 21

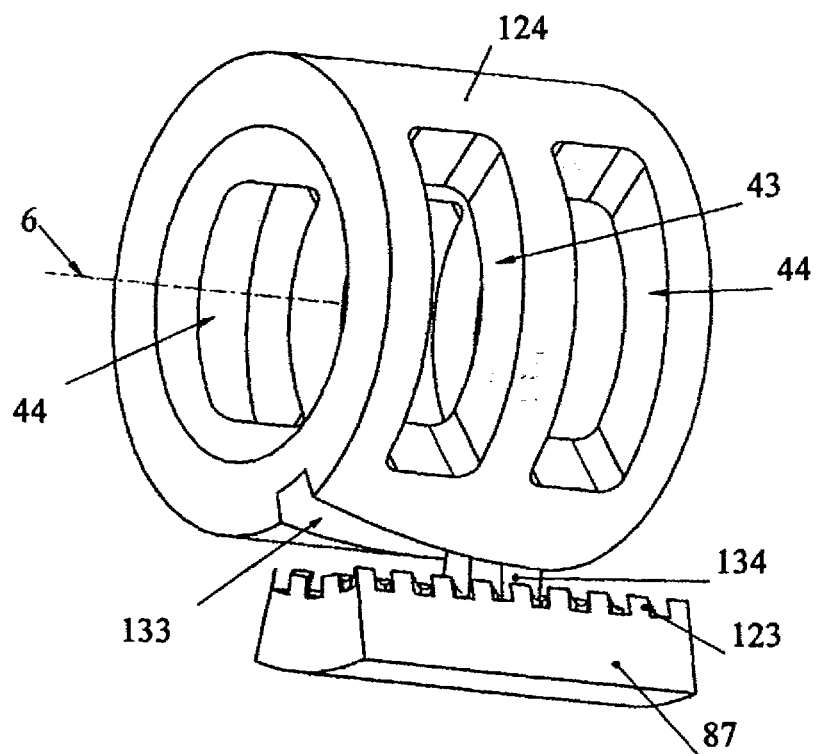


FIG.22

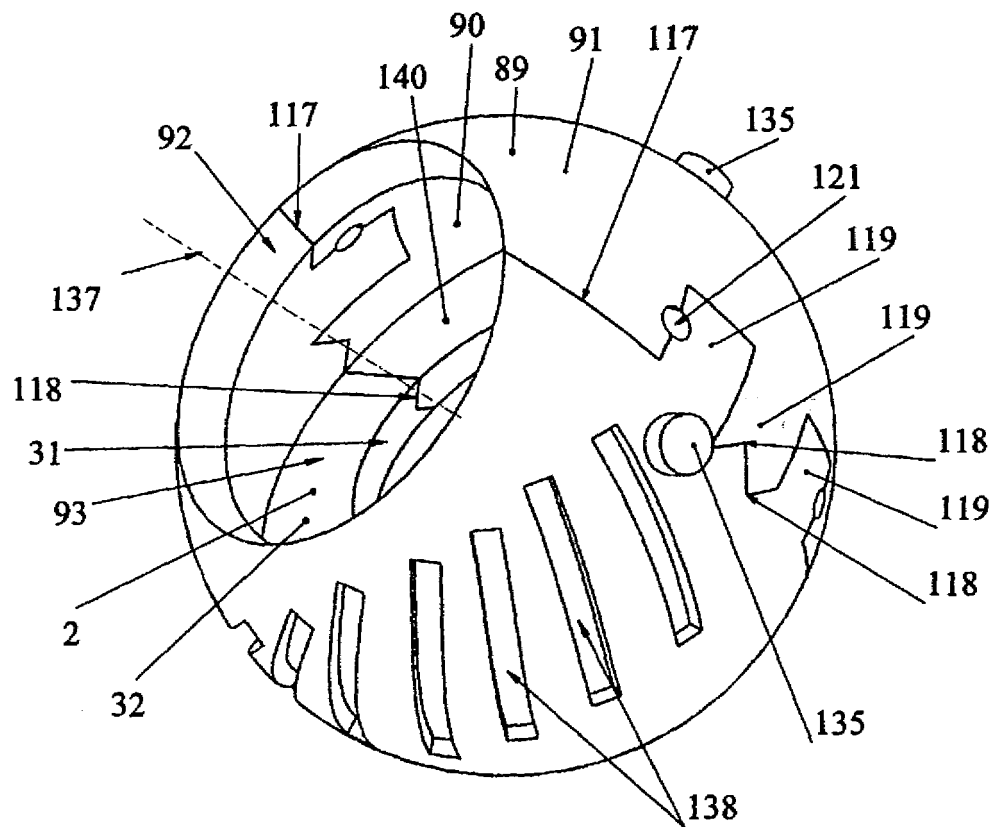


FIG.23

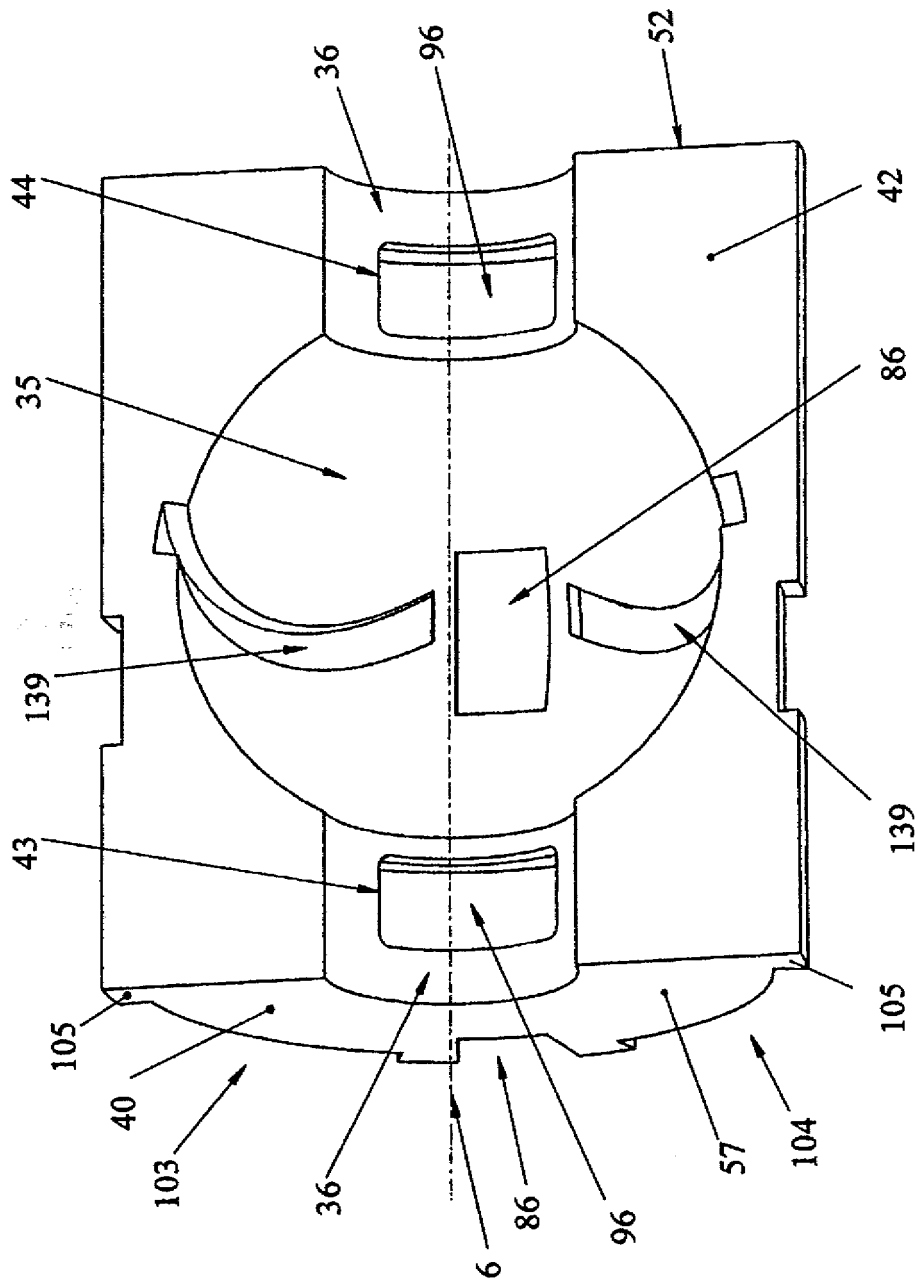


FIG. 24

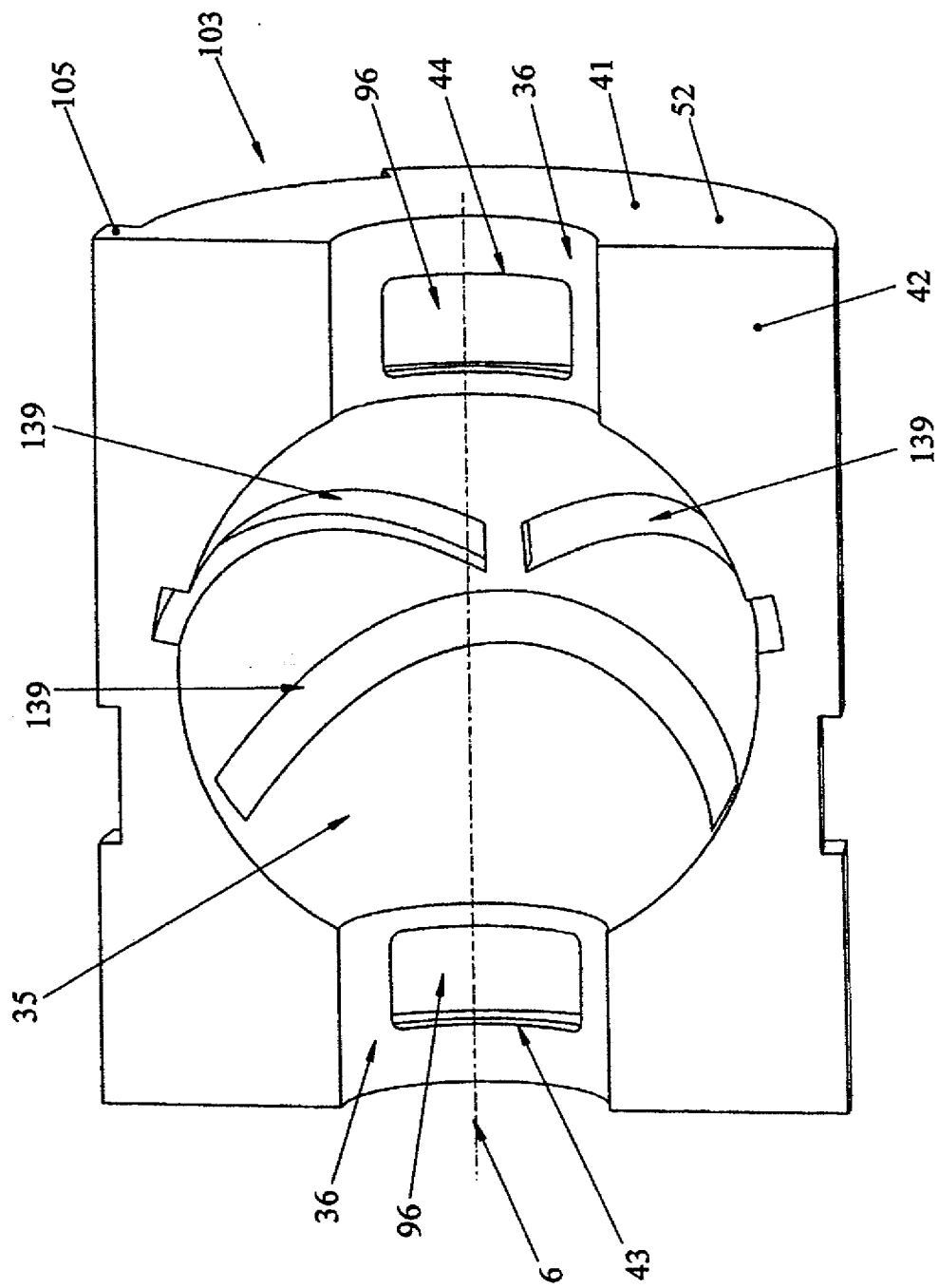


FIG. 25

