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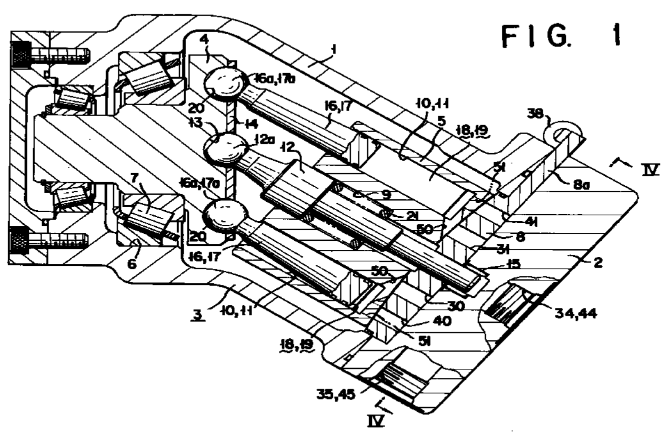
(54) **HYDRAULIC PUMP/MOTOR APPARATUS**

(57) A hydraulic pump and motor system includes a cylinder block (5) with a plurality of fluid chambers (18, 19), each of which has a volume increased and decreased as a piston (16, 17) is reciprocated. The cylinder block (5) is mounted, together with a shaft (4), rotatably in a housing (3) and is rotated along a valve plate (8). The cylinder block (5) when rotated causes each piston (16, 17) to be contractingly operated from an upper dead point to a lower dead point and be expandingly operated from the lower dead point to the upper dead point. A first and a fourth kidney port (30, 40) are formed in the valve plate (8) in a region of one of the left and right hand sides of a straight line (X) that lies connecting between those upper and lower points. A third and a second kidney port (40, 31) are formed in the valve plate (8) in a region of the other of the left and right hand sides of the straight line X). When the cylinder block (5) is rotated, the system causes some of the fluid chambers (18, 19) to communicate with the first and second kidney ports (30, 31) in turn, thereby providing a first pump/motor unit, and at the same time causes the remainder of the fluid chambers (18, 19) to communicate with the third and fourth kidney ports (40, 41) in turn, thereby providing a second pump/motor unit.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a hydraulic pump and motor system, or a hydraulic system in which a first pump/motor unit and a second pump/motor unit are arranged which are mechanically coupled together as being rotatable at an identical speed of rotation.

BACKGROUND ART

[0002] As shown in patent literature JP, P3-33922B, there is known a hydraulic arrangement using a hydraulic pump and motor system that incorporates a first pump/motor unit and a second pump/motor unit in a mechanical combination as operable at an identical speed of rotation. The pump and motor system is used to store a high pressure fluid by utilizing energy of a return fluid from a hydraulic actuator, the stored high pressure fluid serving to operate the actuator.

[0003] As the patent literature cited above shows, a known hydraulic pump and motor system employs a first pump/motor unit and a second pump/motor unit of axial plunger configuration whose drive shafts are axially coupled together via a coupling block to constitute a common operating shaft of the system so that when one of these drive units operates as a pump, the other may operate as a motor, and vice versa.

[0004] So configured, the known hydraulic pump and motor system involves a relatively large number of system components, making it costly to manufacture, and an axially elongate structure, rendering it bulky and requiring it to take a relatively large area to place and a complicated assembling procedure. Further, many sliding parts such as valve plates and cylinder blocks are entailed, so that a large amount of oil may leak, leaving the system poor in efficiency and slow to react in effecting a required pressure conversion.

[0005] It is accordingly an object of the present invention to provide a hydraulic pump and motor system that can resolve those problems mentioned above.

SUMMARY OF THE INVENTION

[0006] The present invention provides in a first form of implementation thereof a pump and motor system which comprises a cylinder block having a plurality of fluid chambers, each of which has a volume increased and decreased as a piston is reciprocated. The cylinder block is mounted, together with a shaft, rotatably in a housing and adapted to be rotated along a valve plate. In the system, the cylinder block when rotated causes each piston to be contractingly operated from an upper dead point to a lower dead point and to be expandingly operated from the lower dead point to the upper dead point. The system includes a first and a fourth kidney port formed in the said valve plate in a region of one of the left and right hand sides of a straight line that extends between the said upper and lower points. The system also includes a third and a second kidney port formed in the said valve plate in a region of the other of the left and right hand sides of the said straight line. The system is so constructed that rotation of the said cylinder block causes some of the said fluid chambers to communicate with the said first and second kidney ports in turn, thereby providing a first pump/motor unit, and rotation of the said cylinder block also causes the remainder of the said fluid chambers to communicate with the said third and fourth kidney ports in turn, thereby providing a second pump/motor unit.

[0007] According to the first form of the present invention described above, the first pump/motor unit may operate as a motor when the second pump/motor unit is operating as a pump, and the second pump/motor unit may operate as a motor when the first pump/motor unit is operating as a pump.

[0008] A pump and motor system being thus provided in which only with a single housing and a single cylinder block can two pump/motor units be constituted one of which may perform a pump action while the other is performing a motor action, the system can be built with a reduced number of its component parts and thus also with a reduced cost. Further, the axial length of the system can be shortened rendering it compact, and therefore also reducing the area for its placement and making its assembling easier. Further, only the single cylinder block and a single valve plate required and arranged in a sliding contact with each other lessen the sliding contact areas where oil may leak, and also enhance the system's efficiency and its rate of pressure conversion.

[0009] Also, by permitting a return pressure fluid from an actuator to be furnished to the first kidney port and allowing a pressure storage to be connected to the third kidney port, the energy of the return fluid from the actuator can be utilized to store fluid of elevated pressure in the pressure storage, and the stored elevated pressure fluid can be recycled to operate the actuator.

[0010] Further, by permitting the first and third kidney ports to be connected to a first and a second hydraulic circuit provided with a directional switching valve, and allowing the second and fourth kidney ports to be supplied with a discharge pressure fluid from a hydraulic pump, it is possible to distribute the flow into the first and second hydraulic circuits.

[0011] A second form of implementation of the present invention provides a pump and motor system defined in the first form thereof set forth above with a system's configuration in which the said first and second kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from said third and fourth kidney ports, respectively. Further, in this system's configuration, the said valve plate is arranged to be rotatable in a direction in which the said cylinder block is rotatable, there being further provided a means for rotating the said valve plate.

[0012] According to the second form of implementation of the invention, rotating the valve plate in one direction by a given angle permits the first and second kidney ports to be positioned, respectively, in regions of left and right hand sides of the straight line that extends between the first and second dead points of the system and the third and fourth kidney ports to be each positioned across the regions of left and right hand sides of the straight line.

[0013] Alternatively, rotating the valve plate in the other direction by a given angle permits the first and second kidney ports to be each positioned across the regions of left and right hand sides Of the straight line and the third and fourth kidney ports to be positioned, respectively, in regions of left and right hand sides of the straight line.

[0014] This being the arrangement, it is both possible to render the first and second pump/motors units identical and different in capacity. Therefore, where a return fluid from an actuator is to be recycled for the purpose of operating the actuator as mentioned above, it becomes possible to change the rate of pressure conversion of the system and when the flow discharge pressure fluid is distributed, also to change the ratio of its distributed flows.

[0015] A third form of implementation of the present invention provides a pump and motor system defined in the first form thereof set forth above with a system's configuration in which the said shaft and the said cylinder block are mounted in the said housing in a manner such that their center axes of rotation are mutually oriented with a predetermined angle, thereby constituting the said system as a bent axis type piston pump and motor system. Further in this system's configuration, the said shaft is adapted to be swung in a plane that is orthogonal to a plane containing the said center axes of rotation and that contains a center axis of rotation of said shaft, there being provided a means for swinging the said shaft. Further in this system's configuration, the said first and second kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from the said third and fourth kidney ports, respectively.

[0016] According to the third form of implementation of the invention, causing the shaft to be swung permits the first and second pump/motor units to be varied in capacity in essentially the same fashion as mentioned previously.

[0017] A fourth form of implementation of the present invention provides a pump and motor system defined in the first form thereof set forth above with a system's configuration in which the said housing has a swash plate disposed therein for rendering the said system a swash plate type piston pump and motor system. In this system's configuration, the said swash plate is arranged to be rotatable in a direction in which said cylinder block is rotatable, there being provided a means for rotating the said swash plate. Further in this system configuration, the said first and second kidney ports are deviated in phase position about a center of the said valve plate by an angle of 90 degrees from the said third and fourth kidney ports, respectively.

[0018] According to the fourth form of implementation of the invention, rotating the swash plate permits the first and second pump/motor units to be varied in capacity in essentially the same fashion as mentioned previously.

[0019] A fifth form of implementation of the present invention provides a pump and motor system defined in the first form thereof set forth above with a system's configuration in which the said housing has a swash plate disposed therein for rendering the said system a swash plate type piston pump and motor system. In this system's configuration, the said swash plate has an oblique surface that is inclined in a plane containing a center axis of rotation of the said shaft, the said swash plate being adapted to be swung in a plane that is orthogonal to the first mentioned plane and that contains the said center axis of rotation of the shaft, there being provided a means for swinging the said swash plate. In this system's configuration, the said first and second kidney ports are deviated in phase position about a center of the said valve plate by an angle of 90 degrees from the said third and fourth kidney ports, respectively.

[0020] According to the fifth form of implementation of the invention, rotating the swash plate permits the first and second pump/motor units to be varied in capacity in essentially the same fashion as mentioned previously.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present invention will better be understood from the following detailed description and the drawings attached hereto showing certain illustrative embodiments of the present invention. In this connection, it should be noted that such embodiments as illustrated in the accompanying drawings hereof are intended in no way to limit the present invention but to facilitate an explanation and understanding thereof.

[0022] In the accompanying drawings:

Fig. 1 is a cross sectional view showing a pump and motor system representing a first form of embodiment of the present invention;

Fig. 2 is a front view showing a cylinder block;

Fig. 3 is a front view showing a valve plate;

Fig. 4 is a cross sectional view taken along the line IV-IV in Fig. 1;

Fig. 5 is a diagrammatic explanatory view showing a typical example in which a first and a second pump/motor unit in a system as shown in Fig. 1 are utilized;

Fig. 6 is a graph showing the relationships between the capacities and the pressure conversion ratios for the first and second pump/motor units;

Fig. 7 is a front view showing the valve plate as shown in Fig. 3 and as rotated in one direction of rotation;

Fig. 8 is a front view showing the valve plate as shown in Fig. 3 and as rotated in the other direction of rotation;

Fig. 9 is a diagrammatic explanatory view showing another example in which a first and a second pump/motor unit in a system of the invention are utilized;

Fig. 10 is an explanatory view showing an alternative embodiment of a first and a second cylinder bore as included in the pump motor and motor system shown in Figs. 1 and 2;

Fig. 11 is an explanatory view showing another alternative embodiment of a first and a second cylinder bore as included in the system shown in Figs. 1 and 2;

Fig. 12 is a front view showing a valve plate in which six kidney ports are provided in the system of Figs. 1 and 2; Fig. 13 is a front view showing a valve plate in which eight kidney ports are provided in the system of Figs. 1 and 2;

Fig. 14 is a cross sectional view showing a pump and motor system representing a second form of embodiment of the present invention;

Fig. 15 is a cross sectional view taken along the line XV-XV in Fig. 14;

Fig. 16 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the pump and motor system shown in Fig. 14;

Fig. 17 is an explanatory view of the pump and motor system with a shaft as swung in one direction;

Fig. 18 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 17;

Fig. 19 is an explanatory view of the pump and motor system with the shaft that is swung in the other direction;

Fig. 20 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 19;

Fig. 21 is a cross sectional view showing a pump and motor system representing a third form of embodiment of the present invention;

Fig. 22 is an explanatory view showing a tooth and a rack as shown in Fig. 21 as are in mesh with each other;

Fig. 23 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the system shown in Fig. 21;

Fig. 24 is an explanatory view showing the valve plate in the system of Fig. 21 with a swash plate that is rotated in one direction of rotation;

Fig. 25 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 24;

Fig. 26 is an explanatory view showing the valve plate in the system of Fig. 21 with the swash plate that is rotated in the other direction of rotation;

Fig. 27 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 26;

Fig. 28 is a cross sectional view showing a pump and motor system representing a fourth form of embodiment of the present invention;

Fig. 29 is a cross sectional view taken along the line XXIX-XXIX in Fig. 28;

Fig. 30 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the system shown in Figs. 28 and 29;

Fig. 31 is an explanatory view showing the valve plate in the system of Fig. 28 with a swash plate that is rotated in one direction of rotation;

Fig. 32 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 32;

Fig. 33 is an explanatory view showing the valve plate in the system of Fig. 28 with a swash plate that is rotated in the other direction of rotation;

Fig. 34 is an explanatory view showing the positions of an upper and a lower dead point of the valve plate in the state shown in Fig. 33;

Fig. 35 is a cross sectional view showing a pump and motor system representing a fifth form of embodiment of the present invention;

Fig. 36 is a cross sectional view taken along the line XXXVI-XXXVI in Fig. 35;

Fig. 37 is a perspective view showing the portion in which a slide member is attached to a piston in the system shown in Figs. 35 and 36;

Fig. 38 is a cross sectional view showing the piston in the system of Figs. 35 to 37 sliding in one direction;

Fig. 39 is a cross sectional view showing the piston in the system of Figs. 35 to 38 sliding in the other direction;

Fig. 40 is a cross sectional view showing a pump and motor system representing a sixth form of embodiment of the present invention;

Fig. 41 is a cross sectional view taken along the line IXL-IXL in Fig. 40;

Fig. 42 is a cross sectional view showing a piston in the system of Figs. 40 and 41 sliding in the other direction;

Fig. 43 is a cross sectional view showing the piston in the system of Figs. 40 and 41 sliding in one direction;

Fig. 44 is a cross sectional view showing a pump and motor system representing a seventh form of embodiment of the present invention;

Fig. 45 is a cross sectional view showing a pump and motor system representing an eighth form of embodiment of the present invention;

Fig. 46 is a cross sectional view taken along the line IVL-IVL in Fig. 45;

Fig. 47 is a cross sectional view showing a pump and motor system representing a ninth form of embodiment of the present invention;

Fig. 48 is a cross sectional view taken along the line IIL-IIL in Fig. 47;

Fig. 49 is a cross sectional view showing a pump and motor system representing a tenth form of embodiment of the present invention;

Fig. 50 is a cross sectional view taken along the line L-L in Fig. 49;

Fig. 51 is a cross sectional view showing a pump and motor system representing an eleventh form of embodiment of the present invention; and

Fig. 52 is a cross sectional view showing a pump and motor system representing a twelfth form of embodiment of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

[0023] Hereinafter, the various forms of embodiment of the present invention are individually set out with reference to the accompanying drawings.

[0024] First, an explanation is given of the first form of embodiment of the invention.

[0025] Referring to Fig. 1, a casing 1 sectionally shaped in a dogleg form and an end plate 2 are shown to together constitute a housing 3. Within the housing 3, a shaft 4 and a cylinder block 5 are mounted having their center axes mutually inclined with a given angle and are supported rotatably. The shaft 4 is received in an axial bore 6 formed in the casing 1 and is rotatably supported by a bearing 7. The cylinder block 5 is supported to be rotatable in sliding contact with a valve plate 8.

[0026] A stepped bore 9 is formed centrally in the cylinder block 5. A first set of cylinder bores 10 and a second set of cylinder bores 11 are formed relatively radially outwards in the cylinder block 5 as being arranged alternately on a common circle as shown in Fig. 2. A stepped shaft 12 is slidably accepted in the stepped bore 9 and has one end formed into a spherical shape 12a. The spherical end 12a of the shaft 12 is slidably fitted in a spherical recess 13 formed in the shaft 4 with a plate 14 serving to prevent the fitting 12a from coming off the recess 13. The stepped shaft 12 which has its other end passing through the valve plate 8 and terminating in the end plate 2 is rotatably supported thereby with the aid of a bearing 15.

[0027] The cylinder bores 10 in the first set and the cylinder bores 11 in the second set have pistons 16 in a first set and pistons 17 in a second set slidably inserted into them to define chambers 18 in a first set and chambers 19 in a second set in the bores 10 and 11, respectively. The pistons 16 in the first sets and the pistons 17 in the second set have their respective one ends formed to be spherical 16a and 17a, which ends are slidably fitted in spherical recesses 20, respectively, in the shaft 4 and are prevented by the plate 14 from coming off the recesses 20.

[0028] A spring 21 is provided in a space defined between the stepped bore 9 and the stepped shaft 12 and acts to urge the cylinder block 5 against the valve plate 8.

[0029] So assembled as described, it is thus seen that the shaft 4 and the cylinder block 5 as they are jointly rotated cause the pistons 16 in the first set and the pistons 17 in the second set to reciprocate, each of the pistons 16, 17 increasing and decreasing the volume of a respective chamber 18, 19 in both the first and second sets.

[0030] The valve plate 8 as shown in Fig. 3 is formed relatively radially inwards therein with a first kidney port 30 and a second kidney port 31 which are each a slit in the form of an arc. The first kidney port 30 is formed to mostly lie in the right hand side of a straight line X connecting an upper dead point and a lower dead point and to slightly extend into its left hand side. The second kidney port 31 is formed to mostly lie in the left hand side of that straight line X connecting the upper and lower dead points and to slightly extend into the right hand side.

[0031] As shown in Fig. 4, the first and second kidney ports 30 and 31 communicate with a first and a second port 32 and 33, respectively, which are each formed in the end plate 2 as being shaped in the form in cross section of a cocoon. The first and second ports 32 and 33 are formed to lie symmetrically of each other with respect to the above mentioned straight line X.

[0032] As shown in Fig. 3, the valve body 8 is formed relatively radially outwards with a third kidney port 40 and a second kidney port 41 which are each a slit in the form of an arc. The third kidney port 40 is formed to mostly lie in the left hand side of the straight line X that connects the upper dead point and the lower dead point and to slightly extend into its right hand side. The third kidney port 40 is deviated in phase angle position by 90 degrees from the first kidney port 30. The fourth kidney port 41 is formed to mostly lie in the right hand side of that straight line X that connects the upper and lower dead points and to slightly extend into the left hand side. The fourth kidney port 41 is deviated in phase angle position by 90 degrees from the second kidney port 31.

[0033] As shown in Fig. 4, the third and fourth kidney ports 30 and 31 communicate with a third and a fourth port 42 and 43, respectively, which are each formed in the end plate 2 as being shaped in the form in cross section of a cocoon. The third and fourth ports 42 and 43 are formed to lie symmetrically of each other with respect to the above mentioned straight line X.

[0034] The first port 32 communicates with a first main port 34 while the second port 33 communicates with a second main port 35. The third port 42 communicates with a third main port 44 while the fourth port 43 communicates with a fourth main port 45. The first main port 34 communicates with an actuator return circuit 36, the third main port 44 communicates with a pressure storage 46, and the second main port 35 and the fourth port 45 communicate each with a reservoir 37.

[0035] As shown in Fig. 2, the cylinder block 5 is formed with first fluid communication bores 50 in a first set each of which communicates with a respective one of the fluid chambers 18 in the first set. The fluid communication bores 50 in the first set are each inclined as oriented towards the center line of the cylinder block 5 so they may open to and communicate with the first kidney port 30 and the second kidney port 31 as the cylinder block 5 is rotated.

[0036] As shown in Fig. 2, the cylinder block 5 is also formed with second fluid communication bores 51 in a second set each of which communicates with a respective one of the fluid chambers in the second set 19. The fluid communication bores 51 in the second set are each oriented parallel to the central axis of the cylinder block 5 so they may open to and communicate with the third and fourth kidney ports 40 and 41 as the cylinder block 5 is rotated.

[0037] Thus arranged, the pistons 16 and the fluid chambers 18 each in the first set together with the first and second kidney ports 30 and 31 now constitute a first pump/motor unit. So do the pistons 17 and the fluid chamber 19 each in the second set together with the third and fourth kidney ports 40 and 41 constitute a second pump/motor unit.

[0038] One end 8a of the valve plate 8 is shown in Fig. 1 to protrude out of the housing 3. A cylinder 38 is shown as coupled to that end of the valve plate 8. It is the function of the cylinder 38 to rotate the valve plate 8 by a given angle in the direction in which the cylinder block 5 is rotated, as it is expandingly or contractingly operated.

[0039] Fig. 5 diagrammatically shows the construction so far described.

[0040] An explanation is now given of an operation of the first form of embodiment of the invention with the construction thus far set out.

<u>Operation to collect energy of return fluid from the actuator</u>

[0041] A return pressure fluid from the actuator return circuit 36 that flows through the first main port 34 and the first port 32 into the first kidney port 30 is supplied via one fluid communication bores 50 in the first set into a fluid chamber in the first set 18 that is located close to the lower dead point, causing the corresponding piston 16 in the first set to extend and thus to cause the cylinder block 5 to rotate, together with the shaft 4, in a direction as indicated by the arrow <u>a</u> in Fig. 2. The first pump/motor unit is now caused to operate as a motor.

[0042] So rotating the cylinder block 5 permits a piston 17 in the second set that comes closer to the lower dead point to extend and thus the corresponding fluid chamber 19 in the second set to increase its volume. This in turn causes a fluid in the reservoir 37 to be drawn through one fluid communication bore 51 in the second set, the fourth kidney port 41, the fourth port 43 and the fourth main port 45 into that chamber 19 in the second set. Then, that piston 17 in the second set beyond the upper dead point is retracted to reduce the volume of the corresponding fluid chamber 19 in the second set and thus to pressurize the fluid in this chamber 19 to be the pressurized fluid (fluid elevated in pressure) to be discharged through the fluid communication bore 51 in the second set, the third kidney port 40, the third port 42 and the third main port 44 into the pressure storage 46 and stored in it. Thus, the second pump/motor unit is rendered operating as a pump.

<u>Operation to recycle the fluid elevated in pressure stored in the pressure storage</u>

[0043] The fluid elevated in pressure stored in the pressure storage 46 that flows through a fluid communication bore 51 in the second set, the third main port 44 and the third port 42 into the third kidney port 40 is supplied into a fluid chamber 19 in the second set that is close to the lower dead point to cause a piston 17 in the second set to extend and thus to cause the cylinder block 5 to rotate, together with the shaft 4, in the direction indicated by the allow <u>a</u>. Thus, the second pump/motor unit in this case operates as a motor.

[0044] Then, a piston 16 in the first set that is located close to the lower dead point extending and thereby increasing the volume of the corresponding chamber 18, causes a fluid in the reservoir 37 to be drawn through the second kidney port 31, the second port 33 and the second main port 35 into a fluid chamber 18 in the first set. Then, that piston 16 in the first set beyond the upper dead point is retracted, reducing the volume of that fluid chamber 18 in the first set to cause the fluid therein to be pressurized or elevated in pressure, the fluid elevated with in pressure being discharged through the first kidney port 30, the first port 32 and the first main port 34. Thus, the first pump/motor unit in this case operates as a pump.

[0045] In the operations mentioned above, noting that on the valve plate 8 the ports are arranged symmetrically on the left and right hand sides with respect to the straight line X, it can be seen that the first pump/motor unit and the second pump/motor unit becomes identical in capacity and hence their ratio in respect of pressure conversion becomes unity (1) as shown in Fig. 6.

[0046] The valve plate 8 can be rotated in the direction indicated by the arrow <u>b</u> in Fig. 3 by operating the cylinder 38 to be in the state as shown in Fig. 7 the third kidney port 40 and the third kidney 41 lie both entirely on the left hand and right hand sides, respectively, of the straight line X, thereby increasing the capacity of the second pump/motor unit.

[0047] Conversely, the first pump/motor unit is then reduced in capacity since the first and second kidney ports 30 and 31 are each given a greater proportion of area extended into the left and right hand sides of the straight line X, respectively.

[0048] The modification above may double the output torque of the second pump/motor unit operating as a motor when operated with a pressure elevated fluid stored in the pressure storage 46 (where the output torque represents a torque for driving the first pump/motor unit). The ratio in pressure conversion of the second to first pump/motor units may then amount to (2) as shown in Fig. 6.

[0049] The valve plate 8 may be rotated in the direction indicated by the arrow c by operating the cylinder 38 to be in the state as shown in Fig. 8 the third kidney port 40 and the third kidney port 41 may both be given a greater proportion of area extended into the left hand and right hand sides, respectively, of the straight line X, thereby reducing the capacity of the second pump/motor unit.

[0050] Conversely, the first pump/motor unit then becomes larger in volume since the first kidney port 30 and the second kidney port 31 lie both entirely in the left hand and right hand sides, respectively, of the straight line.

[0051] The preceding modification permits the the first pump/motor unit as a pump to operate with a greater discharge when the second pump/motor unit is operated as a motor with an pressure elevated fluid stored in the pressure storage 46.

[0052] Fig. 9 shows an arrangement in which the first and third main ports 34 and 44 are each connected to an actuator circuit 53 including a directional control valve 52 and the second and fourth main ports 35 and 45 are connected to the discharge path 54a of a hydraulic pump 54, thereby permitting a pressure fluid discharged from the hydraulic pump to be distributed to be supplied into the actuator circuits 53.

[0053] While in the first form of embodiment of the invention so far described, the cylinder bores 10 in the first set and the cylinder bores 11 in the second are arranged both lying on a common circle, it is also possible, as shown in Fig. 10 to arrange a first set of cylinder bores 10 as lying on an outer circle and a second set of cylinder bores 11 as lying on an inner circle. It is also possible as that the the cylinders 10 and 11 of the first and second sets have different diameters as shown in Fig. 11.

[0054] In another form of variation, the valve plate 8 may, as shown in Fig. 12, be formed further with a fifth and a sixth kidney port 55 and 56, and the cylinder block further with a third set of cylinder bores each of which communicates with the fifth and sixth kidney ports 55 and 56 in turn.

[0055] In this manner, a hydraulic pump and motor system that is constituted with a first, a second and a third pump /motor unit interconnected is provided.

[0056] Alternatively, the valve plate 8 may, as shown in Fig. 13, be further with a fifth and a sixth kidney port 55 and 56 and a seventh and an eighth kidney port 57 and 58, and the cylinder block further with a third set of cylinder bores each of which communicates with the fifth and sixth kidney ports 55 and 56 in turn and a fourth set of cylinder bores each of which communicates with the seventh and eighth kidney ports 57 and 58 in turn.

[0057] In this case, a hydraulic pump and motor system that is constituted with a first, a second, a third and a fourth pump/motor unit interconnected is provided.

[0058] An explanation is next given of a second form of embodiment of the present invention with reference to Figs. 14 and 15.

[0059] In this embodiment, a first and a second pump/motor unit are provided having their capacities varied by permitting the shaft 4 to be swung in a plane being orthogonal to the sheet of Fig. 14 and containing a center axis of the shaft (within the plane defined by the sheet of Fig. 15).

[0060] In a specific construction of this embodiment, the shaft 4 is received in a bore 61 formed in a shaft support member 60 and is supported therein rotatably by means of a bearing 62. There are mounted above the shaft support member 60 an upper convex arc-shaped surface 63 and an upper arcfaced projection 64 formed in a body and below the shaft support member 60 a lower convex arc-shaped surface 65 and a lower arc-faced projection 66 formed in a body.

[0061] The casing 1 is fastened to a cover 67 by means of bolts 68. Attached to the inner surface of the cover 67 are an upper guide piece 69 having a concave arc-shaped guide surface 71 joined therewith and a lower guide piece 70 having a concave arc-shaped guide surface 72 joined therewith. The upper arc-faced projection 69 is disposed in contact with the lower surface of the upper guide piece 69 and the upper convex arc-shaped surface 64 lies in contact with the concave arc-shaped guide surface 71. The lower arc-faced projection 66 is disposed in contact with the upper surface of the lower guide piece 70 and the lower arc-shaped convex surface 65 lies in contact with the concave arc-shaped guide surface 72.

[0062] It is seen that the arrangement described in the preceding paragraphs permits the shaft support member 60 to be supported by the cover 67 with the ability to be swung in the plane on the sheet containing Fig. 15.

[0063] As can be seen from Fig. 15, the housing 3 may have a first and a second rod 73 and 74 mounted therein to be slidable axially (in the leftward and rightward direction in Fig. 15). In this case, the first rod 73 has coupled to an end thereof a first contact member 75 so that the first rod 73 may be swung about it in any given direction. The first contact member 75 is in contact with one side of the shaft support member 60. The second rod 74 has coupled to an end thereof a second contact member 76 so that the second rod 74 may be swung about it in any given direction. The second contact member 76 is in contact with another side of the shaft support member 60.

[0064] The first rod 73 is coupled to a cylinder not shown so as to be movable between its extended and retracted positions. The second rod 74 under the action of a spring not shown is held at a mid position between its extended and retracted positions.

[0065] In the arrangement described, with that cylinder not hydraulically actuated, the first and second rods 73 and 74 assume mid their positions as shown in Fig. 15 so that the pistons located at uppermost and lowermost positions as seen in the longitudinal cross section of the shaft 4 may be in a maximum extended and a minimum retracted state, respectively.

[0066] Then, noting that the upper and lower dead points of the system are represented by the uppermost and lowermost portions of the valve plate 8 as shown in Fig. 16, it is therefore seen that the first and second pump/motor units described have an identical capacity here as in the case shown in Fig. 3.

[0067] Extending the first rod 73 by the cylinder causes the shaft support member 60 to be swung in the counterclockwise direction as shown in Fig. 17 so that any of the pistons located to one side from its uppermost position and located to the other side from its lowermost position may be in a maximum extended and to a minimum retracted state, respectively.

[0068] Then, noting that the line connecting between the upper and lower dead points has shifted to one side as indicated by the letter X' in Fig. 18, it is therefore seen that the first and second pump/motor units described have a lower and a greater capacity, respectively here as in the case shown in Fig. 7.

[0069] Retracting the first rod 73 by the cylinder causes the shaft support member 60 to be swung in the clockwise direction as shown in Fig. 19 so that any of the pistons located to the other side from its uppermost position and located to one side from its lowermost position may be in a minimum extended and to a maximum retracted state, respectively.

[0070] Then, noting that the line connecting between the upper and lower dead points has shifted to the other side as indicated by the letter X" in Fig. 20, it is therefore seen that the first and second pump/motor units described have a greater and a smaller capacity, respectively here as in the case shown in Fig. 8.

[0071] An explanation is next given of a third form of embodiment of the present invention.

[0072] Referring first to Fig. 21, the the shaft 4 and the cylinder block 5 are shown here again as rotatably mounted in the housing 3. In this embodiment, a swash plate 80 is mounted in the housing 3 so it may be rotated in a direction in which the cylinder block 5 is rotated. The pistons 16 in the first set and the pistons 17 in the second sets have their respective ends each of which has a piston shoe 81 coupled thereto so it may be swung. For each of the shows 81 a show retainer 82 is provided to urge the piston shows 81 into a facial contact with the front surface 80a of the swash plate 80 slidably circumferentially therealong. A swash plate type piston pump/motor unit is thereby provided.

[0073] The swash plate 80 has a cylindrical peripheral surface 80b which as shown in Fig. 22 are formed with a train of teeth 83 over a circumferential range of 180 degrees. A rack 84 is disposed in mesh with teeth 83 and mounted slidably on the housing 3 so as to be slidable in a direction that is transverse to the shaft 4.

[0074] As shown in Fig. 22, a neutral position for the rack 4 is established when it comes to be in mesh with a circumferential mid portion of the whole teeth 83. When the rack 84 reaches the neutral position, the uppermost and lowermost portions of the valve plate 8 as shown in Fig. 23 become the lower and upper dead points of the system, respectively. This being identical to a state as shown in Fig. 3, it is seen that then the first and second pump/motor units described have an identical capacity.

[0075] Moving the rack 84 in one direction so as to rotate the swash plate 80 by 45 degrees in one rotary direction as shown in Fig. 24 causes the line connecting between the upper and lower dead points to shift by 45 degrees in one rotary direction as indicated by the letter X' in Fig. 25. This being identical to a state as shown in Fig. 7, it is seen that then the first and second pump/motor units described have a smaller and a greater capacity, respectively.

[0076] Moving the rack 84 in the other direction so as to rotate the swash plate 80 by 45 degrees in the other rotary direction as shown in Fig. 26 causes the line connecting between the upper and lower dead points to shift by 45 degrees in the other rotary direction as indicated by the letter X" in Fig. 27. This being identical to a state as shown in Fig. 8, it is seen that then the first and second pump/motor units described have a greater and a smaller capacity, respectively.

[0077] An explanation is next given of a fourth form of embodiment of the present invention.

[0078] Referring to Figs. 28 and 29, this embodiment is designed to change the capacities of the first and second pump/motor units described by causing the swash plate to be swung in a plane that is orthogonal to the sheet of Fig. 28 and that contains the center axis of the shaft 4. (The plane in which the swash plate is to be swung here is the plane defined by the sheet of Fig. 29.)

[0079] In a specific construction of this embodiment, the swash plate 80 as shown has at an upper rear side an upper convex arc-shaped surface 90 and an upper arc-faced projection 91 joined therewith, and at a lower rear side a lower convex arc-shaped surface 92 and a lower arc-faced projection 93 joined therewith.

[0080] A swash plate support member 94 is attached to the casing 1. Mounted on the inner surface of the swash plate support member 29 are an upper guide piece 95 having a concave arc-shaped guide surface 97 joined therewith and a lower guide surface 96 having a concave arc-shaped guide surface 98 joined therewith.

The upper arc-faced projection 91 is disposed in contact with the lower surface of the upper guide piece 95 and the upper convex arc-shaped surface 90 lies in contact with the concave arc-shaped guide surface 97. The lower arc-faced projection 93 is disposed in contact with the upper surface of the lower guide piece 96 and the lower convex arc-shaped surface 92 lies in contact with the concave arc-shaped guide surface 98.

[0081] It is seen that the arrangement described in the preceding paragraphs permits the swash plate 80 to be supported by the swash plate support member 94 with the ability to be swung in the plane on the sheet containing Fig. 29.

[0082] As can be seen from Fig. 29, the housing 3 may have a first and a second rod 99 and 100 mounted therein to be each axially slidable (each in a leftward and rightward direction in Fig. 29), forming a first pressure receiving chamber 99a and a second pressure receiving chamber 99b. In this case, an end of the first rod 99 has coupled with a first contact member 101 so that the first rod 99 may be swung about it in any given direction. The first contact member 101 is disposed in contact with one side of the swash plate 80. An end of the second rod 100 has coupled with a second contact member 102 so that the second rod 100 may be swung about it in any given direction. The second contact member 102 is in contact with another side of the swash plate 80.

[0083] Each of the first and second rods 99 and 100, placed under the action of a spring 103, is normally held at a mid position between its extending and retracting positions.

[0084] In the arrangement described, with the first and second pressure receiving chambers 99a and 100a brought into communication with a fluid reservoir, the first and second rods 9 and 100 assume their mid positions as shown in Fig. 29 so that the pistons located at uppermost and lowermost positions as seen in the longitudinal cross section of the shaft 4 (the swash plate 80) may be in a maximum extended state and a maximum retracted state, respectively.

[0085] Then, noting that the upper and lower dead points of the system are assumed by the uppermost and lowermost portions of the valve plate 8 as shown in Fig. 30, it is therefore seen that the first and second pump/motor units described have an identical capacity here as in the case shown in Fig. 3.

[0086] Bringing the first and second pressure receiving chambers 99a and 100a in fluid communication with a pressure fluid supply and a fluid reservoir, respectively, to cause the first rod 99 to extend permits the swash plate 80 to be swung in the counter-clockwise direction as shown in Fig. 31 so that any of the pistons located to one side from its uppermost position and located to the other side from its lowermost position may be in a maximum extended state and a minimum retracted state, respectively.

[0087] Then, noting that the line connecting between the upper and lower dead points has shifted to one side as indicated by the letter X' in Fig. 32, it is therefore seen that the first and second pump/motor units described have a lower and a greater capacity, respectively here as in the case shown in Fig. 7.

[0088] Bringing the second and first pressure receiving chambers 100a and 99a in fluid communication with a pressure fluid supply and a fluid reservoir, respectively, to cause the second rod 100 to extend permits the swash plate 80 to be swung in the clockwise direction as shown in Fig. 32 so that any of the pistons located to the other side from its uppermost position and located to one side from its lowermost position may be in a maximum extended state and a minimum retracted state, respectively.

[0089] Then, noting that the line connecting between the upper and lower dead points has shifted to the other side as indicated by the letter X" in Fig. 34, it is therefore seen that the first and second pump/motor units described have a greater and a smaller capacity, respectively here as in the case shown in Fig. 8.

[0090] An explanation is next given of a fifth form of embodiment of the present invention as implemented in a second example of the construction in which the valve plate 8 is rotated to change the capacities of the first and second pump/motor units described.

[0091] In this embodiment as shown in Figs. 35 and 36, the end plate 2 is formed with a piston bore 110 opening to its opposite ends 2a, and a piston 111 is inserted into the piston bore 110 so it may slidably be moved therein. Then, attaching a cover 112 to each of the opposite ends 2a of the end plate 2 closes the piston bore 110, thereby a first and a second pressure receiving chamber 113 and 114 are defined.

[0092] As shown, the first pressure receiving chamber 113 communicates with a first fluid port 115 formed in one of the covers 112, and the second pressure receiving chamber 114 communicates with a second fluid port 116 formed in the other cover 112.

[0093] The piston 111 is normally held at a neutral position as shown in Fig. 36 by a pair of springs 117, thus providing a typical three-position operated cylinder arrangement.

[0094] As shown in Fig. 37, the peripheral surface of the piston 111 is formed in its longitudinal mid portion with a guide recess 118 that orients transversely to the longitudinal axis of the piston 111. A slide member 119 is disposed in the guide recess 118 so it may as guided thereby move in it, sliding in a direction transverse to the longitudinal axis of the piston 111. A pin 120 for rotating the valve plate 8 is fitted in the slide member 119.

[0095] The pin 120 passes through an elongate bore 121 formed in the end plate 2 to extend longitudinally of the piston 111 and then, projecting out of it, is fitted into a hole 122 in the valve plate 8.

[0096] Thus, the piston 111 sliding causes the valve plate 8 to be rotated by the pin 120, which in turn causes the slide member 119 to slide in and along the guide recess 118.

[0097] Now, in order to change the capacities of the first and second pump/motor units described:

[0098] When the piston 111 lies at its neutral position as shown in Fig. 36, the valve plate 8 assumes a neutral position as shown in Fig. 3, rendering the first and second pump/motor units described identical in capacity to each other.

[0099] A directional switching valve not shown may now be switched over to permit a pressure fluid from a supply source to be admitted into the first pressure receiving chamber 113 via the first fluid port 115 and a pressure fluid in the second pressure receiving chamber 114 to be admitted into the reservoir via the second fluid port 116. This causes the piston 111 to slide rightwards to have a first position as shown in Fig. 38.

[0100] The piston 111 having the first position causes the valve plate 8 to rotate in one rotary direction and to have a rotary position as shown in Fig. 7. This renders the first pump/motor unit described smaller in capacity and the second pump/motor unit described unit greater in capacity.

[0101] Switching the directional switching valve not shown to permit pressure fluid from the supply source to be admitted into the second pressure receiving chamber 114 via the second fluid port 115 and pressure fluid in the first pressure receiving chamber 113 to be admitted into the reservoir via the second fluid port 115 causes the piston 111 to slide leftwards, having a second position as shown in Fig. 39.

[0102] The piston 111 having the second position causes the valve plate 8 to rotate in the other rotary direction and to have a rotary position as shown in Fig. 8. This renders the first pump/motor unit described greater in capacity and the second pump/motor unit described smaller in capacity.

[0103] An explanation is next given of a sixth form of embodiment of the present invention as implemented in a third example of the design in which the capacities of the first and second pump/motor units described are varied.

[0104] This example as shown in Figs. 40 and 41 employs the same structure as used in the second example described above in moving the piston 111 leftwards and rightwards slidably to turn the valve plate 8 to a first and a second rotary position.

[0105] In this embodiment, a cylindrical portion 123 is provided integrally with each of covers 112 and is fitted in a pair of large diameter bores 111a that are formed at axially opposite sides of the piston 111, thereby forming a first and a second annular pressure receiving chamber 124 and 125. Each of the large diameter bores 111a in the piston 111 communicates with a fluid reservoir, e. g. , an interior of the housing.

[0106] A first spring catch 126 is disposed in each of the cylindrical portion 123, and a second spring catch 127 is slidably fitted in the first spring catch 126. A spring 128 is interposed between the first and second spring catches 126 and 127 to serve to normally hold the piston 111 at its neutral position.

[0107] A rod 129 is slidably inserted in an axial center of the piston 111 and is normally held at its neutral position as shown in Fig. 41 by a pair of auxiliary springs 132 each of which is interposed between a third and a fourth spring catches 130 and 131.

[0108] The first pressure receiving chamber 124 is in fluid communication via a third fluid port 133 formed in one of the covers 112 with a fourth fluid port 134 formed in the end plate 2. The second pressure receiving chamber 125 is in fluid communication via a fifth fluid port 135 formed in the other cover 112 with a sixth fluid port 136 formed in the end plate 2. The fourth and sixth fluid ports 134 and 136 are at all times under a higher of the pressures of first and second pump/motor units as described that may be introduced by a shuttle valve.

[0109] A first switching valve 137 is provided to establish and block a fluid communication between the first pressure receiving chamber 124 and one of the large diameter bores 111a in the piston 111. The first switching valve 137 comprises a spool 139 inserted into and fitted in a spool bore 138 formed in the end plate 2 and, held by the auxiliary springs 132 to lie at the position shown, blocks the fluid communication between the first pressure receiving chamber 124 and the one large diameter bore 111a. Admitting a pressure fluid into the first fluid port 115 pushes the spool 139 to cause the first pressure receiving chamber 124 to communicate via a fluid port 140 with the one large diameter bore 111a in the piston 111.

[0110] A second switching valve 141 is provided to establish and block a fluid communication between the second pressure receiving chamber 125 and the other large diameter bores 111a in the piston 111. The second switching valve 141 comprises a spool 143 inserted into and fitted in a spool bore 142 formed in the end plate 2. Admitting a pressure fluid into the second fluid port 116 pushes the spool 143 to cause the second pressure receiving chamber 125 to communicate via a fluid port 144 with the other large diameter bore 111a in the piston 111.

[0111] A continuously operable servo cylinder arrangement is thus constructed and here adopted.

[0112] The first and second pump/motor units with varied capacities are provided in this example as well as described below.

[0113] In the absence of a pressure fluid supplied both in the first and second fluid ports 115 and 116, the spools 139 and 143 in the first and second switching valves 137 and 141 are both held by the auxiliary springs 132 to lie each in a blocking position. Then, neither first nor second pressure receiving chamber 124, 125 being in fluid communication with the corresponding large diameter bore 111a of the piston 111 or the fluid reservoir, the piston 111 has its neutral position as shown in Fig. 41 to hold the valve plate 8 at its neutral position as previously described in connection with Fig.

3. Thus, the first and second pump/motor units are provided having an identical capacity.

[0114] Admission of pressure fluid into the first fluid port 115 from a hydraulic pilot valve not shown causes the spool 138 in the first switching valve 137 to be pushed against the auxiliary spring 132, which causes the first pressure receiving chamber 124 to communicate with the one large diameter bore 111a. As a result, pressure lowering in the first pressure receiving chamber 124, pressure rising in the second pressure receiving chamber 125 causes the piston 111 to slidably move leftwards as shown in Fig. 42 to have a second position.

[0115] The piston 111 arriving at the second position causes the valve plate 8 to rotate in the other direction and then has the other rotary position as shown in Fig. 8. Thus, there result a first pump/motor unit with a greater capacity and a second pump/motor unit with a smaller capacity.

[0116] The piston 111 slidably moving leftwards increases the force that compressing the auxiliary spring 132 (on this side) thrusts the spool 139. When this thrusting force is greater than an amount that is commensurate with the pressure of pressure fluid admitted into the first fluid port 115, the spool 139 reaches a blocking position to block fluid communication of the first pressure receiving chamber 124 with the one large diameter bore 111a. This rendering the first and second pressure receiving chambers 124 and 125 identical in pressure, the piston 111 there ceases moving.

[0117] Thus, how far the piston 111 is slidably movable leftwards is determined by the pressure of pressure fluid in the first fluid port 115, and to what extent the valve plate 8 may be rotated in the other direction is determined by the pressure of pressure fluid admitted into the first fluid port 115. Fig. 42 shows the piston 111 that has been moved leftwards to its stroke end by maximizing the pressure of pressure fluid in the first fluid bore 115.

[0118] From the preceding description, it is seen that a first and second pump/motor units can be provided whose capacities are varied continuously by changing the pressure of pressure fluid admitted into the first fluid port 115, e. g., by changing the manipulated amount of the operating lever for a hydraulic pilot valve.

[0119] Admission of pressure fluid into the second fluid port 116 from a hydraulic pilot valve not shown causes the spool 143 in the second switching valve 141 to be pushed against the auxiliary spring 132, which causes the second pressure receiving chamber 125 to communicate with the other large diameter bore 111a. As a result, pressure lowering in the second pressure receiving chamber 125, pressure rising in the first pressure receiving chamber 124 causes the piston 111 to slidably move rightwards as shown in Fig. 43 to assume a first position.

[0120] The piston arriving at the first position causes the valve plate 8 to rotate in the one direction and then assume the one rotary position as shown in Fig. 7. Thus, there result a first pump motor unit with a smaller capacity and a second pump/motor unit with a greater capacity.