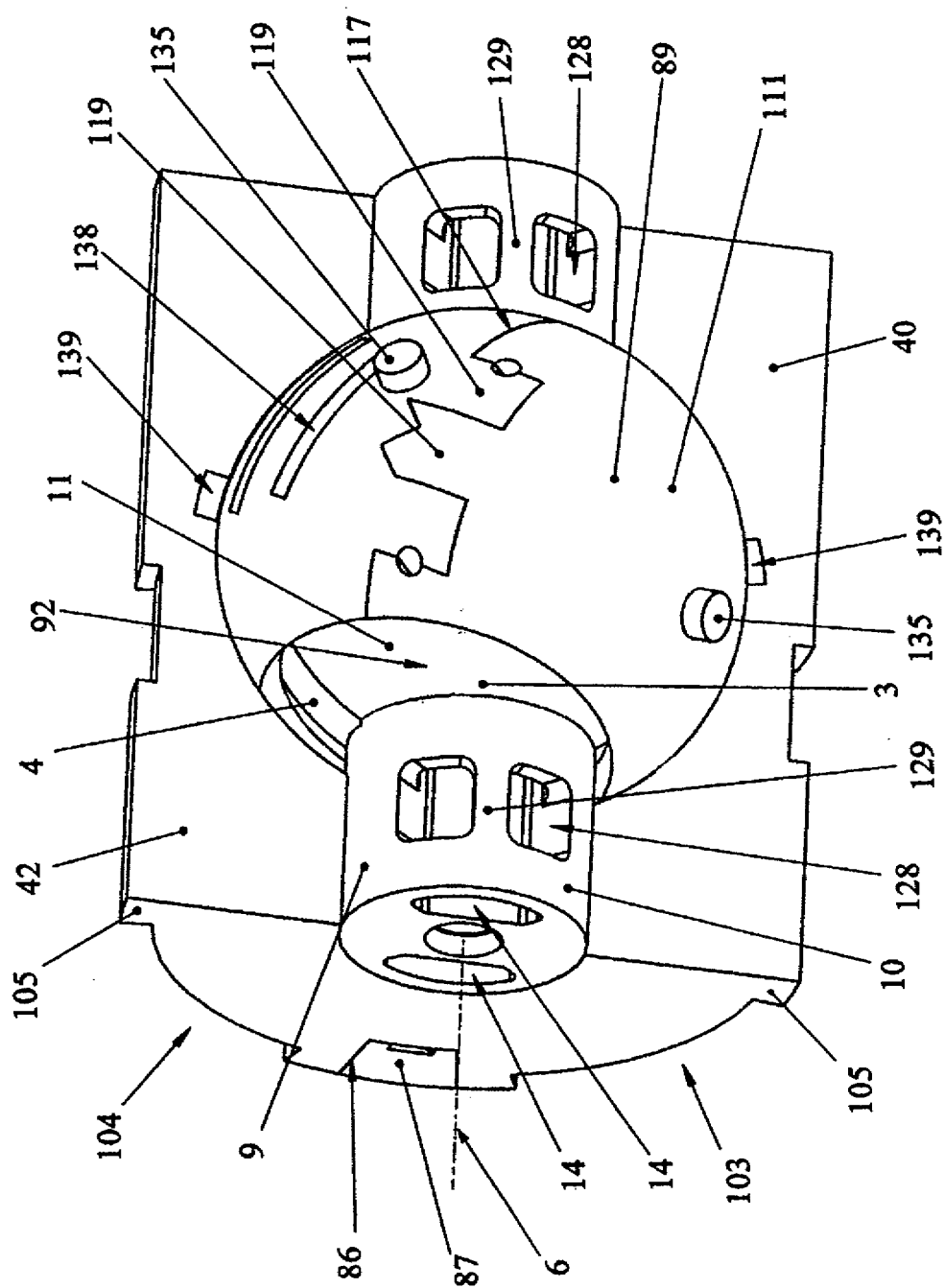


FIG. 26

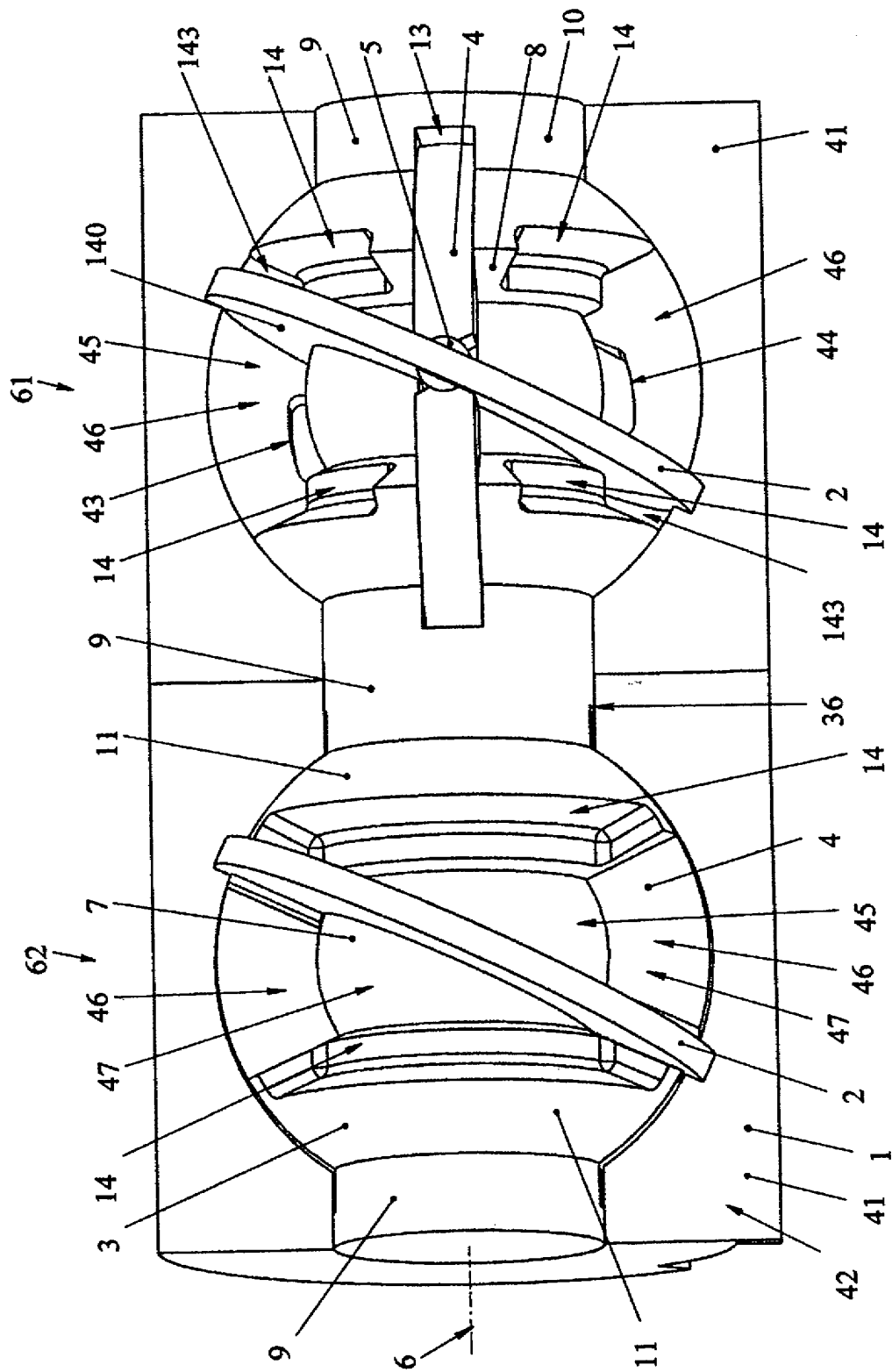


FIG. 27

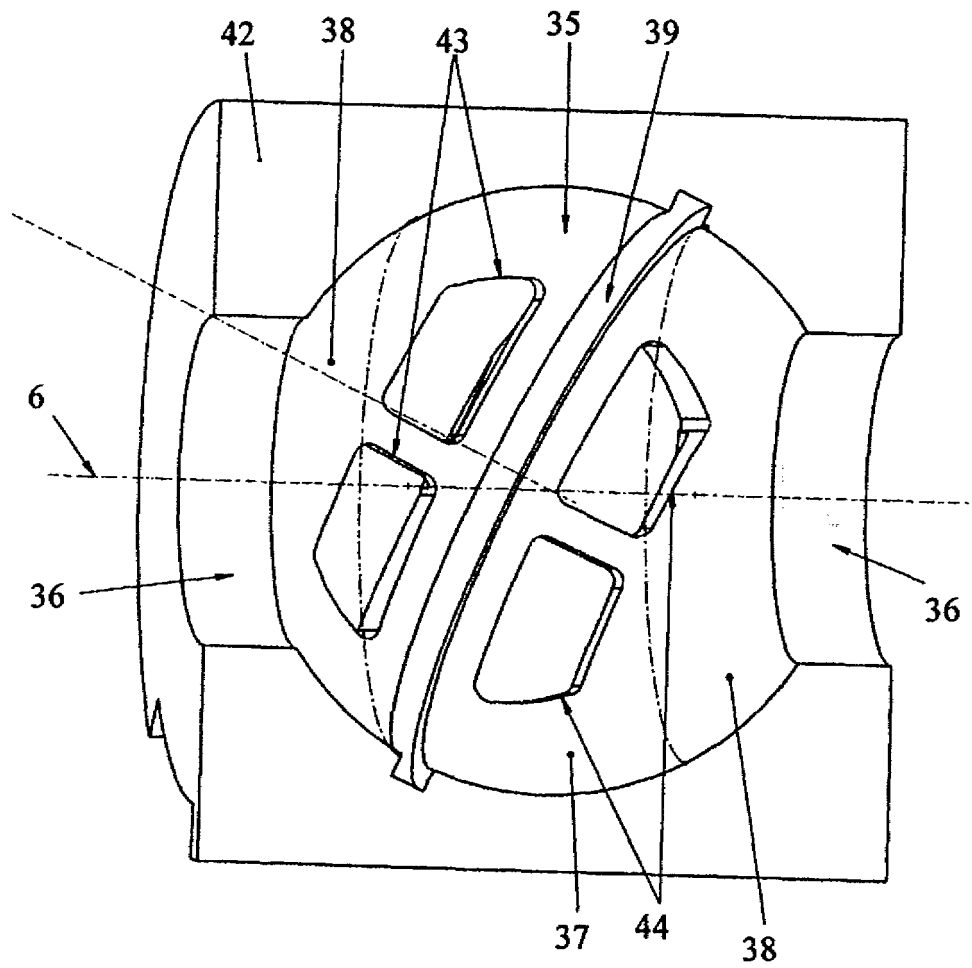


FIG.28

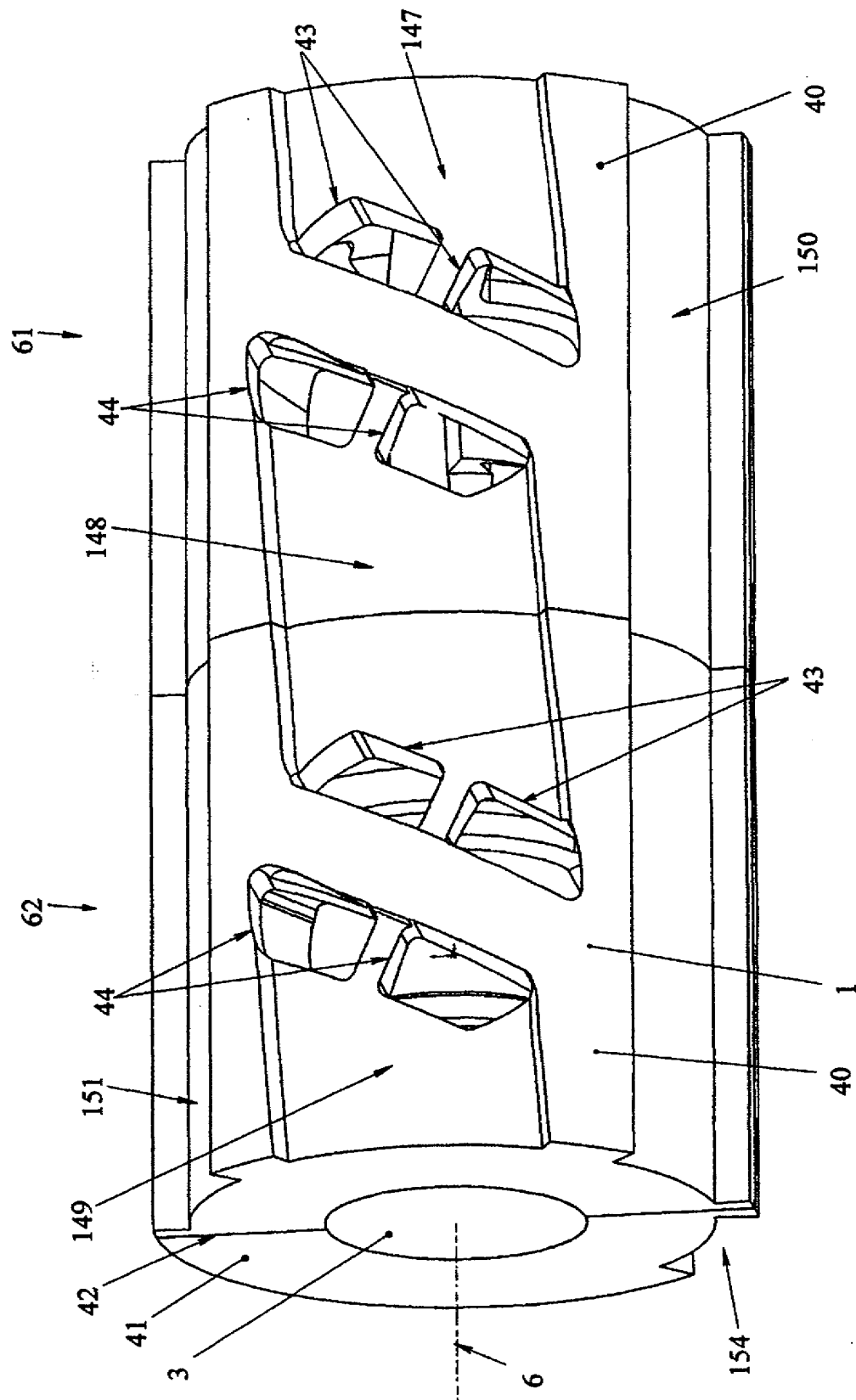


FIG. 29

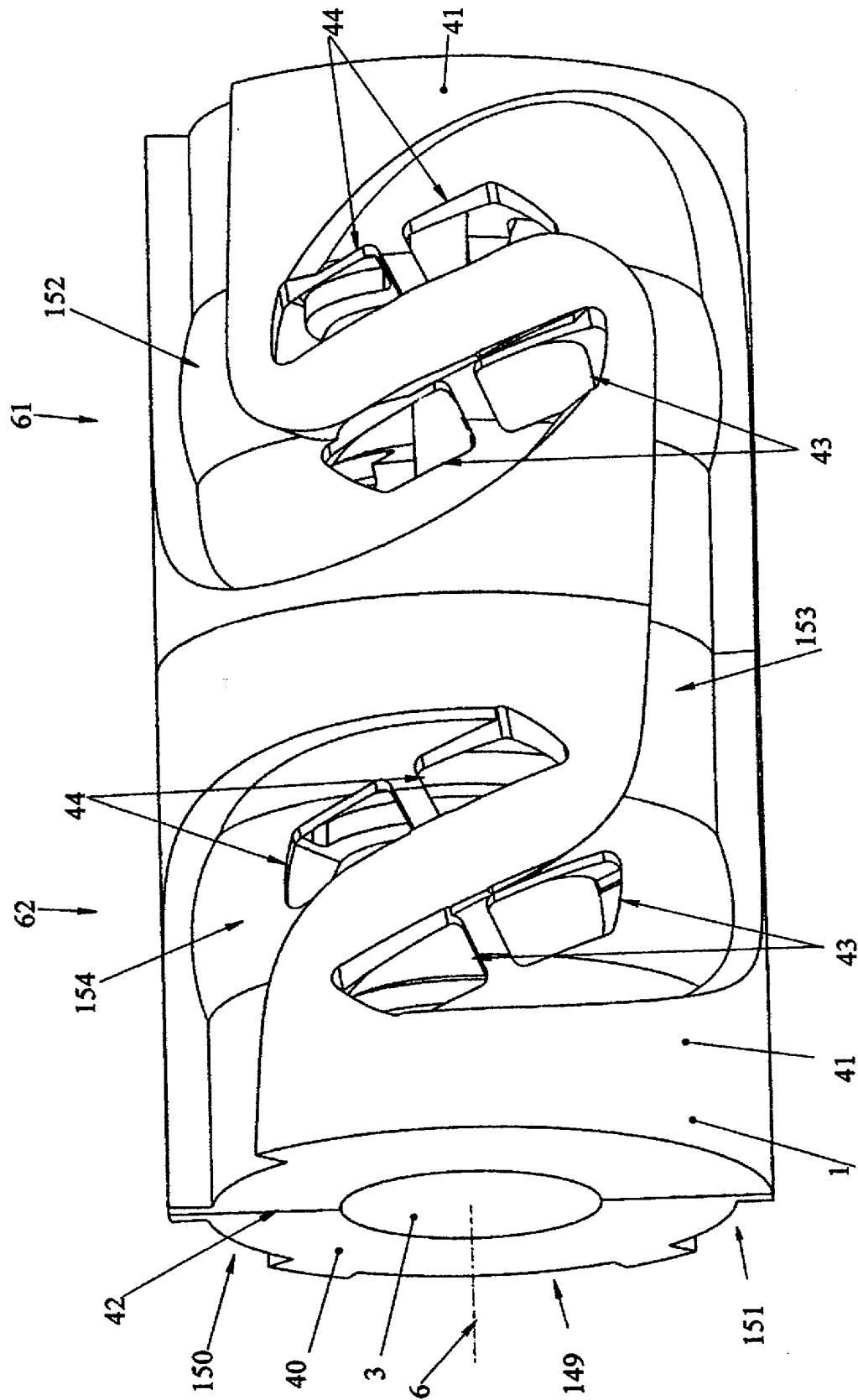