[0121] The piston 111 slidably moving rightwards increases the force that compressing the auxiliary spring 132 (on this side) thrusts the spool 143. When this thrusting force is greater than an amount that is commensurate with the pressure of pressure fluid admitted into the second fluid port 116, the spool 143 reaches a blocking position to block fluid communication of the second pressure receiving chamber 125 with the other large diameter bore 111a. This rendering the first and second pressure receiving chambers 124 and 125 identical in pressure, the piston 111 there ceases moving.

[0122] Thus, how far the piston 111 is slidably movable rightwards is determined by the pressure of pressure fluid in the second fluid port 116, and to what extent the valve plate 8 may be rotated in the one direction is determined by the pressure of pressure fluid admitted into the second fluid port 116. Fig. 43 shows the piston 111 that has been moved rightwards to its stroke end by maximizing the pressure of pressure fluid in the second fluid bore 116.

[0123] From the preceding description, it is seen that a first and second pump/motor units can be provided whose capacities are varied continuously by changing the pressure of pressure fluid admitted into the second fluid port 116, e. g., by changing the manipulated amount of the operating lever for a hydraulic pilot valve.

[0124] An explanation is next given of a seventh form of embodiment of the present invention as implemented in a second example of the configuration in which the shaft 4 is swung to vary the capacities of the first and second pump /motor units.

[0125] As shown in Fig. 44, the casing 1 is formed with a first and a second bore 150 and 151. A first rod 73 as shown previously in Fig. 15 is inserted into and fitted in the first bore 150, thereby defining a first pressure receiving chamber 152. A second rod 74 as shown likewise in Fig. 15 is inserted into and fitted in the second bore 151, thereby defining a second pressure receiving chamber 153.

[0126] The first and second pressure receiving chambers 152 and 153 are shown to be in fluid communication with a first and a second fluid bore 154 and 155, respectively.

[0127] The first and second pump/motor units with varied capacities are provided in this example as well as described below.

[0128] As shown in Fig. 44, admitting pressure fluid through the second fluid port 155 into the second pressure receiving chamber 153 (by switching over a directional control valve not shown) while permitting the first pressure receiving chamber 152 to communicate through the first fluid bore 154 to a fluid reservoir causes the shaft support member 60 that carries the shaft 4 to swing clockwise until its one end comes into contact with a first stopper 156 that is formed integrally with the casing 1.

[0129] Then, noting that as previously described and shown in Fig. 20, the line connecting between the upper and lower dead points has shifted to the other side as indicated by the letter X" in that Figure, it is therefore seen that the first and second pump/motor units described have, here too, a greater and a smaller capacity, respectively.

[0130] Admitting pressure fluid through the first fluid port 154 into the first pressure receiving chamber 152 (by switching over the directional control valve not shown) and permitting the second pressure receiving chamber 153 to communicate through the second fluid bore 155 to the fluid reservoir causes the shaft support member 60 that carries the shaft 4 to swing counter-clockwise until its other end comes into contact with a second stopper 157 that is formed integrally with the casing 1.

[0131] Then, noting that as previously described and shown in Fig. 20, the line connecting between the upper and lower dead points has shifted to the one side as indicated by the letter X' in that Figure, it is therefore seen that the first and second pump/motor units described have, here too, a smaller and a greater capacity, respectively.

[0132] An explanation is next given of an eighth form of embodiment of the present invention as implemented as a third example of the configuration in which the shaft 4 is swung to vary the capacities of the first and second pump and motor units.

[0133] As shown in Figs. 45 and 46, a cap or cover 67 provided and arranged to support the shaft support member 60 permitting it to be swung is provided with a continuously operable servo cylinder arrangement for rotating the valve plate 8, that as mentioned before likewise includes a piston 111, and a first and a second switching valve 137 and 141. The shaft support member 60 is here provided with a projection 60a that is fitted in a slide member 119 included in the piston 111, thereby coupling the member 60 and the piston 111 together.

[0134] This being the arrangement, admitting pressure fluid into the first or second fluid bore 116 by operating a hydraulic pilot valve not shown causes the shaft support member 60 that carries the shaft 4 to be swung in one or other rotary direction with an angle determined by the pressure of pressure fluid admitted into the first or second fluid bore 115 or 116.

[0135] Thus, a first and a second pump/motor unit as described are here again provided whose capacities are continuously variable.

[0136] An explanation is next given of a ninth form of embodiment of the present invention as implemented as a second example of the configuration in which the swash plate 80 is swung to vary the capacities of the first and second pump/motor units.

[0137] As shown in Figs. 47 and 48, the casing 1 is provided with a three position operated cylinder arrangement as mentioned previously for rotating the valve plate 8. The swash plate 80 here includes a projection 80a that is fitted in a slide member 119 included in the piston 111 to couple the piston 111 and the swash member 80 together.

[0138] This being the arrangement, admitting pressure fluid through the first fluid bore 115 into the first pressure receiving chamber 113 causes the swash plate 80 to be swung in one rotary direction. Likewise, admitting pressure fluid through the second fluid bore 116 into the second pressure receiving chamber 114 cause the swash plate 80 to be swung in the other rotary direction. Thus, a first and a second pump/motor unit as described are provided, here too, having their capacities varied as desired.

[0139] An explanation is next given of a tenth form of embodiment of the present invention as implemented as a third example of the configuration in which the swash plate 80 is swung to vary the capacities of the first and second pump/motor units.

[0140] As shown in Figs. 49 and 50, the casing 1 may have a continuously operated servo cylinder arrangement attached thereto that as mentioned previously is provided to rotate the valve plate 8. The swash plate 80 here again includes a projection plate 80 that is fitted in a slide member 119 included in the piston 111 to couple the piston 111 and the swash member 80 together.

[0141] This being the arrangement, admitting pressure fluid through the first or second fluid bore 115 or 116 to cause the swash plate 80 to be swung in the one or other rotary direction by an angle that is determined by the pressure of the admitted fluid, provides a first and a second pump/motor unit as described, here too with their capacities that can be varied as desired.

[0142] An explanation is next given of an eleventh form of embodiment of the present invention as implemented as a second example of the configuration in which the swash plate 80 is swung by a rack arrangement to vary the capacities of the first and second pump/motor units.

[0143] As shown in Fig. 51, the casing 1 may have a three position operated cylinder arrangement as before described attached thereto for rotating the valve plate 8, in which the piston 111 is provided with a teeth formation 160 that is arranged to be in mesh with a teeth formation 83 provided on the swash plate 80 to constitute the rack arrangement.

[0144] This being the case, too, admitting pressure fluid into the first or second fluid bore 115 or 116 to cause the piston 111 to be slid rightwards or leftwards and then via the rack arrangement constituted by the teeth formations 160 and 83 to cause the swash plate 80 to be swung in the one or other rotary direction, provides, here again, a first and a second pump/motor unit as described having their capacities varied as desired.

[0145] An explanation is next given of a twelfth form of embodiment of the present invention as implemented as a third example of the configuration in which the swash plate 80 is swung by a rack arrangement to vary the capacities of the first and second pump/motor units.

[0146] As shown in Fig. 52, the casing 1 may have a continuously operated servo cylinder arrangement as described previously attached thereto for rotating the valve plate 8, in which the piston 111 is provided with a teeth formation 160 that is arranged to be in mesh with a teeth formation 83 provided on the swash plate 80 to constitute the rack arrangement.

[0147] This being the arrangement, too, admitting pressure fluid into the first or second fluid bore 115 or 116 to cause the piston 111 to be slid rightwards or leftwards by a stroke, and then via the rack arrangement constituted by the teeth formations 160 and 83 to cause the swash plate 80 to be swung in the one or other rotary direction, by an angle, that is determined by the pressure of admitted fluid, here again provides a first and a second pump/motor unit with their capacities that can be varied continuously.

[0148] While the present invention has hereinbefore been thereof, it will readily be appreciated by a person skilled in the art to be obvious that many alterations thereof, omissions therefrom and additions thereto can be made without departing from the essence and the scope of the present invention. Accordingly, it should be understood that the invention is not intended to be limited to the specific embodiments thereof set out above, but to include all possible embodiments thereof that can be made within the scope with respect to the features specifically set forth in the appended claims and encompasses all the equivalents thereof.

Claims

1. A hydraulic pump and motor system, comprising:

a cylinder block having a plurality of fluid chambers, each of the chambers having a volume increased and decreased as a piston is reciprocated, the cylinder block being mounted, together with a shaft, rotatably in a housing and adapted to be rotated along a valve plate, wherein the cylinder block when rotated causes each piston to be contractingly operated from an upper dead point to a lower dead point and to be expandingly operated from the lower dead point to the upper dead point;
a first and a fourth kidney port formed in said valve plate in a region of one of the left and right hand sides of a straight line that extends between said upper and lower points; and
a third and a second kidney port formed in said valve plate in a region of the other of the left and right hand sides of said straight line,
wherein rotating said cylinder block causes some of said fluid chambers to communicate with said first and second kidney ports in turn, thereby providing a first pump /motor unit, and
wherein rotating said cylinder block causes the remainder of said fluid chambers to communicate with said third and fourth kidney ports in turn, thereby providing a second pump/motor unit.

2. A hydraulic pump and motor system as set forth in claim 1,

wherein said first and second kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from said third and fourth kidney ports, respectively, and

wherein said valve plate is arranged to be rotatable in a direction in which said cylinder block is rotatable, the system further comprising a means for rotating said valve plate.

3. A hydraulic pump and motor system as set forth in claim 1,

wherein said shaft and said cylinder block are mounted in said housing in a manner such that their center axes of rotation are mutually oriented with a predetermined angle, thereby constituting said system as a bent type piston pump and motor system, and

wherein said shaft is adapted to be swung in a plane that is orthogonal to a plane containing said center axes of rotation and that contains a center axis of rotation of said shaft, the system further including a means for swinging said shaft, and

wherein said first and second kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from said third and fourth kidney ports, respectively.

4. A hydraulic pump and motor system as set forth in claim 1,

wherein said housing has a swash plate disposed therein for rendering said system a swash plate type piston pump and motor system,

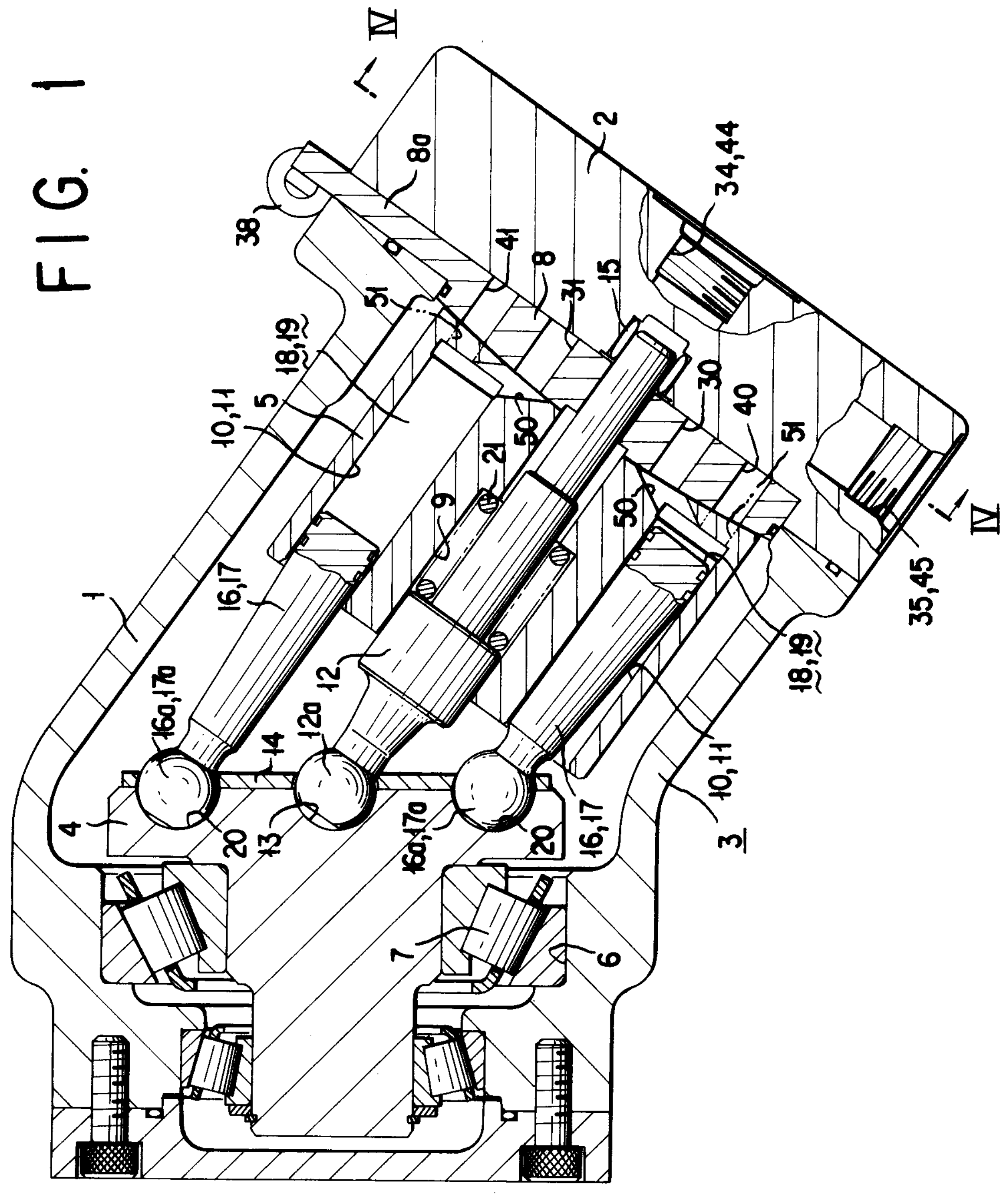
wherein said swash plate is arranged to be rotatable in a direction in which said cylinder block is rotatable, the system further including a means for rotating said swash plate, and wherein said first and third kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from said second and fourth kidney ports, respectively.

5. A hydraulic pump and motor system as set forth in claim 1,

wherein said housing has a swash plate disposed therein for rendering said system a swash plate type piston pump and motor system,

wherein said swash plate has an oblique surface that is inclined in a plane containing a center axis of rotation of said shaft, said swash plate being adapted to be swung in a plane that is orthogonal to the first mentioned plane and that contains said center axis of rotation of the shaft, the system further including a means for swinging said swash plate, and

wherein said first and second kidney ports are deviated in phase position about a center of said valve plate by an angle of 90 degrees from said third and fourth kidney ports, respectively.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16,17
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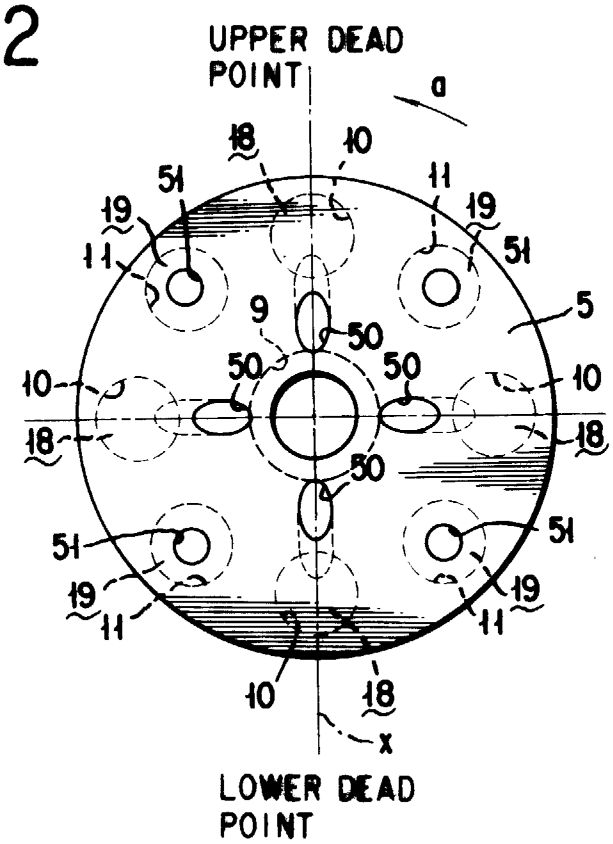
6

FIG. 1

FIG. 2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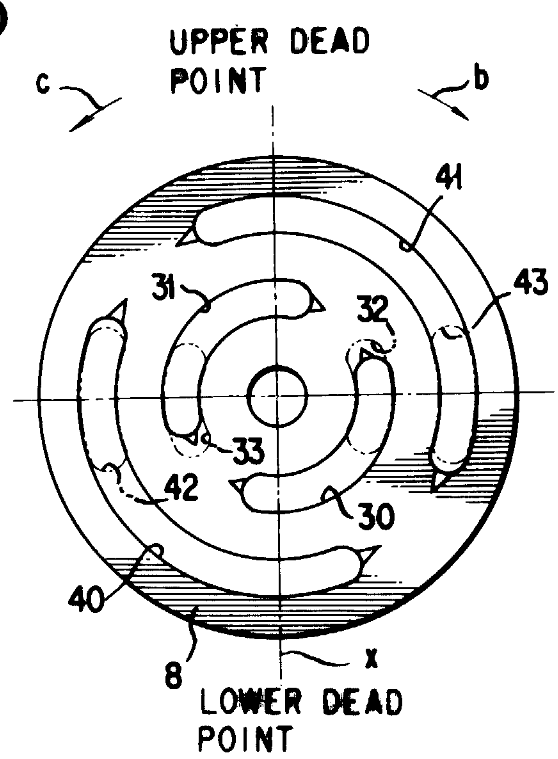
50
50
10
10
18
18
50
51
51
19
11
19
11
10
18
x
LOWER DEAD
POINT

FIG. 3


UPPER DEAD
POINT
c
b
41
31
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33
42
30
40
8
x
LOWER DEAD
POINT

FIG. 4

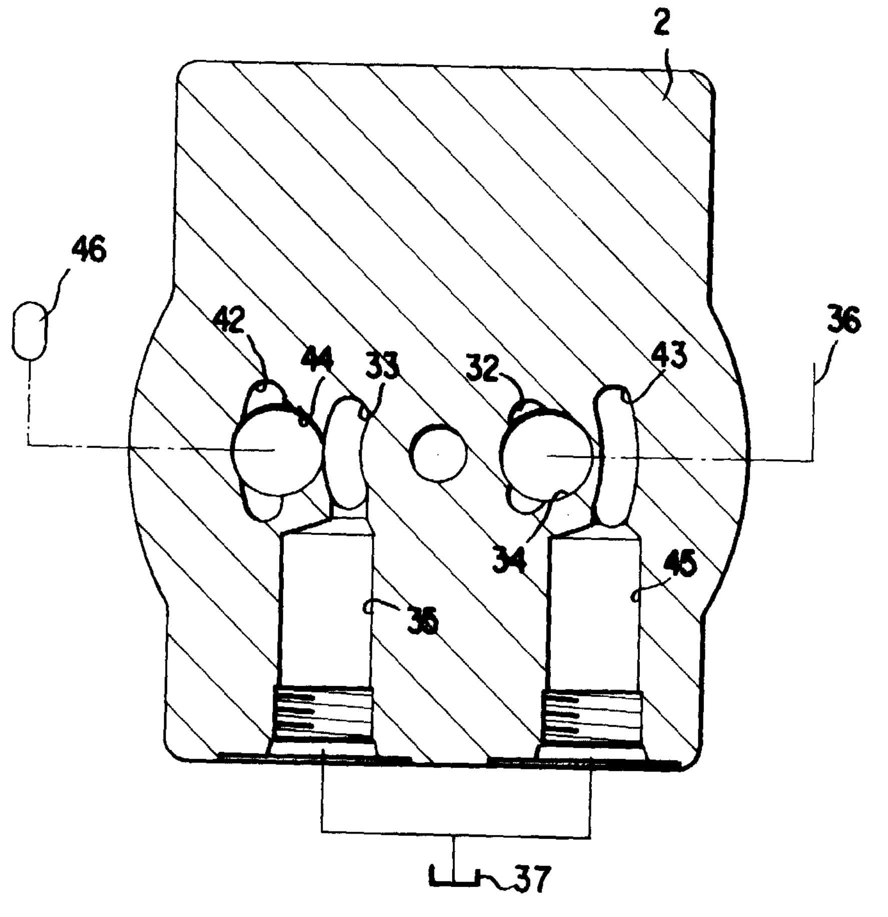


FIG. 5

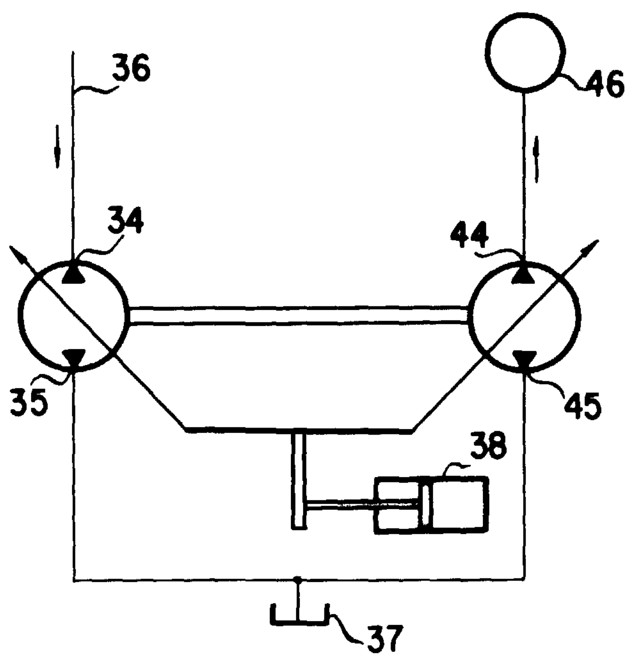


FIG. 6

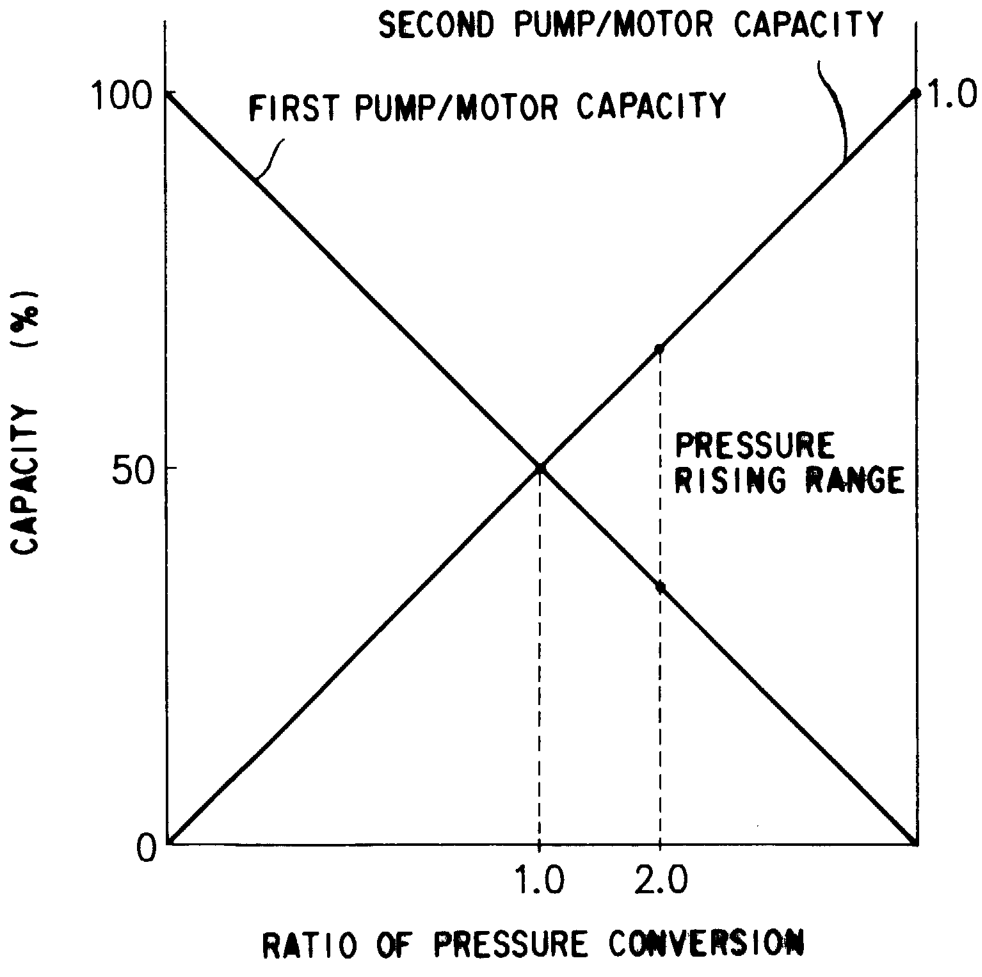

SECOND PUMP/MOTOR CAPACITY
100
FIRST PUMP/MOTOR CAPACITY
1.0
CAPACITY (%)
50
PRESSURE RISING RANGE
0
1.0
2.0
RATIO OF PRESSURE CONVERSION

FIG. 7

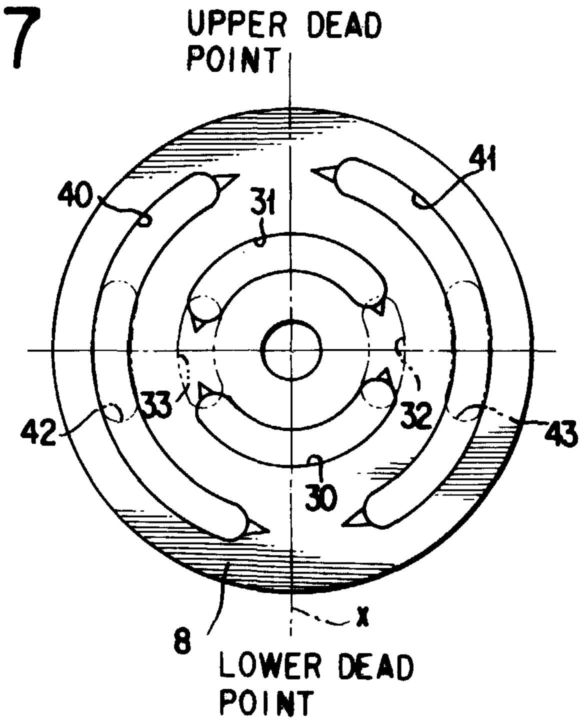

UPPER DEAD POINT
41
40
31
42
33
32
43
30
8
X
LOWER DEAD POINT

FIG. 8

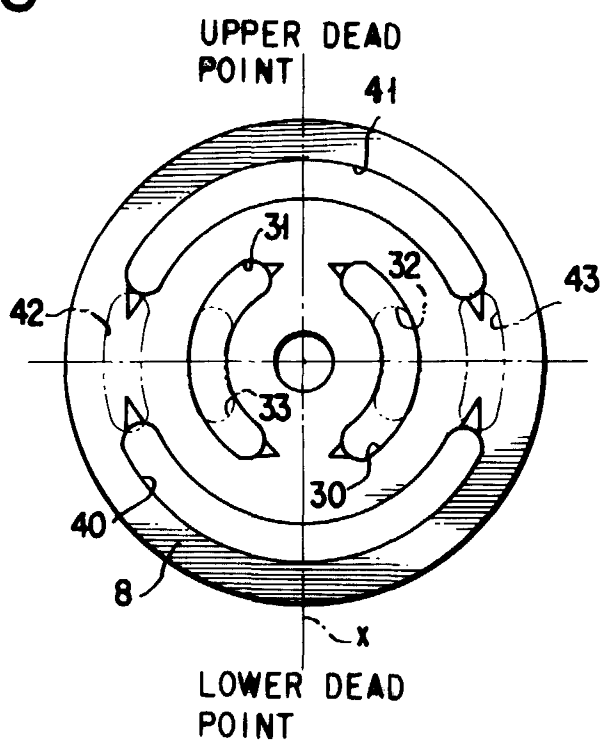

UPPER DEAD POINT
41
31
32
43
42
33
30
40
8
X
LOWER DEAD POINT

FIG. 9

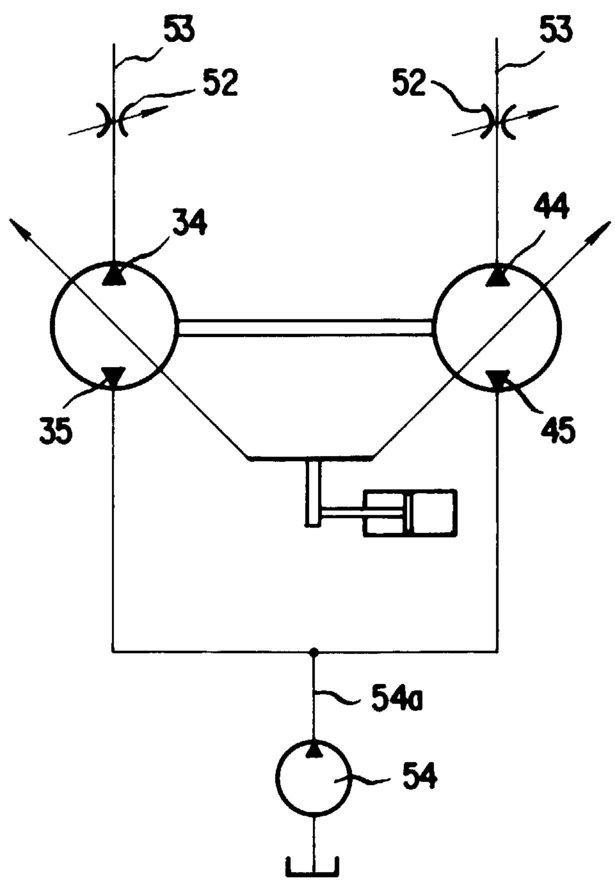


FIG. 10

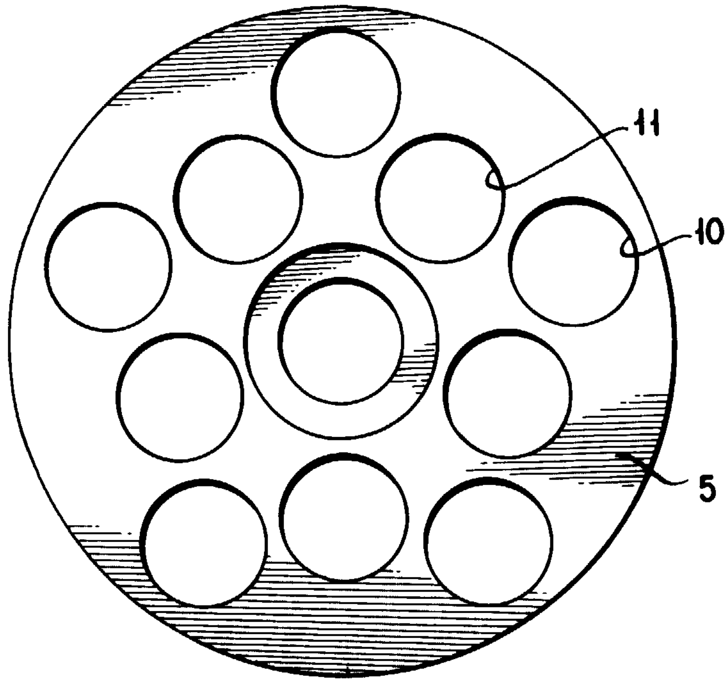


FIG. 11

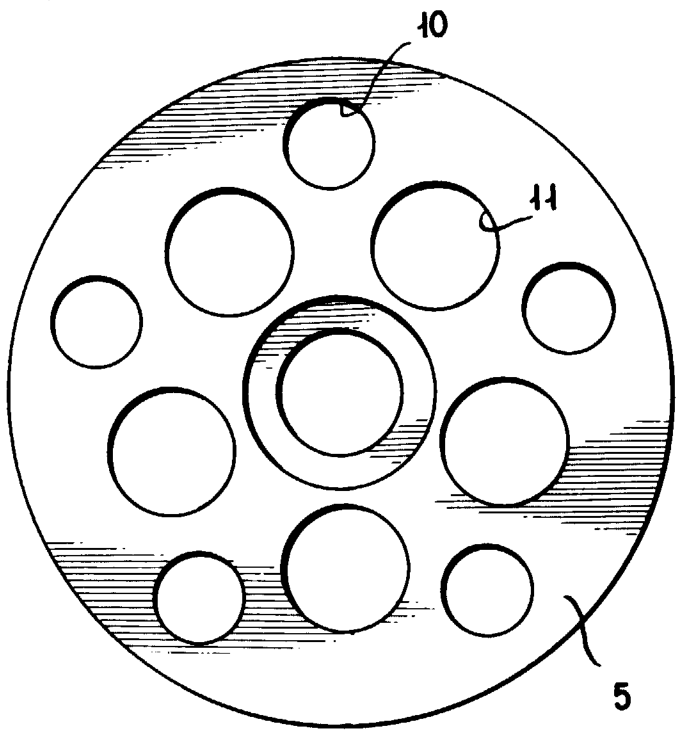


FIG. 12

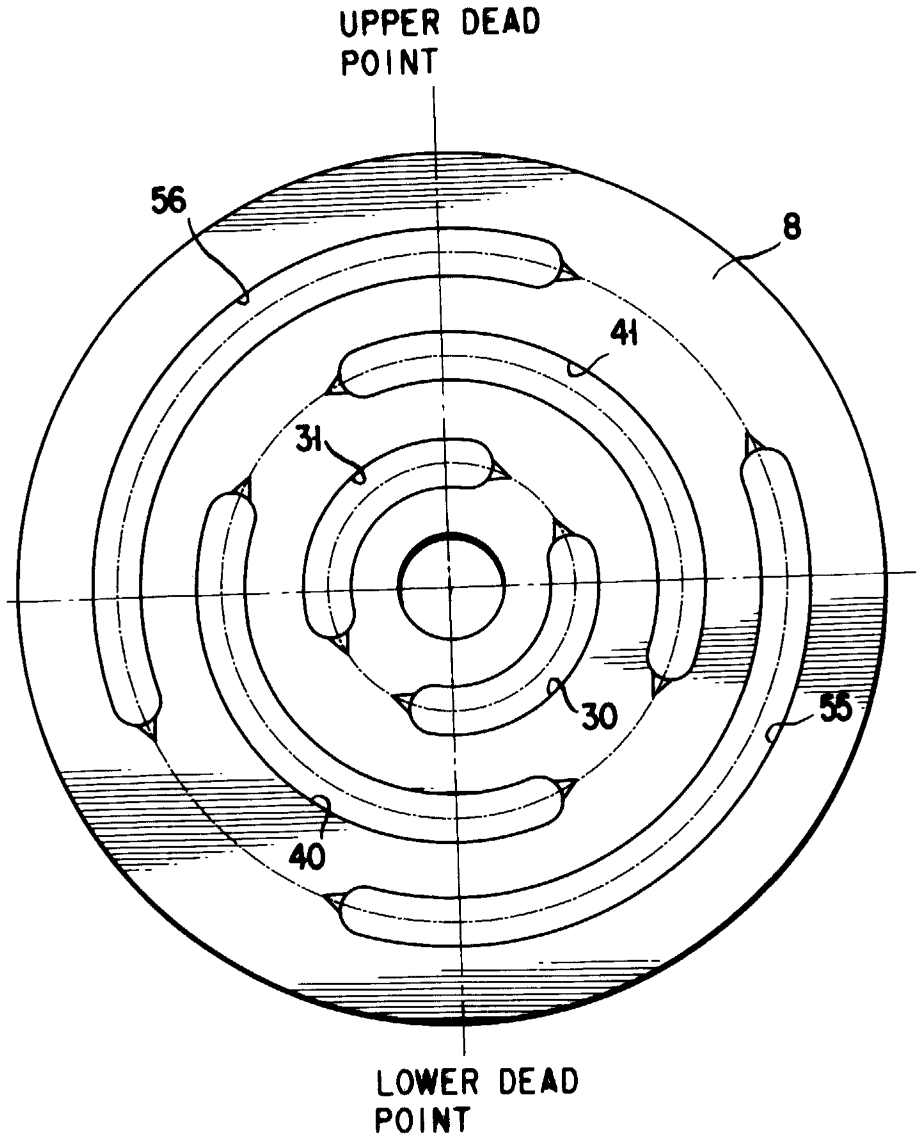


FIG. 13

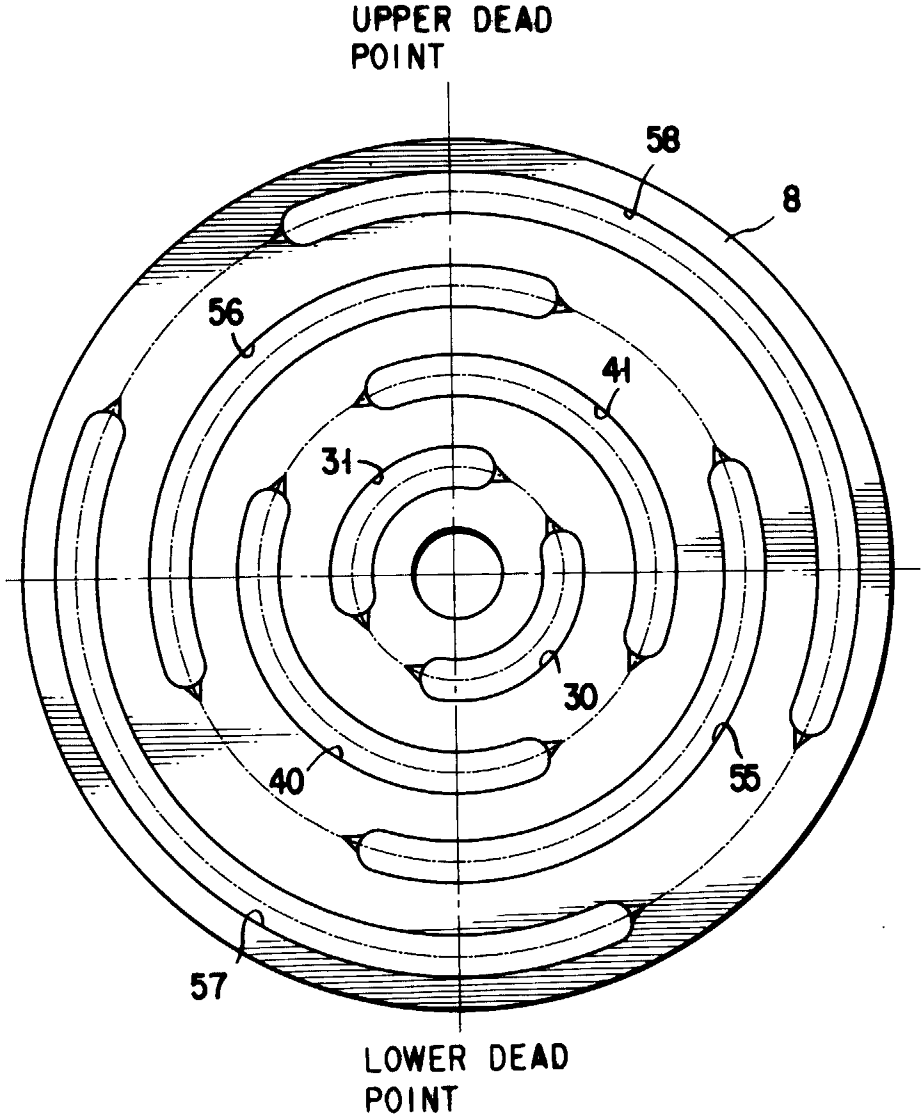


FIG. 14

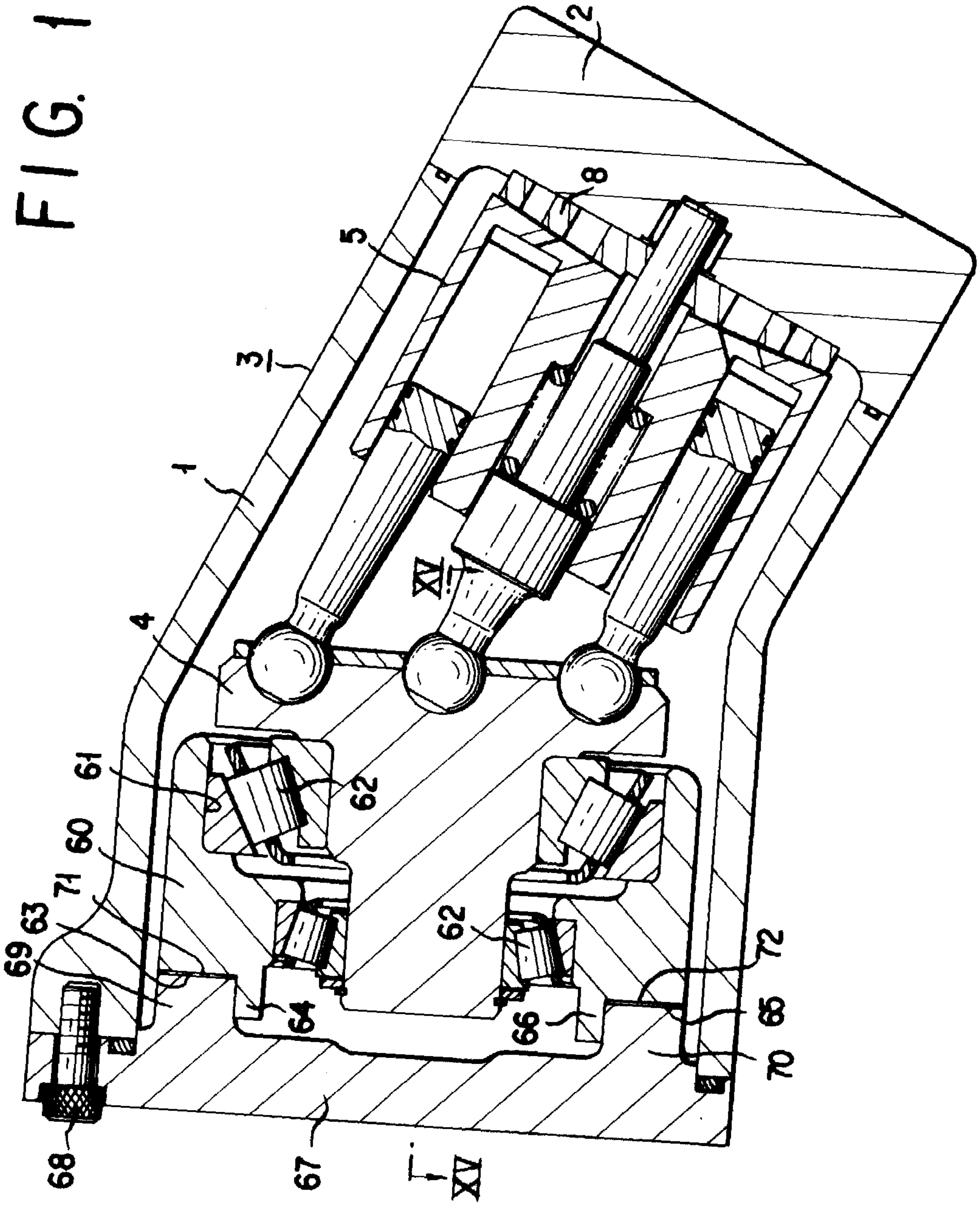


FIG. 15

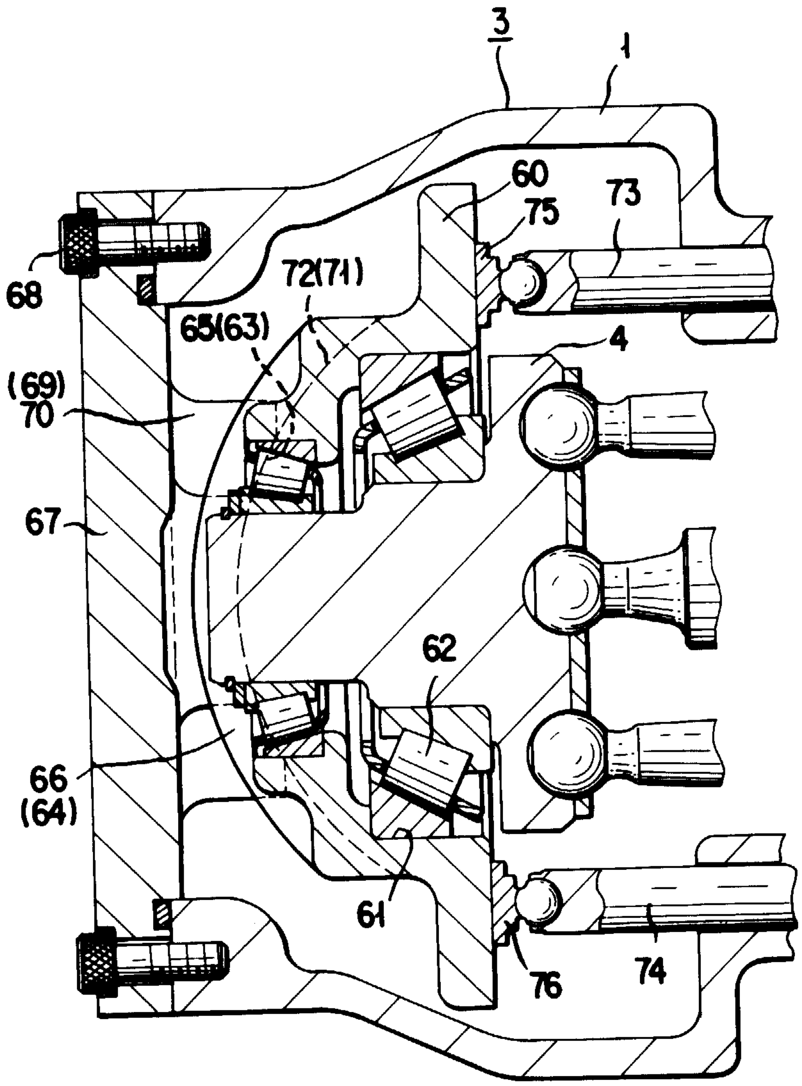