FIG. 30

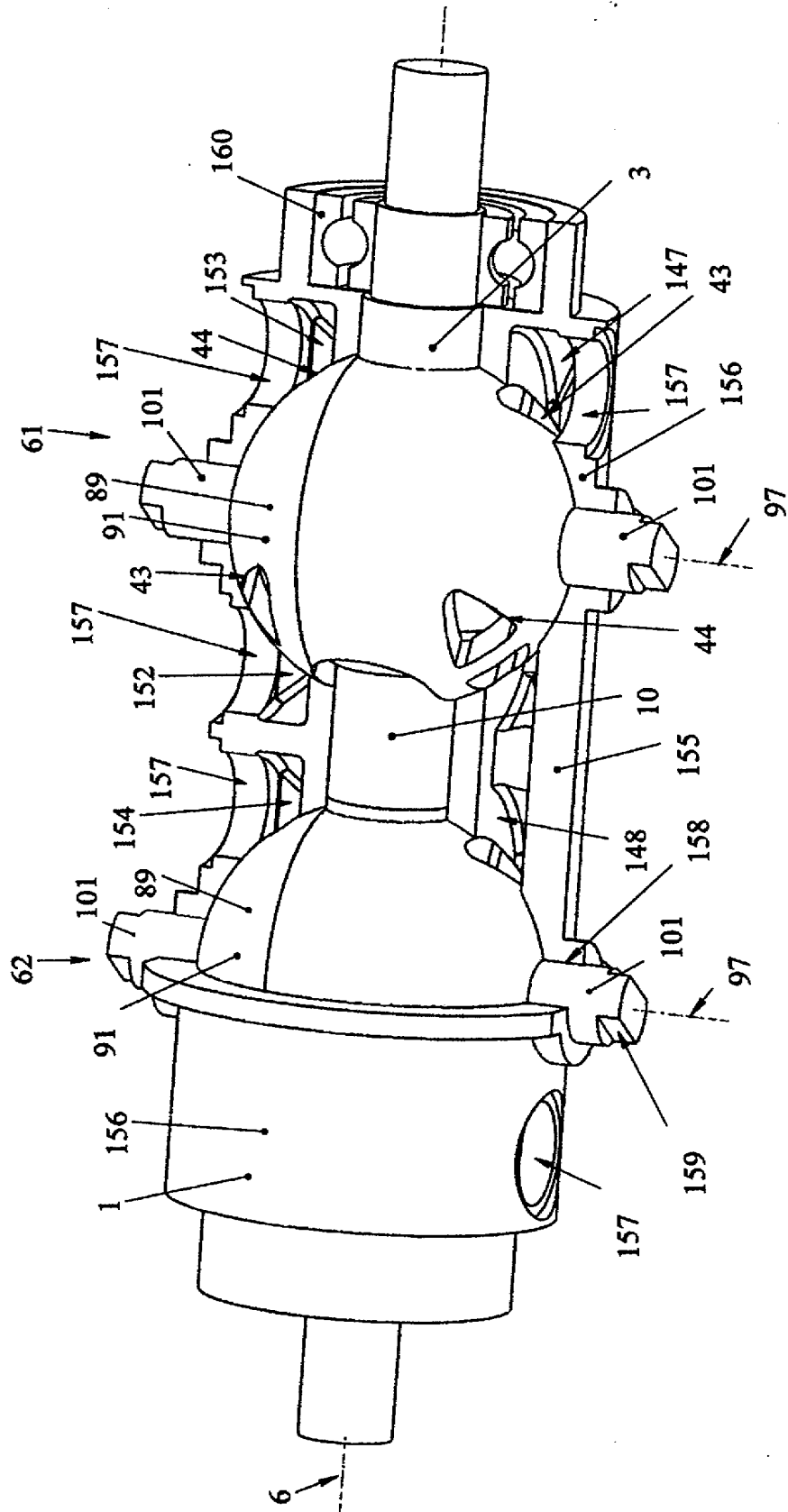


FIG. 31

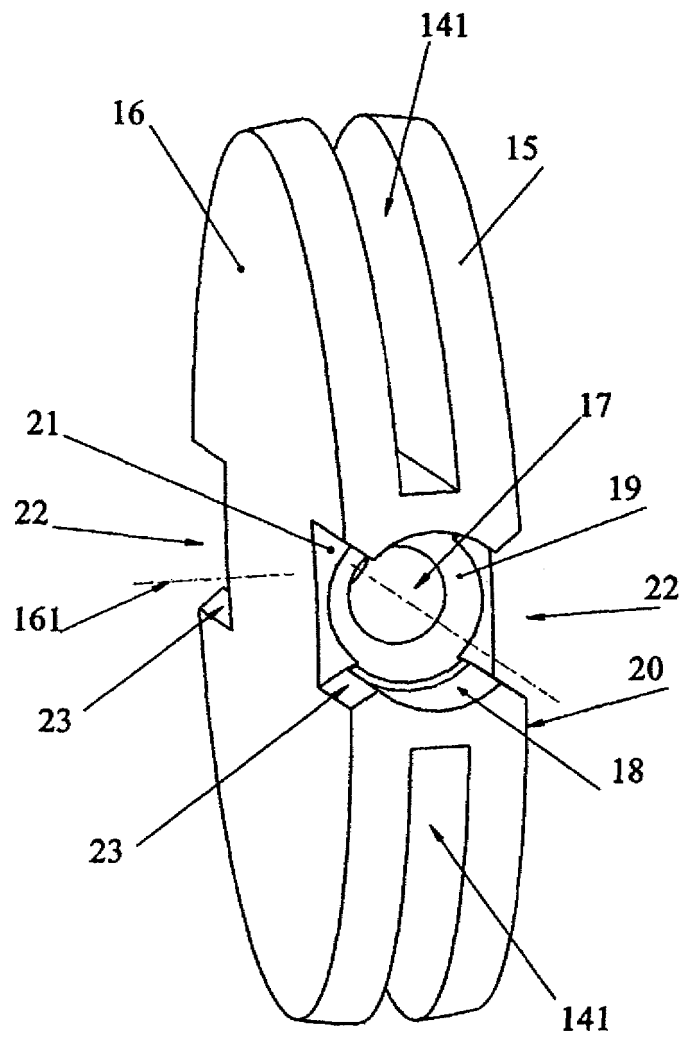


FIG.32

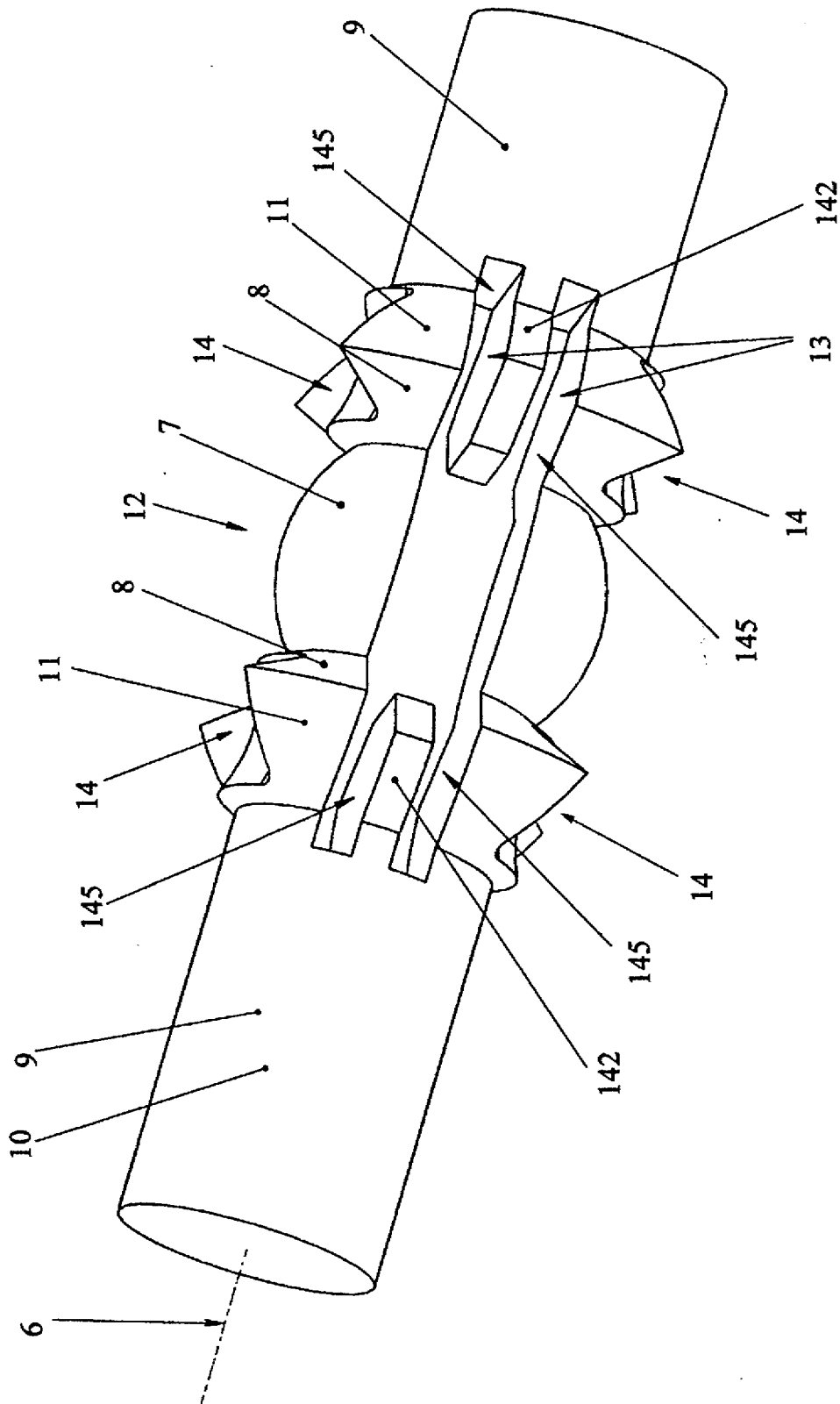


FIG.33

INTERNATIONAL SEARCH REPORT