FIG. 16

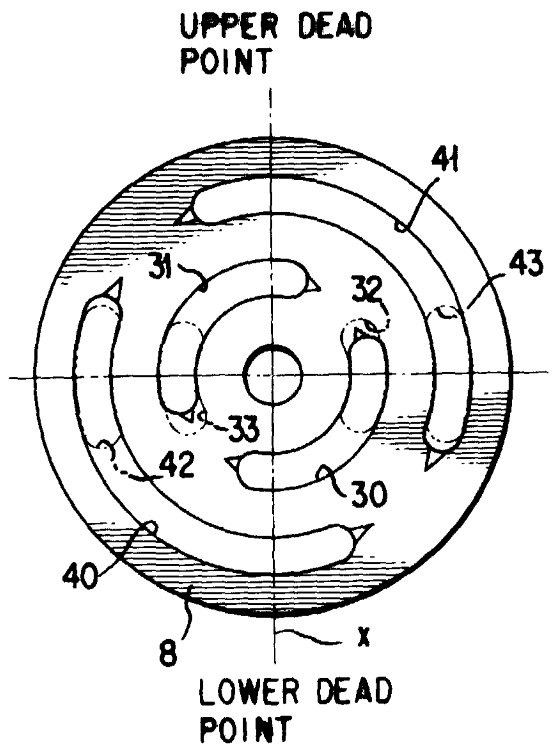


FIG. 17

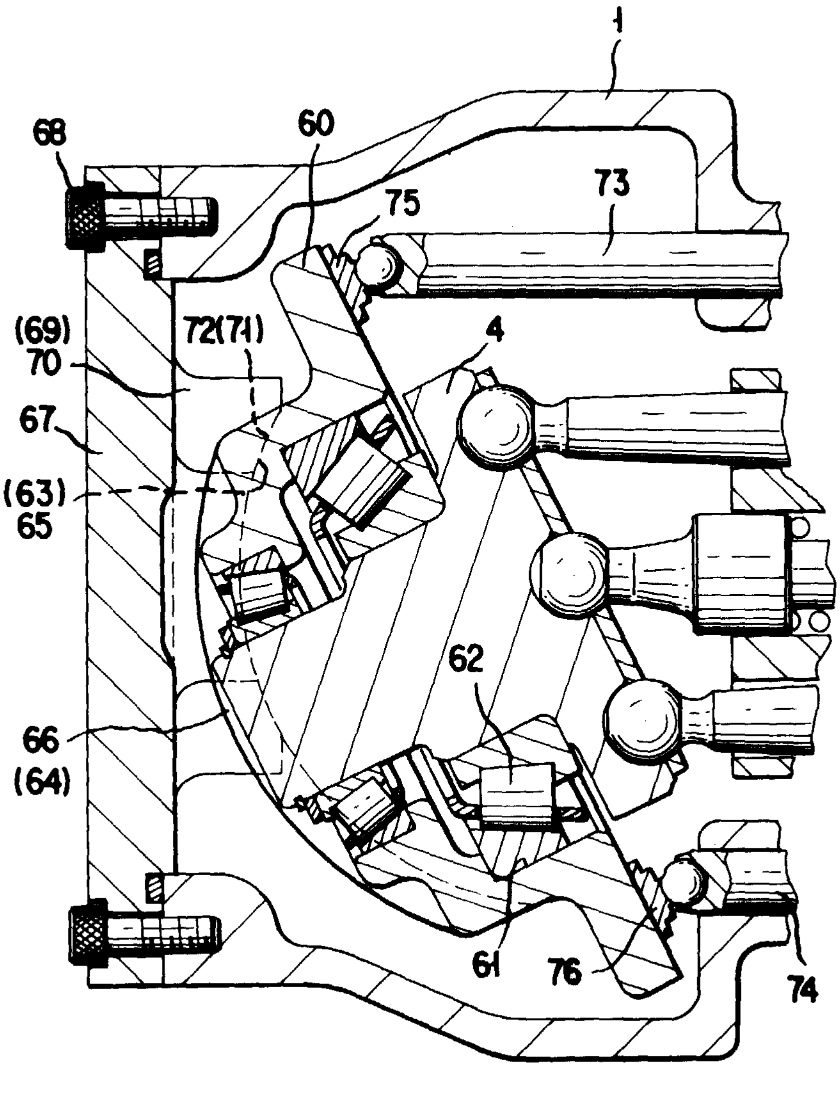


FIG. 18

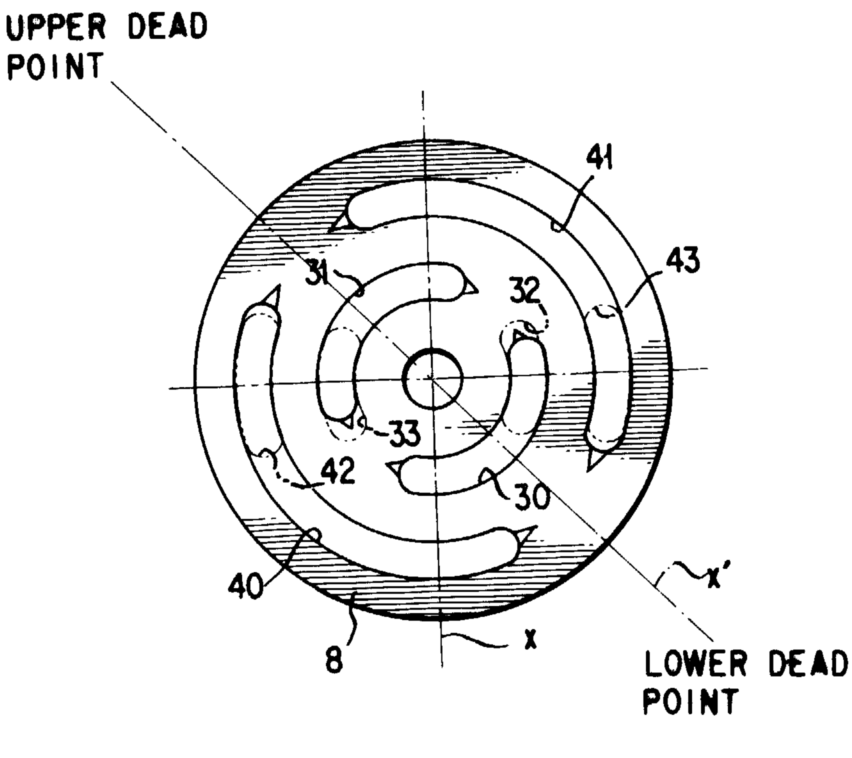


FIG. 19

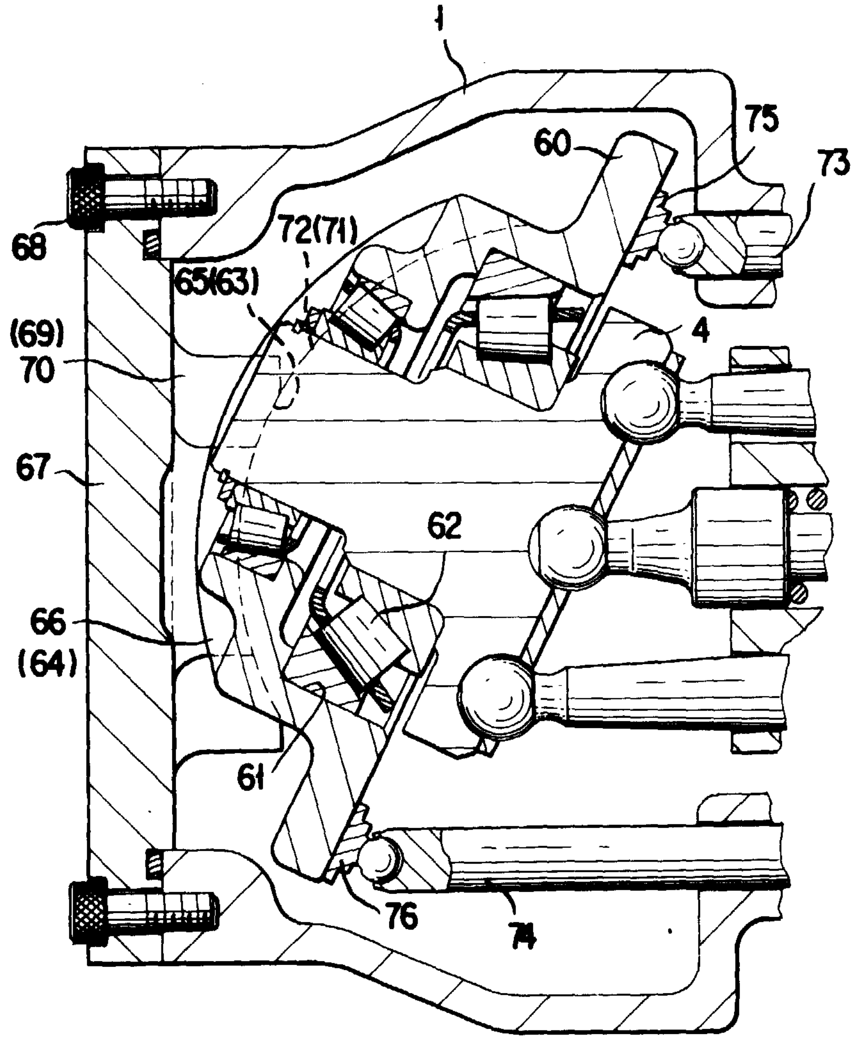


FIG. 20

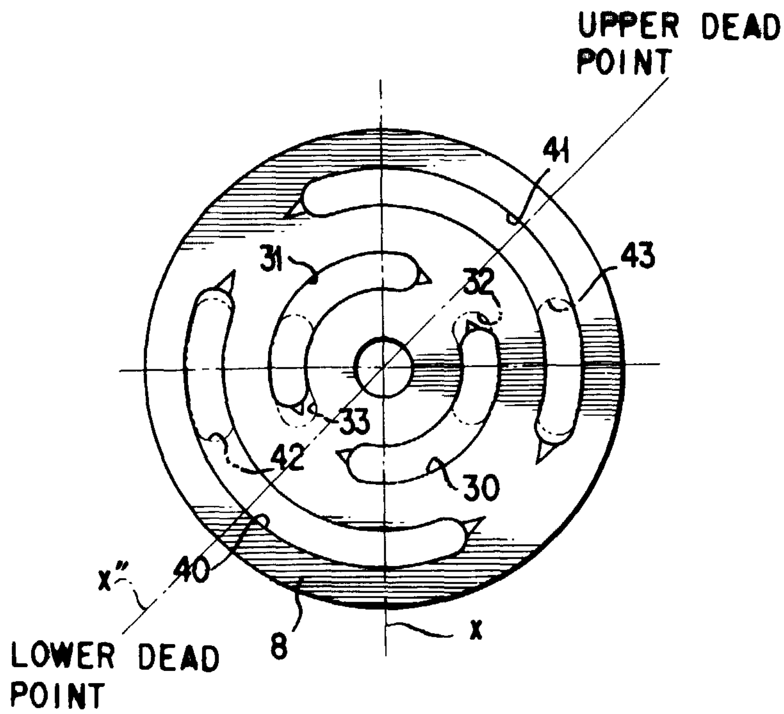


FIG. 21

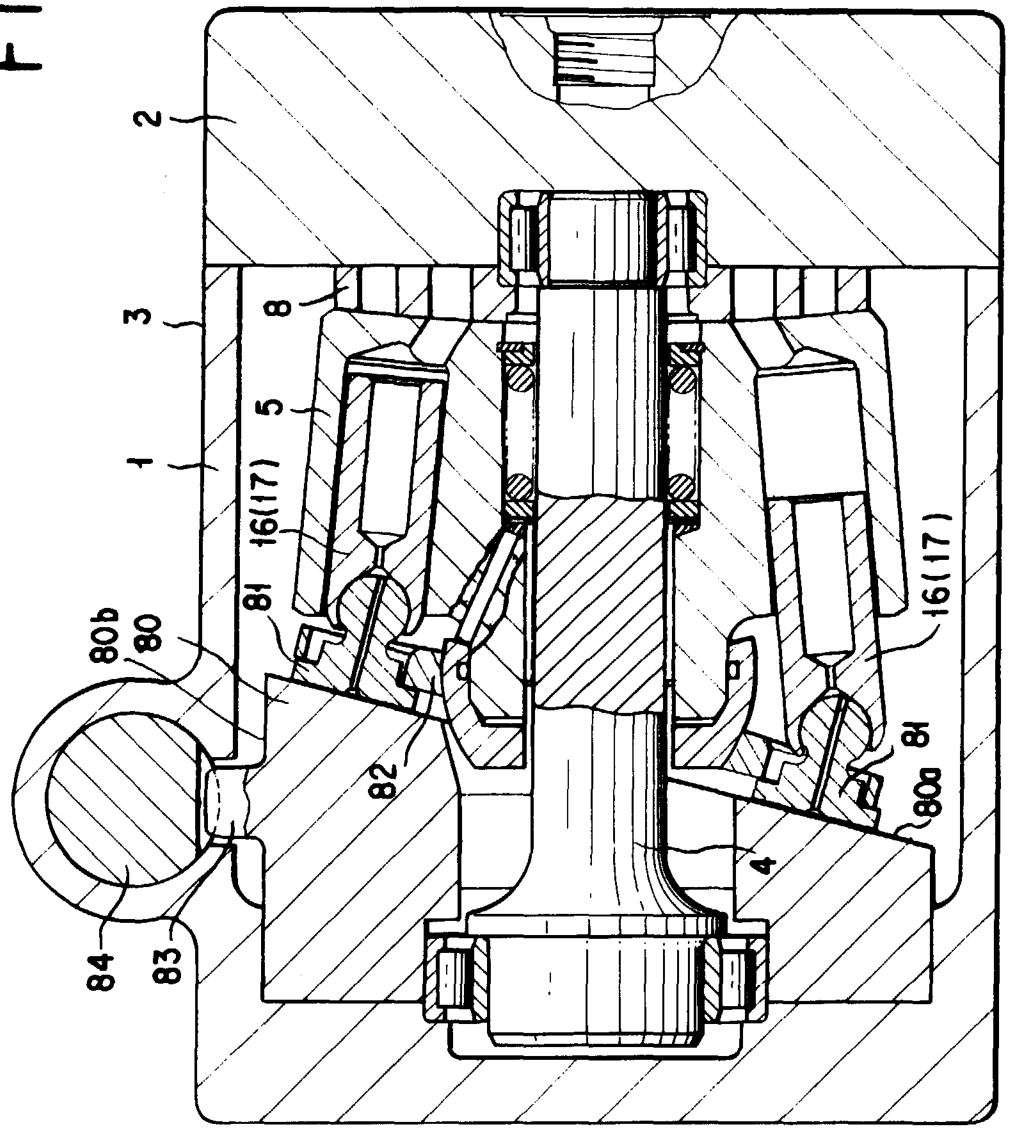


FIG. 22

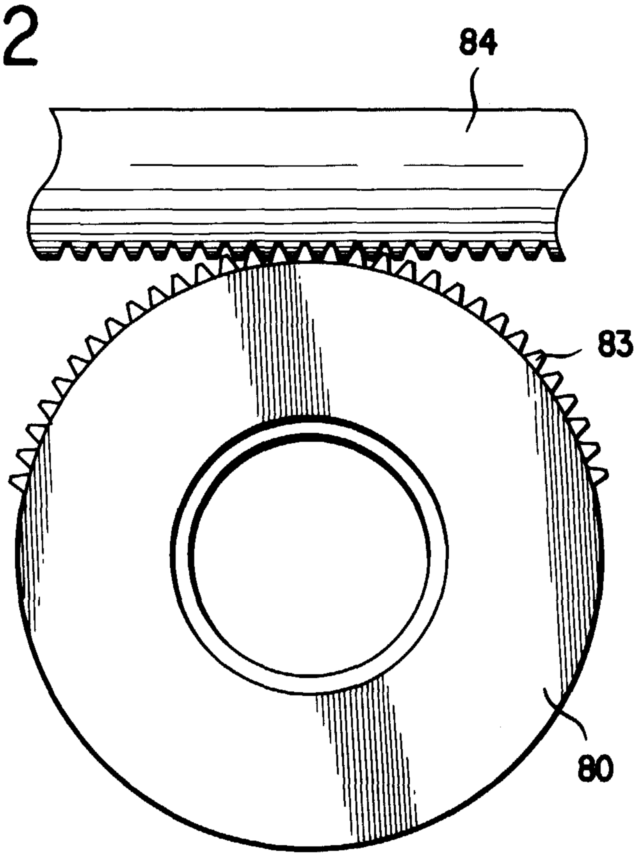

84
83
80

FIG. 23

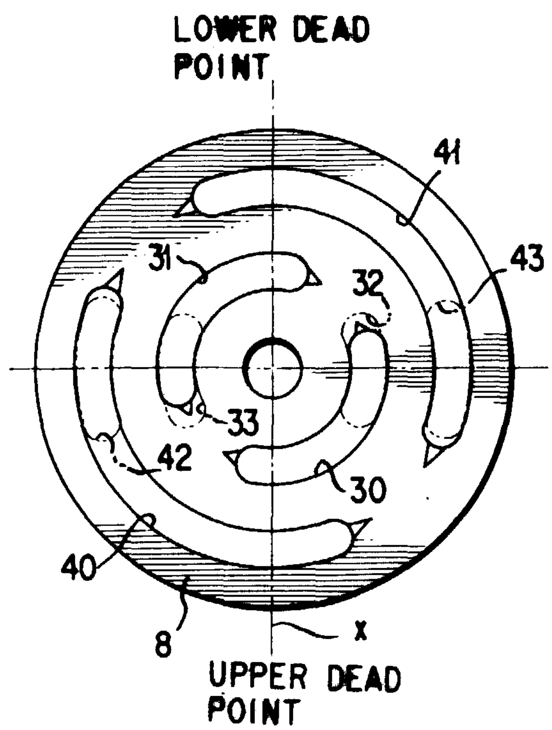

LOWER DEAD POINT
41
43
31
32
33
42
30
40
8
X
UPPER DEAD POINT

FIG. 24

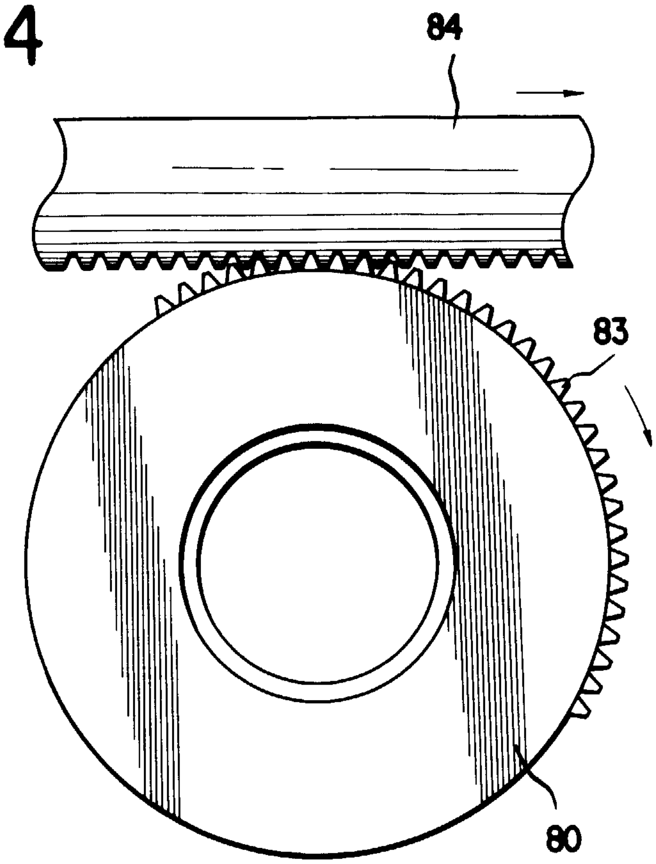

84
83
80

FIG. 25

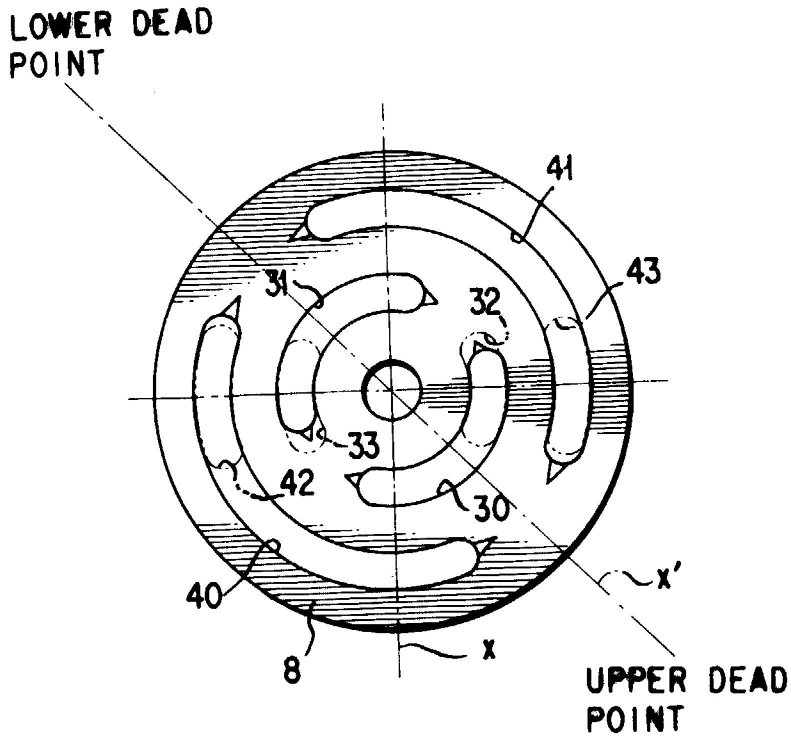

LOWER DEAD
POINT
41
43
31
32
33
42
30
40
x'
8
x
UPPER DEAD
POINT

FIG. 26

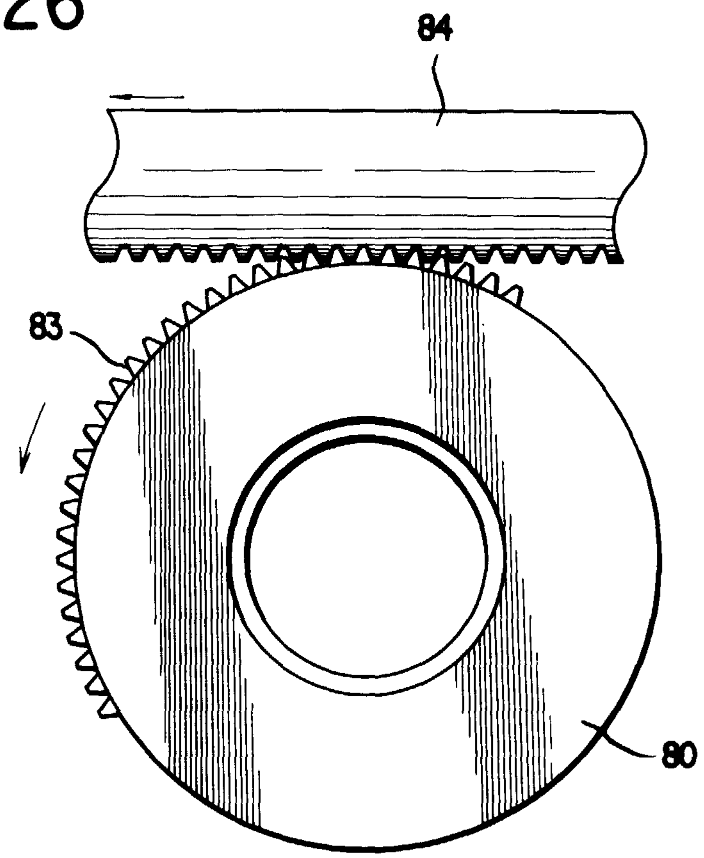


FIG. 27

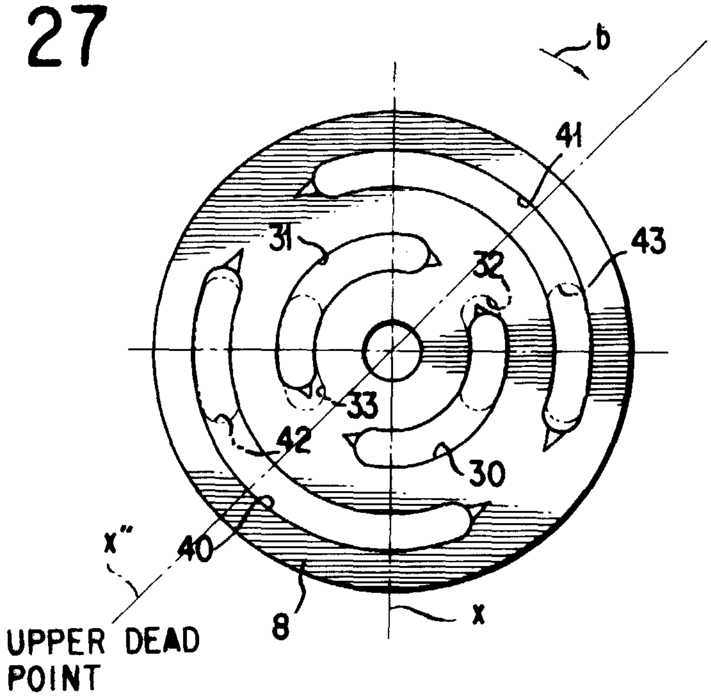


FIG. 28

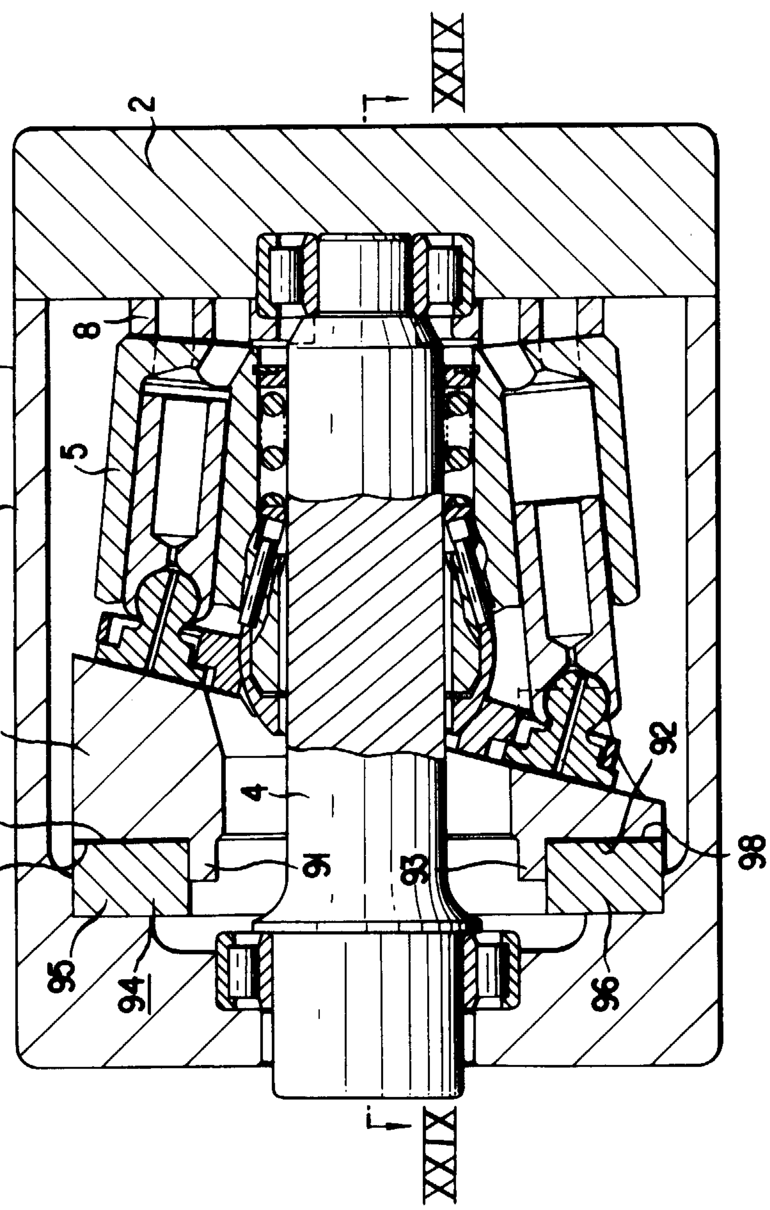


FIG. 29

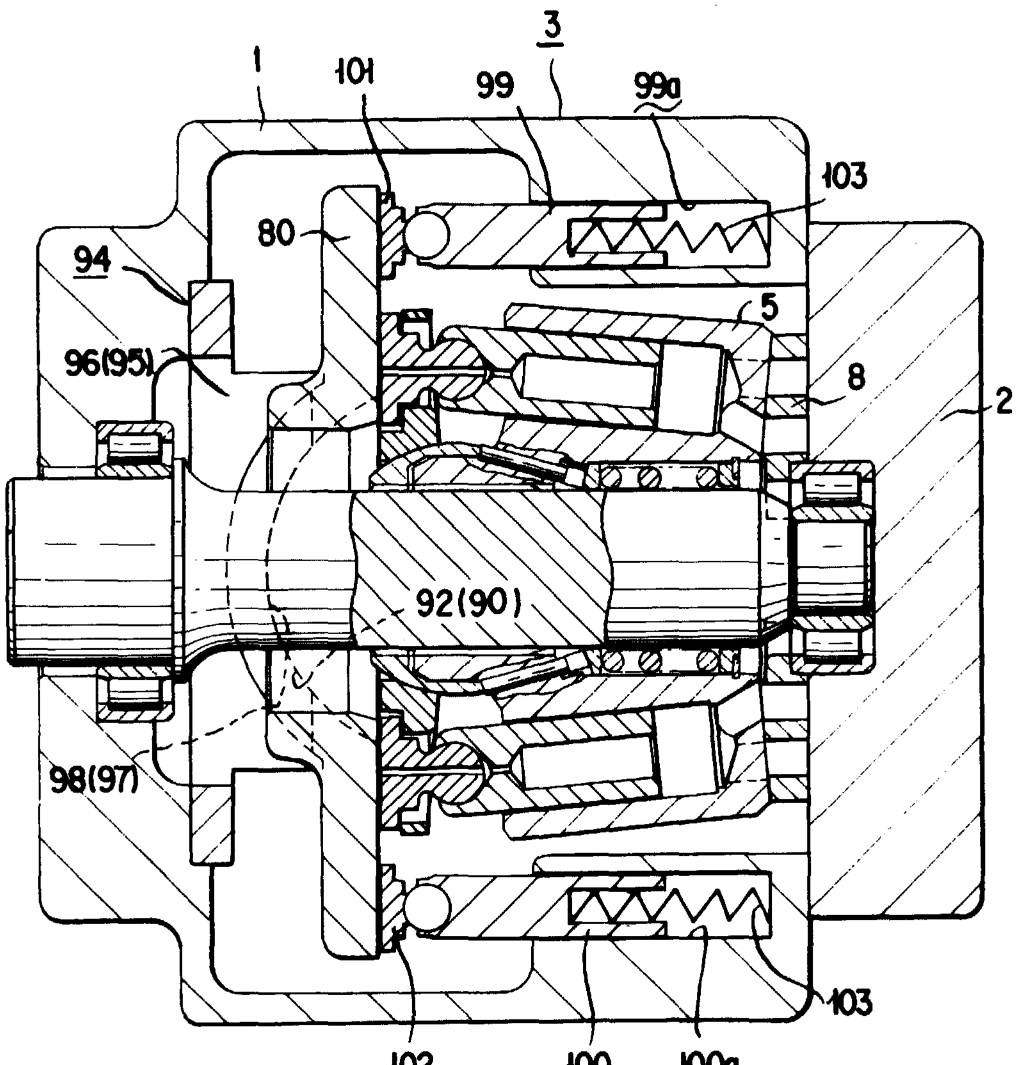


FIG. 30

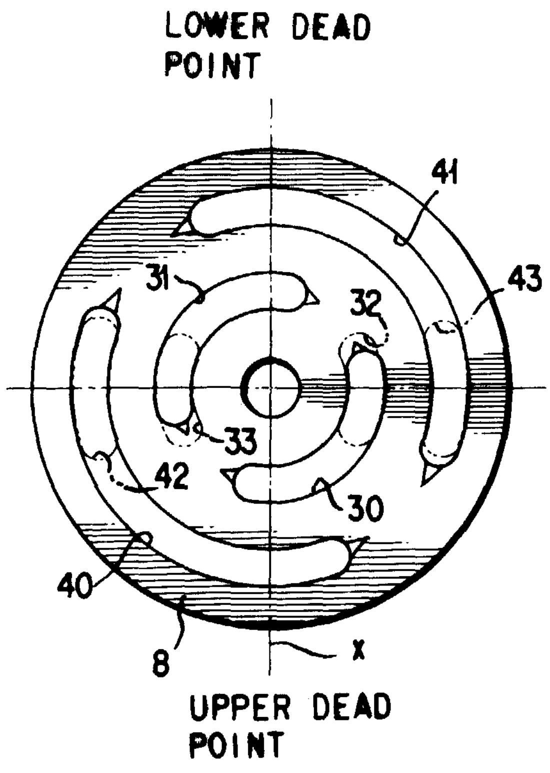


FIG. 31

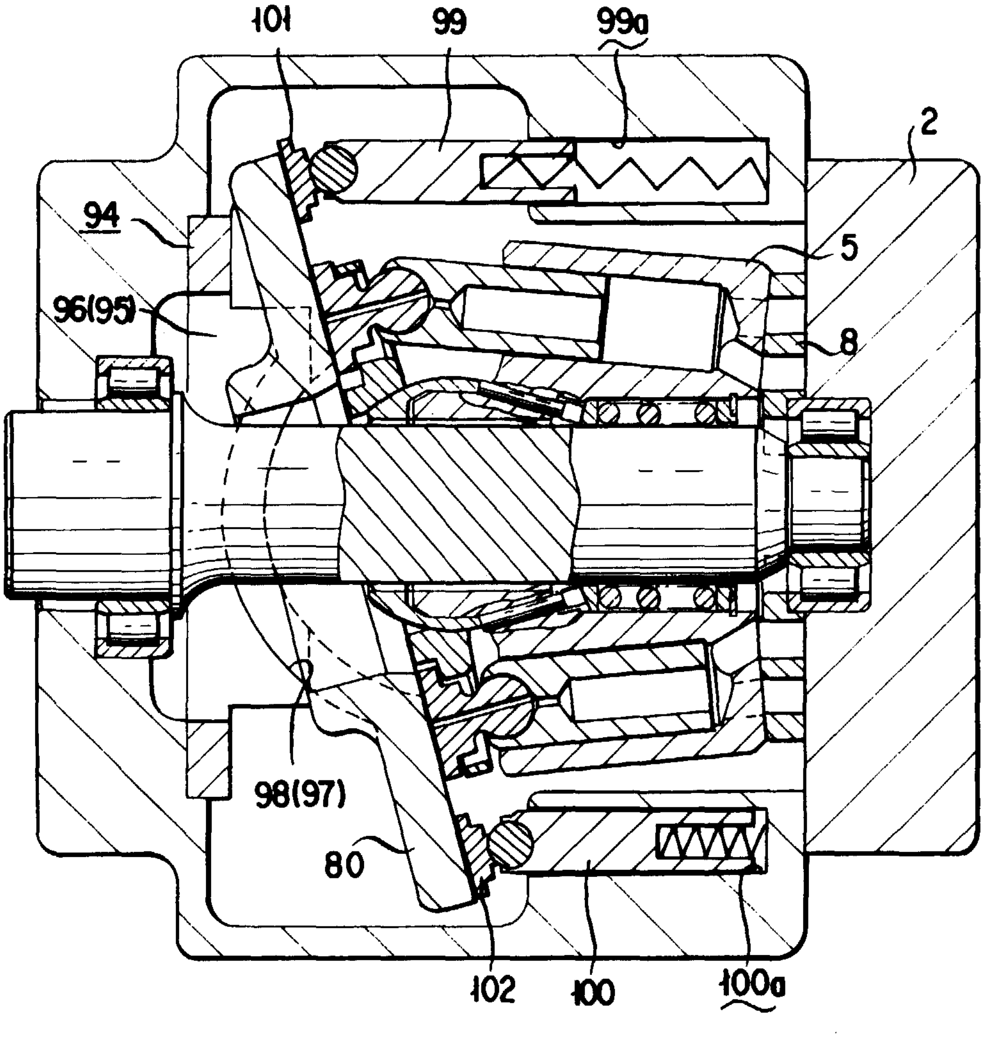


FIG. 32

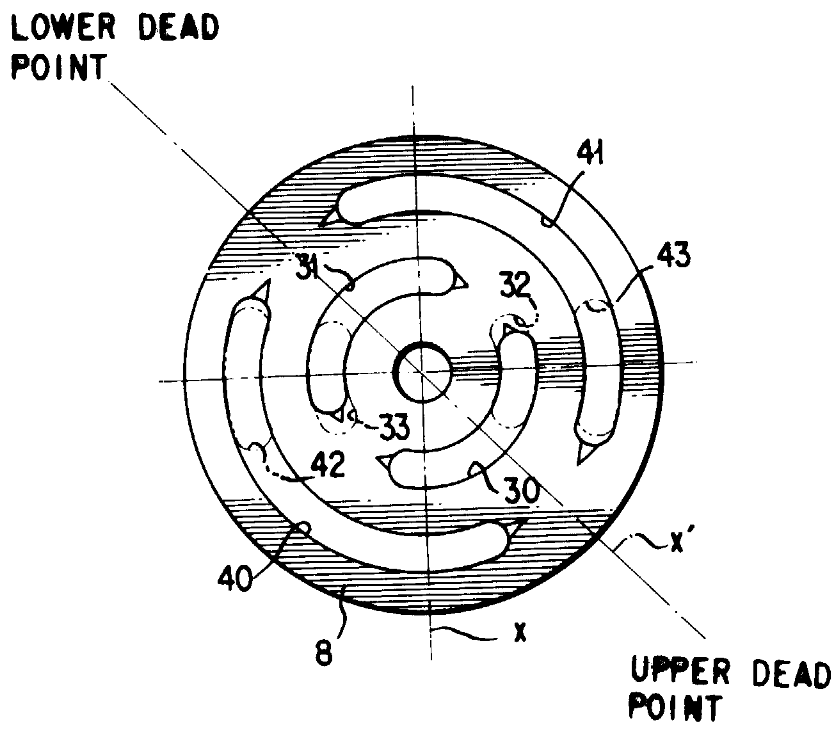


FIG. 33

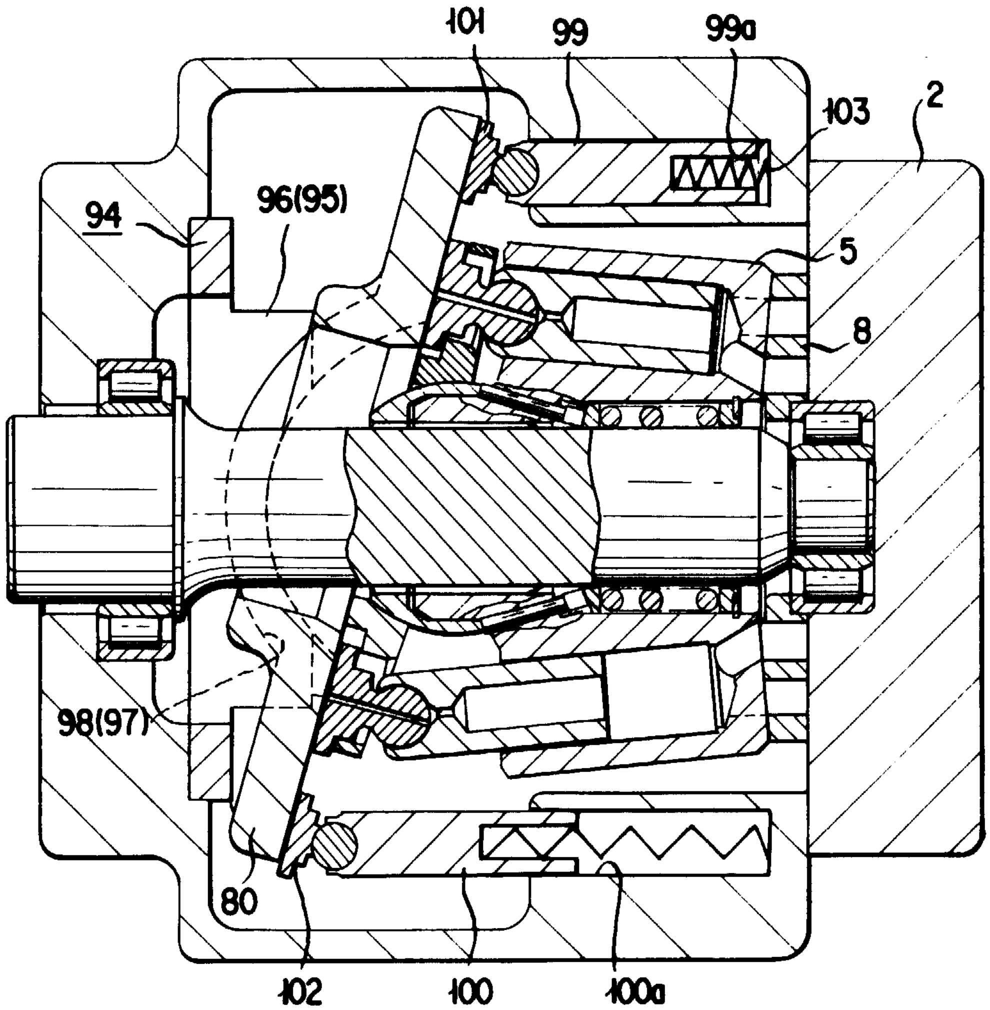


FIG. 34

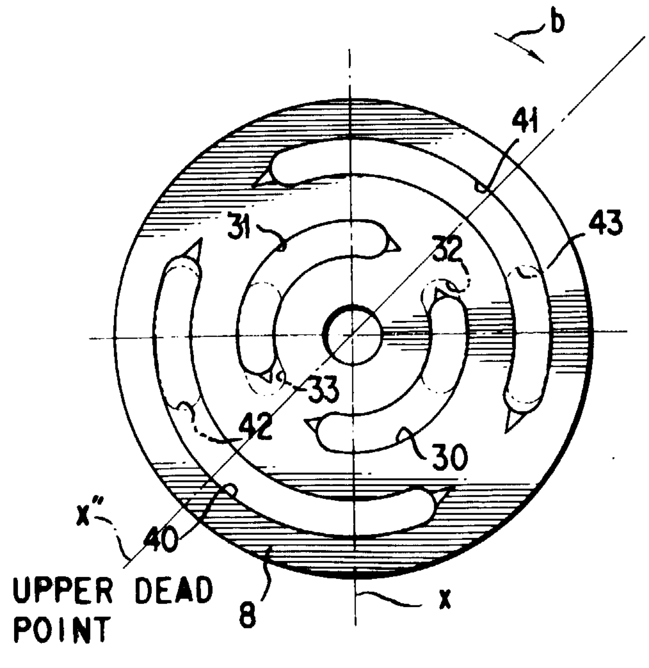
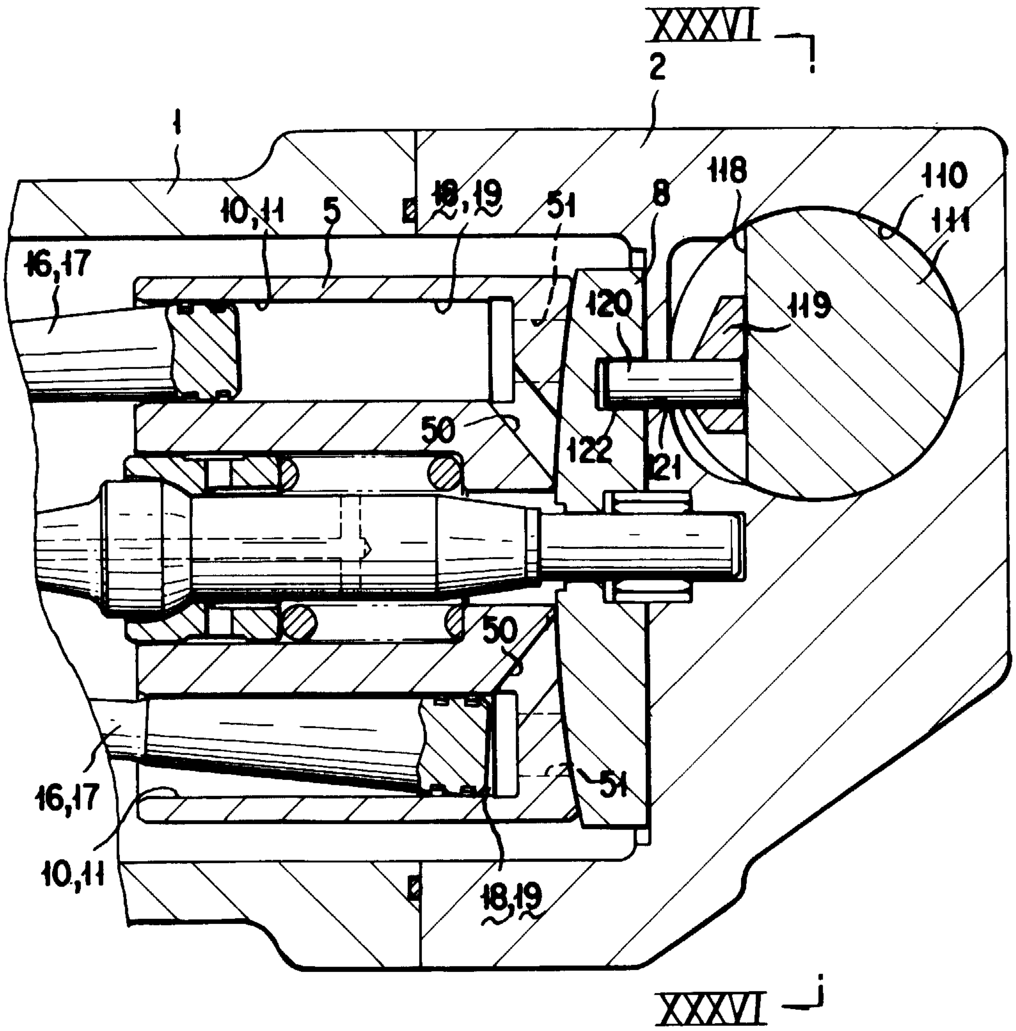