International application No.

PCT/RU 2011/000031

A. CLASSIFICATION OF SUBJECT MATTER		
F01C 3/06 (2006.01) F04C3/06 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
F01C 1/00, 3/00-3/06, 9/00, 20/00-20/26, F02B 53/00-53/14, F04C 2/00, 3/00-3/06, 9/00, 14/00-14/26 A61N 1/32		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
RUPAT, Esp@cenet, USPTO, CA (Chem.Abstr), SIPO, CNPAT, CNIPR, KIPRIS, K-PION, IPDL, AIPN, WIPO		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RU 2376478 C2 (DIDIN ALEKSANDR VLADIMIROVICH et al.) 20.12.2009	1-12
A	DE 964866 A (MAURICE PELLADEAU) 29.05.1957	1-12
A	GB 790190 A (RECHERCHES ETUDES PRODUCTION R.E.P.) 05.02.1958	1-12
A	US 826985 A (DANIEL APPEL) 24.07.1906	1-12
A	GB 403914 A (JAMES LEWIS KEMPTHORNE) 04.01.1934	1-12
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
18 May 2011 (18.05.2011)		26 May 2011 (26.05.2011)
Name and mailing address of the ISA/		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

REFERENCES CITED IN THE DESCRIPTION

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- RU 2202695 [0009]
- RU 2382884 [0011] [0040]
- RU 2376478 [0017]