FIG. 35


XXXVI
2
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118
110
111
10,11
5
18,19
51
8
16,17
120
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50
122
121
50
16,17
51
10,11
18,19
XXXVI

FIG. 36

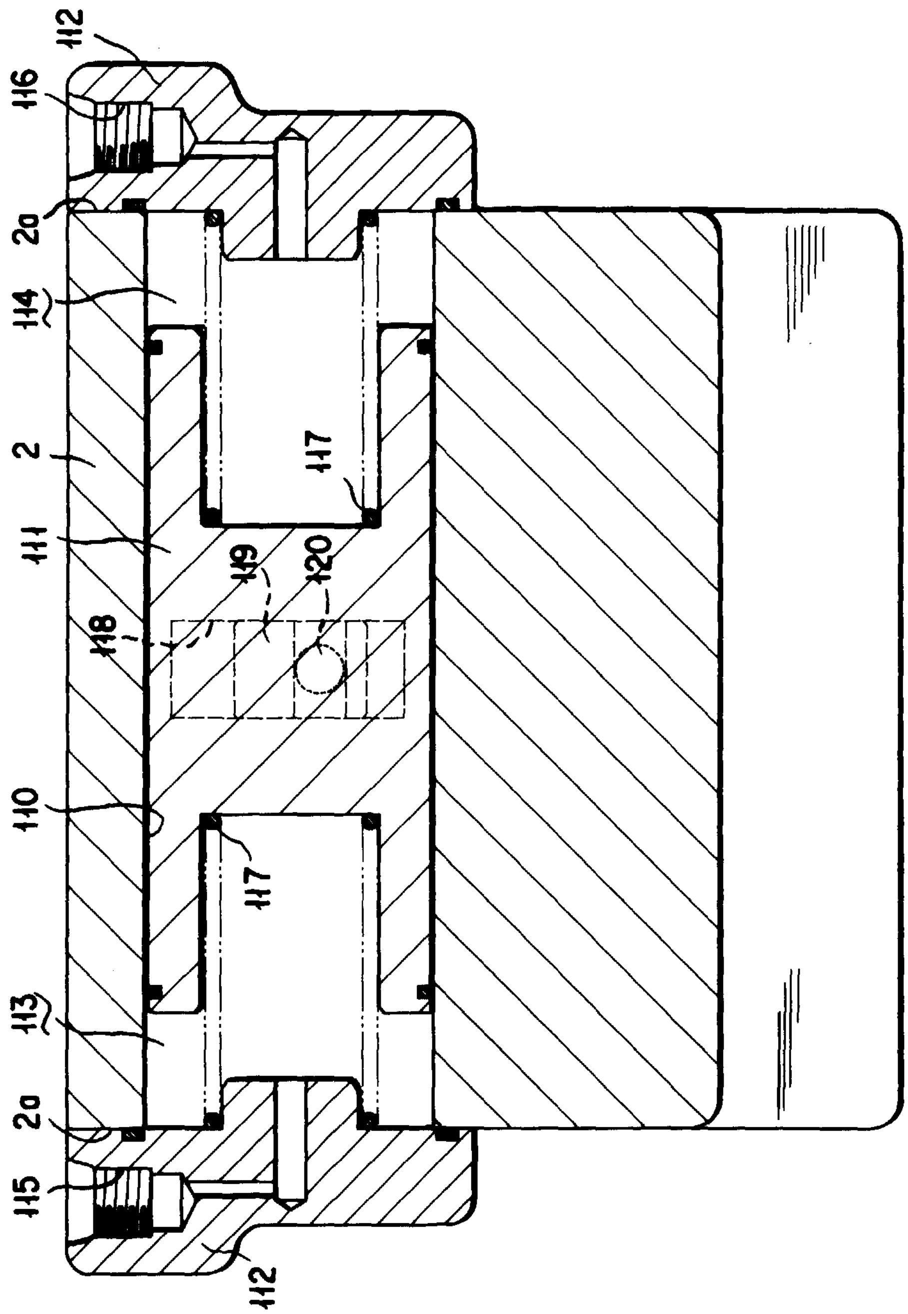


FIG. 37

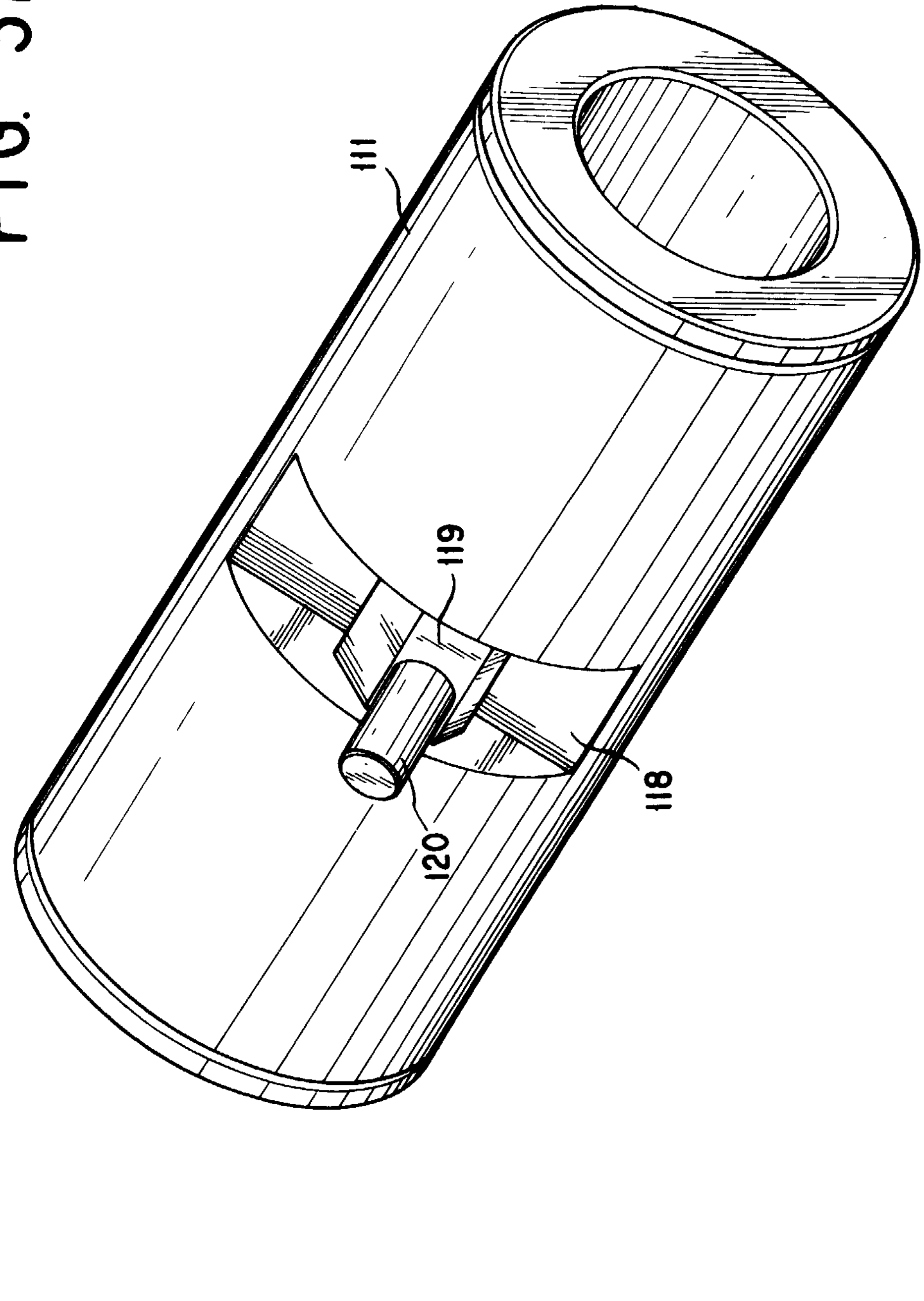


FIG. 38

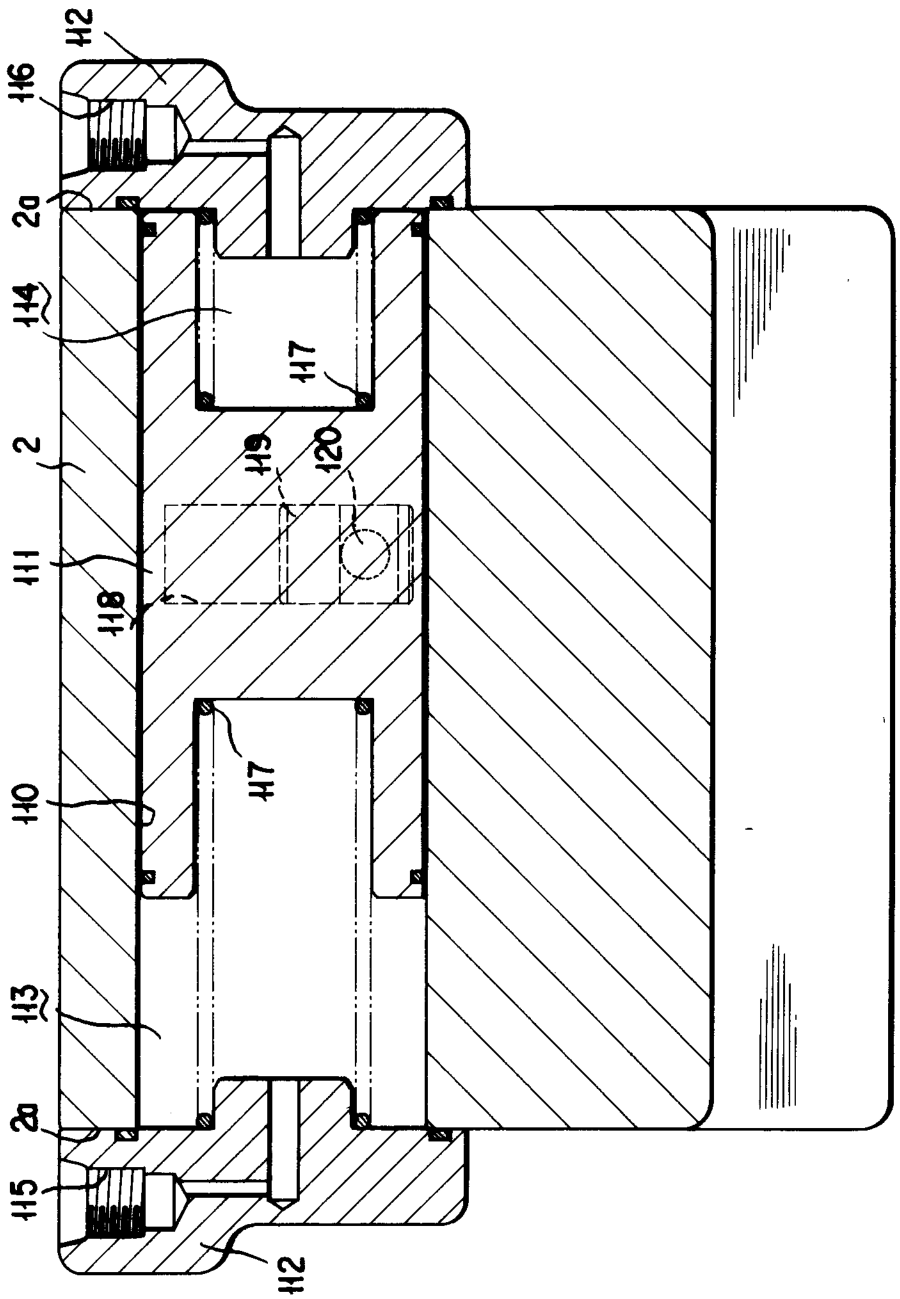


FIG. 39

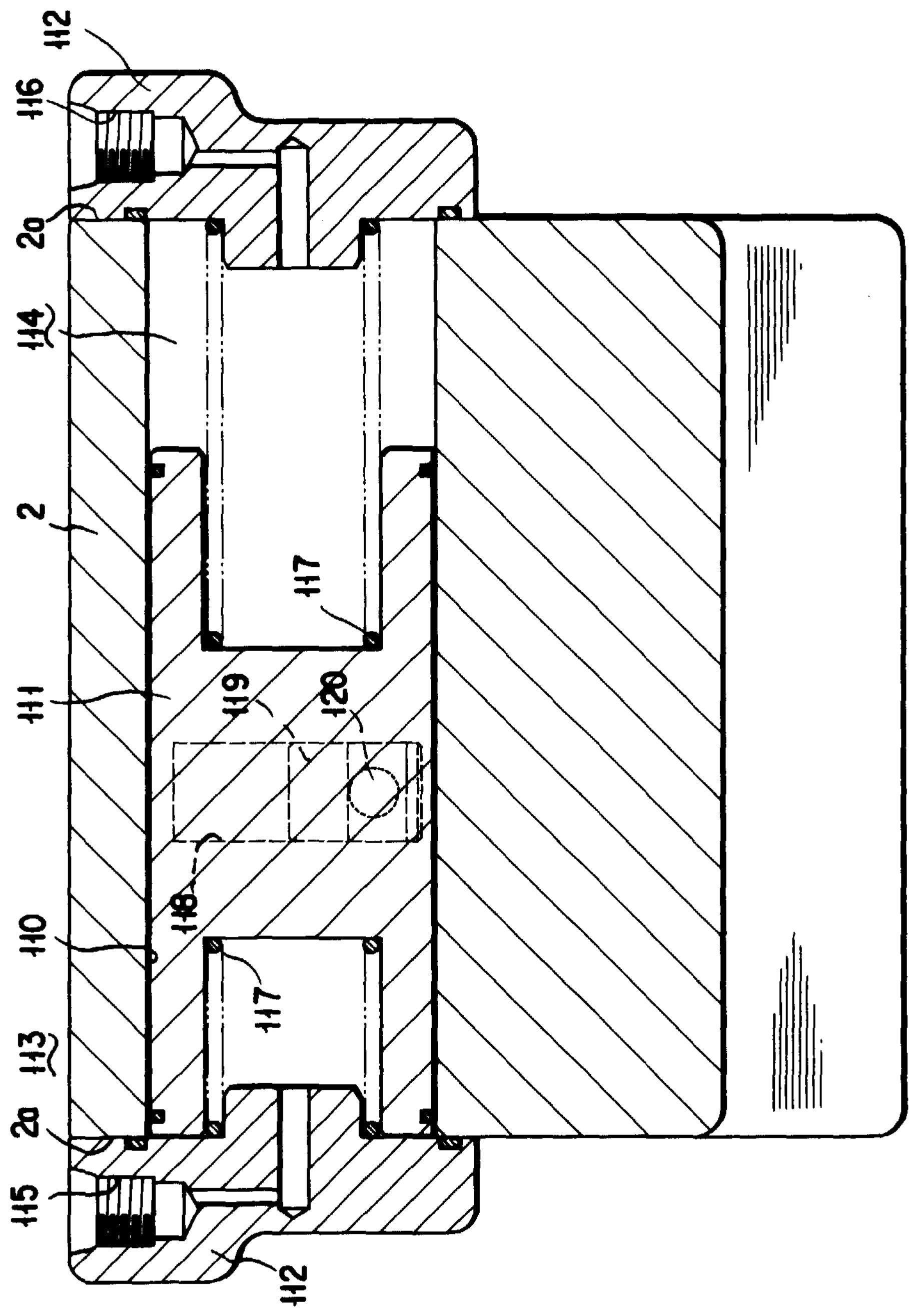
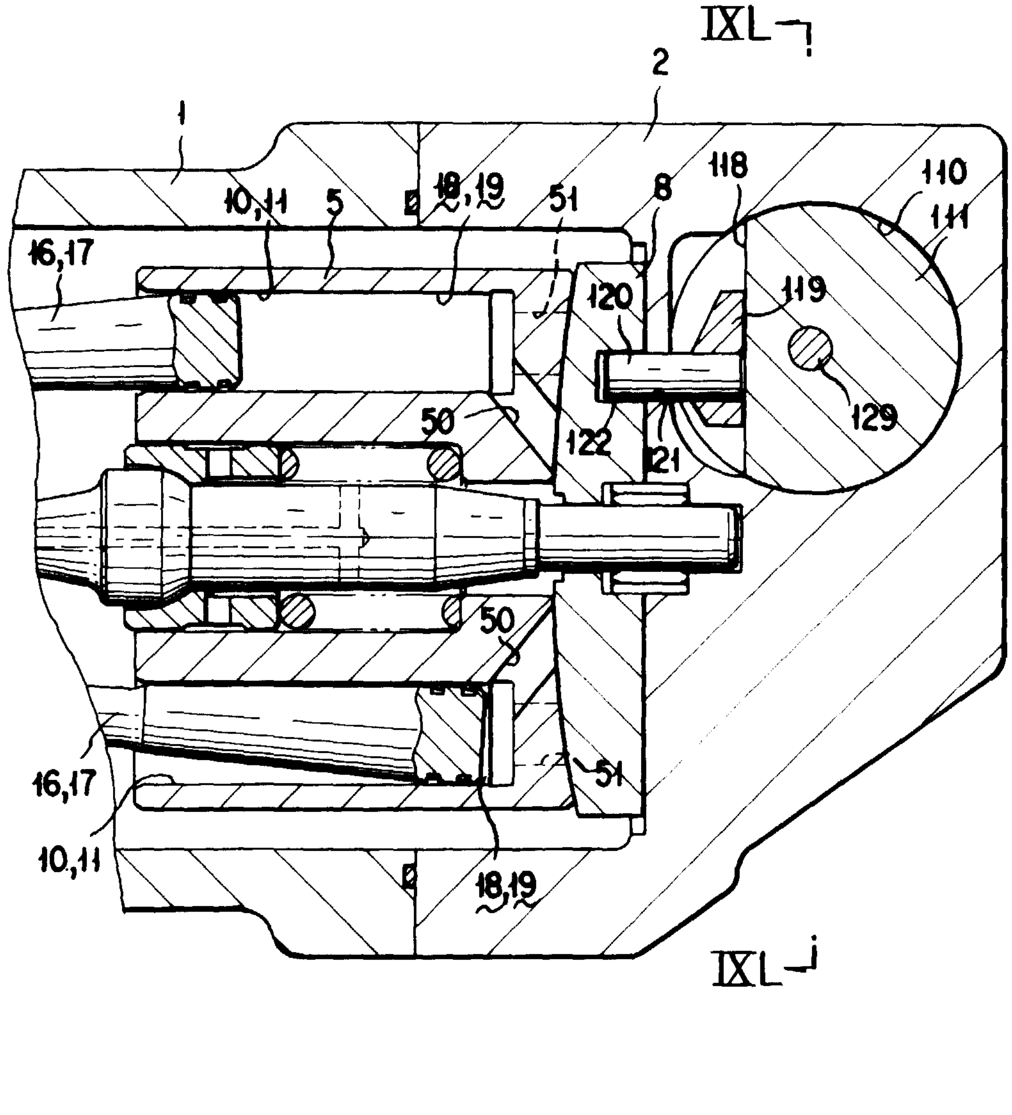


FIG. 40


IXL
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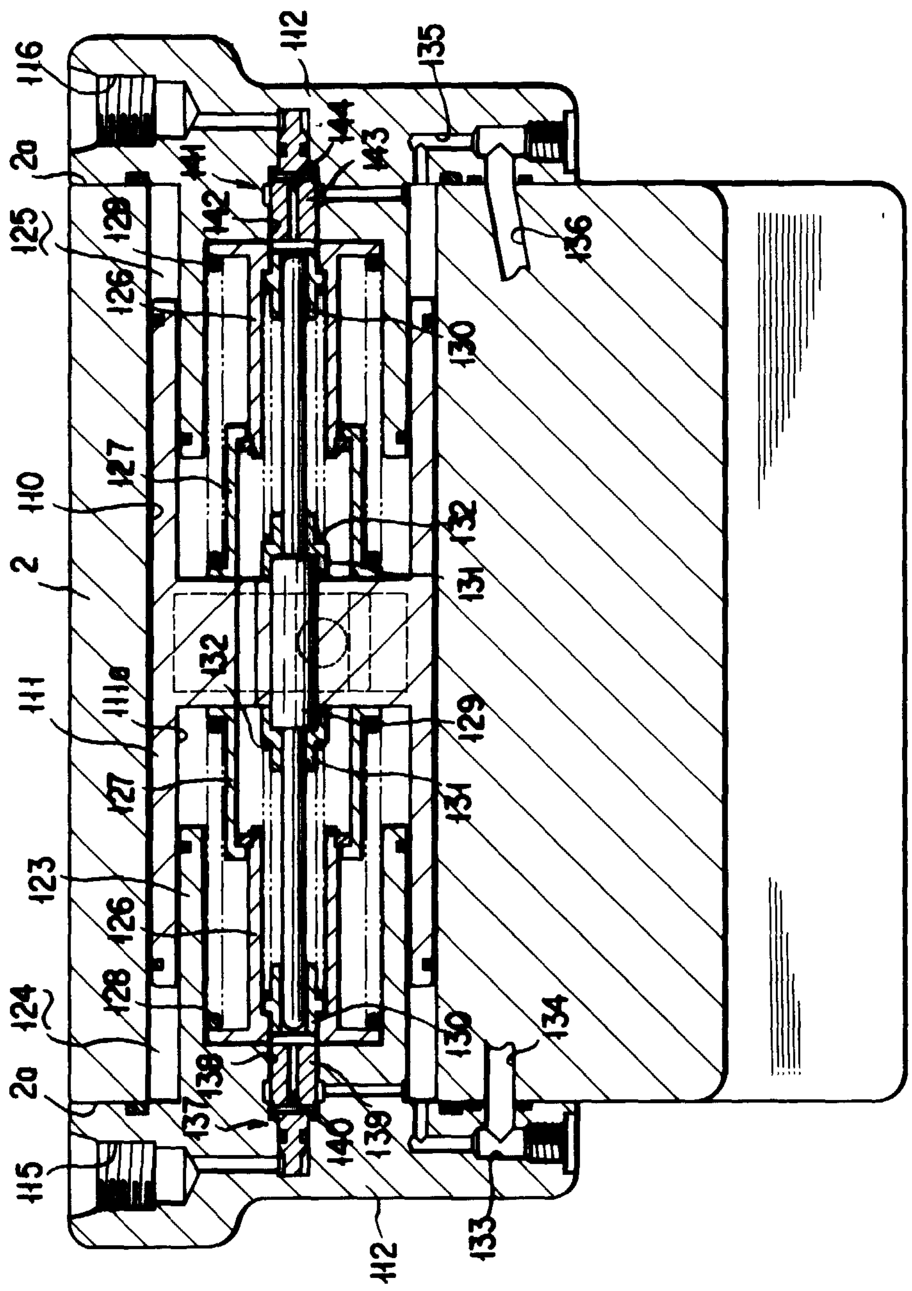
121
50
16,17
51
10,11
18,19
IXL

FIG. 41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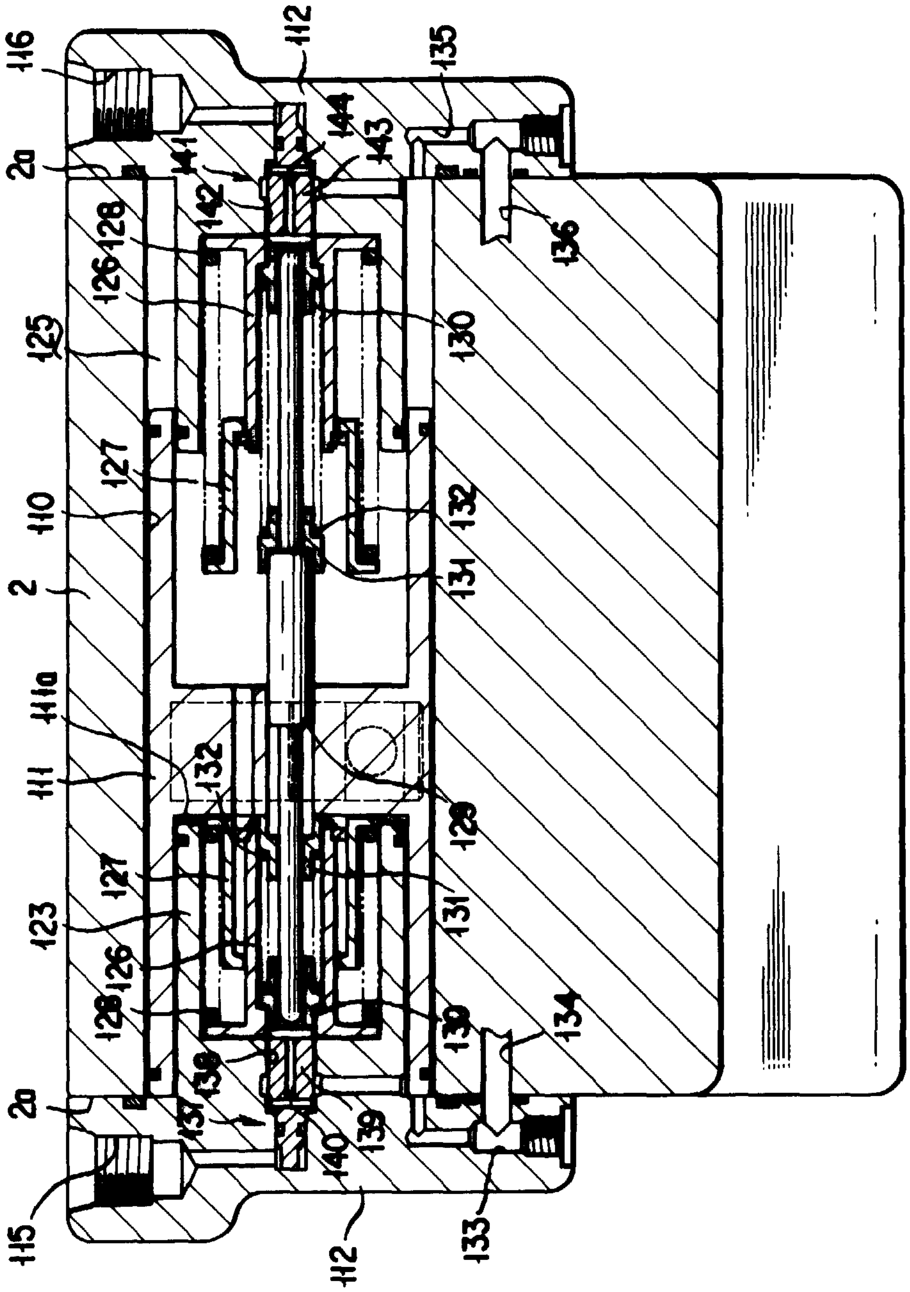
139
133
112

FIG. 42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2a
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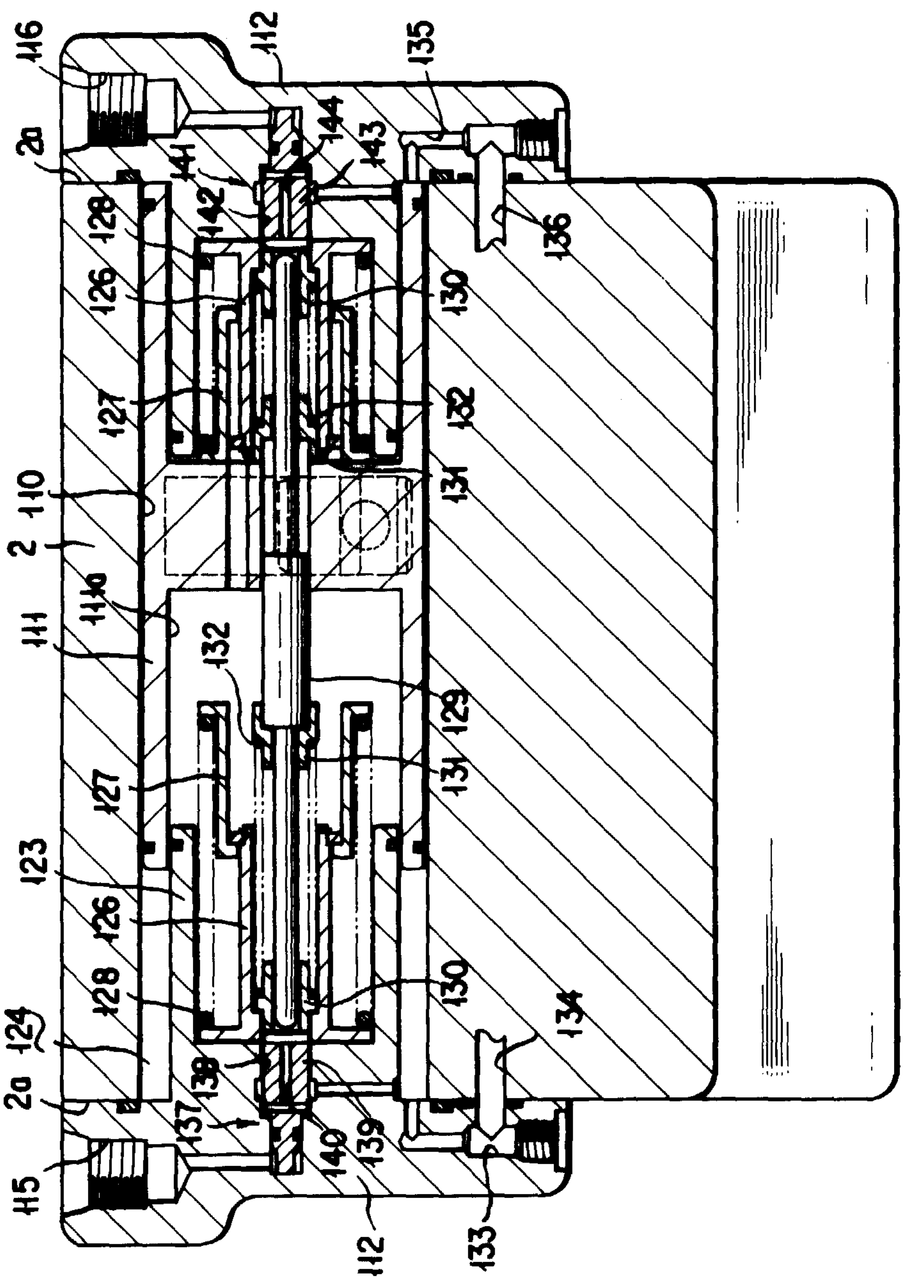
FIG. 43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2a
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115
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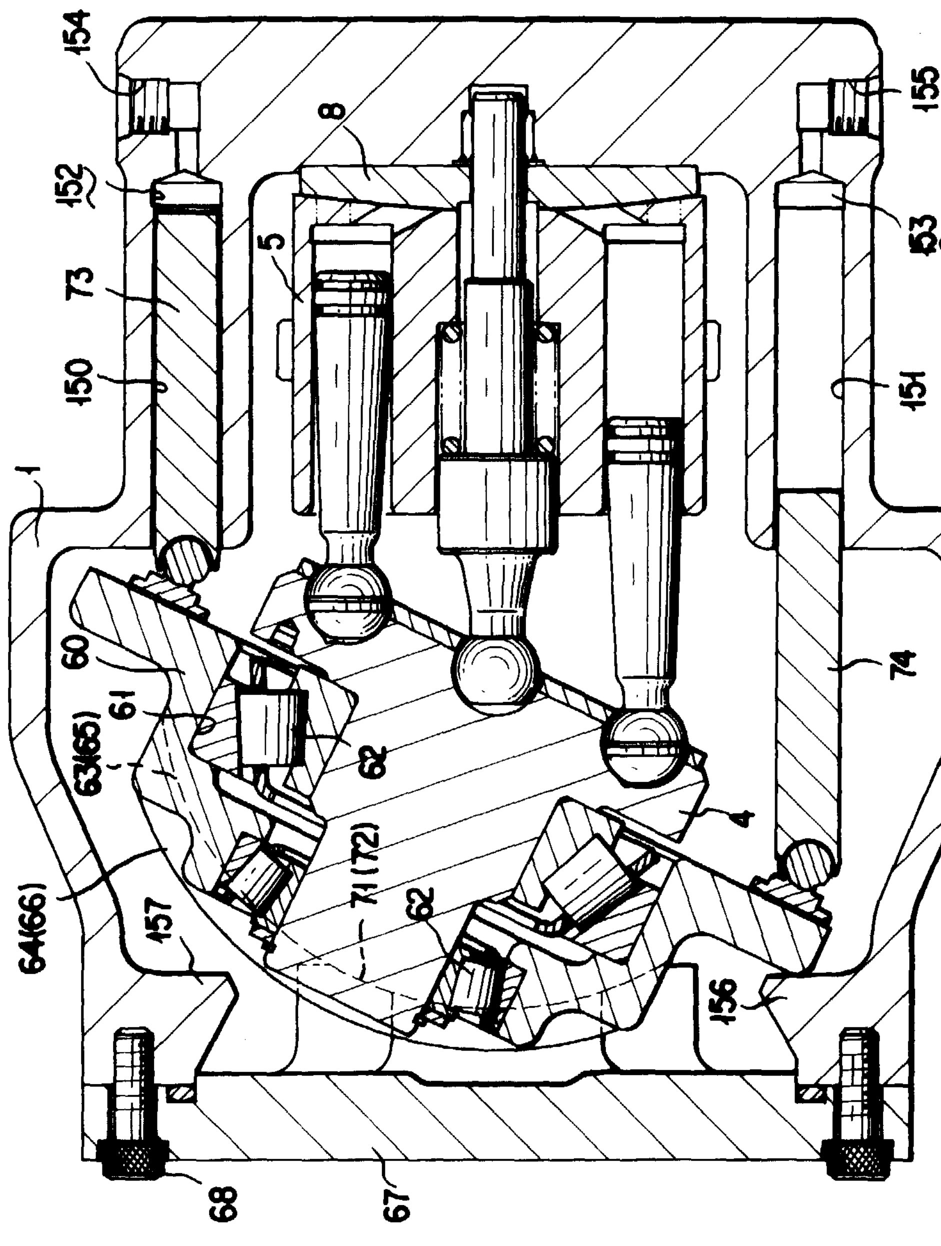
133

FIG. 44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63(65)
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71(72)
62
64(66)
157
156
68
67

FIG. 45

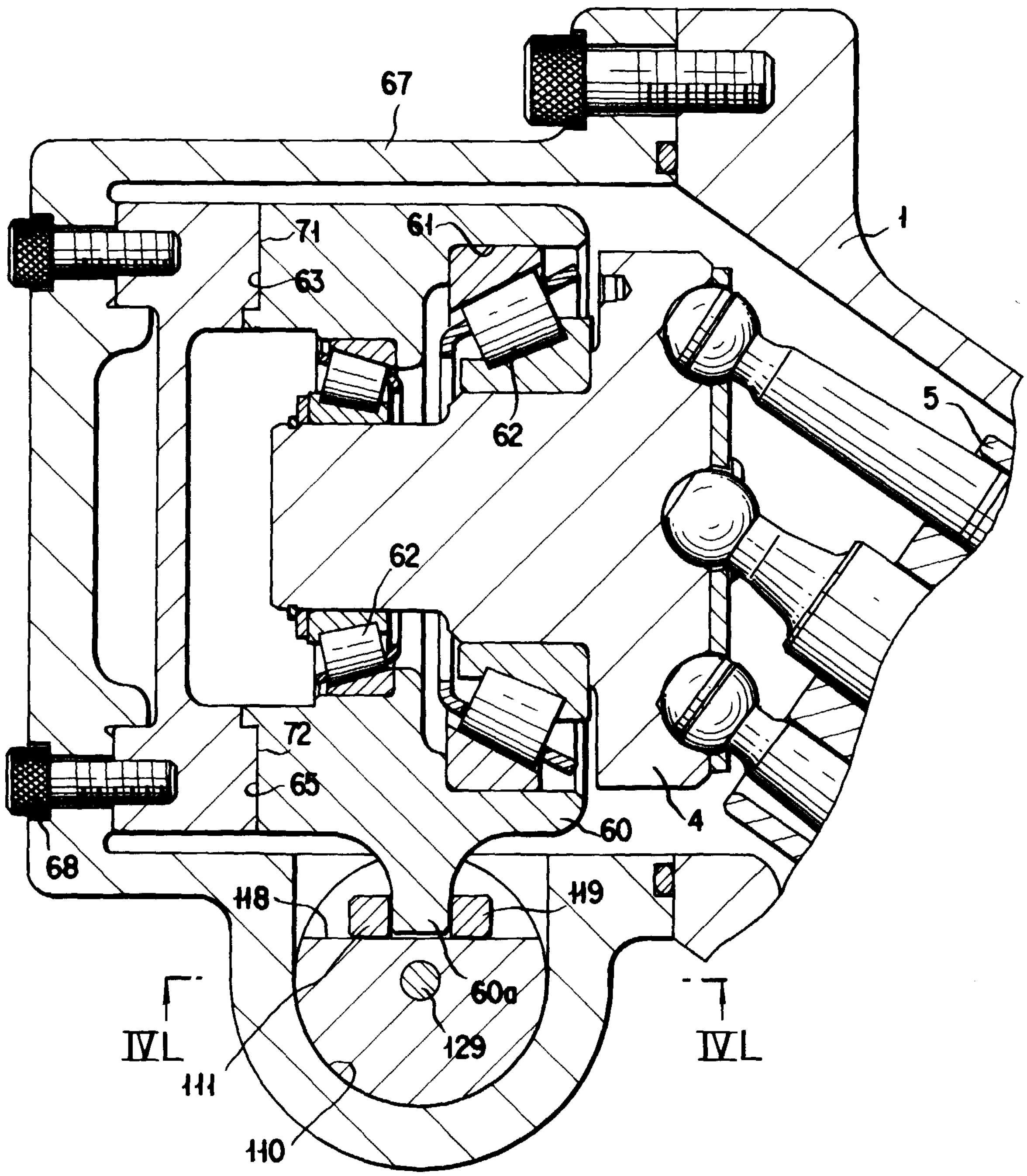
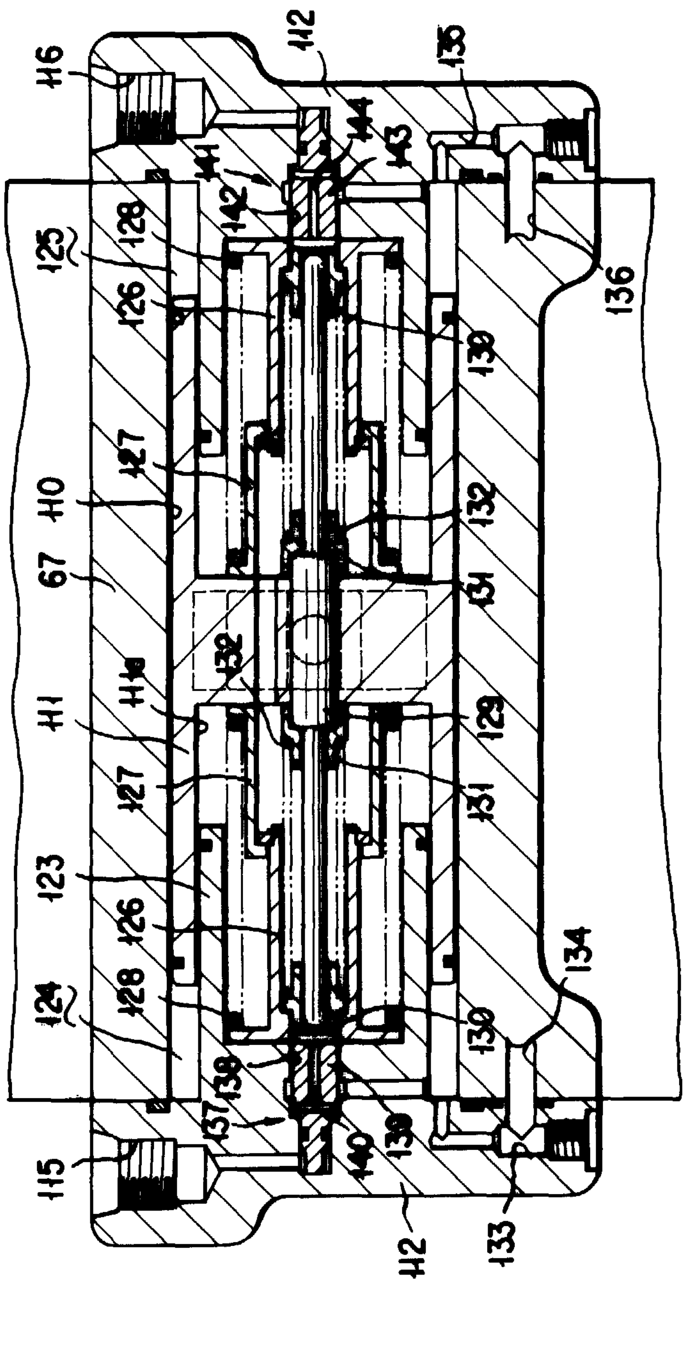


FIG. 46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123
124
134
139
137
138
140
115
133

FIG. 47

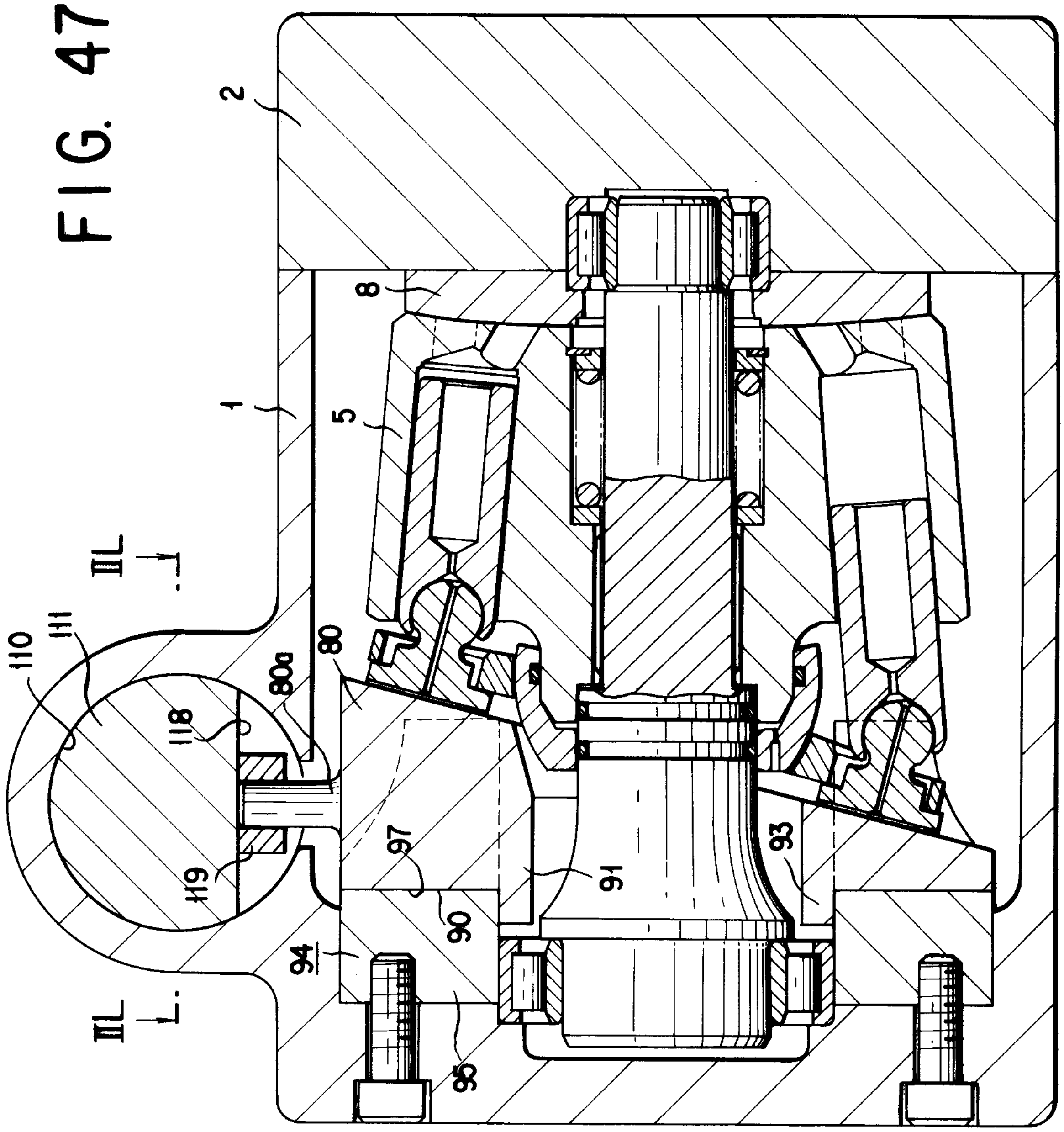


FIG. 48

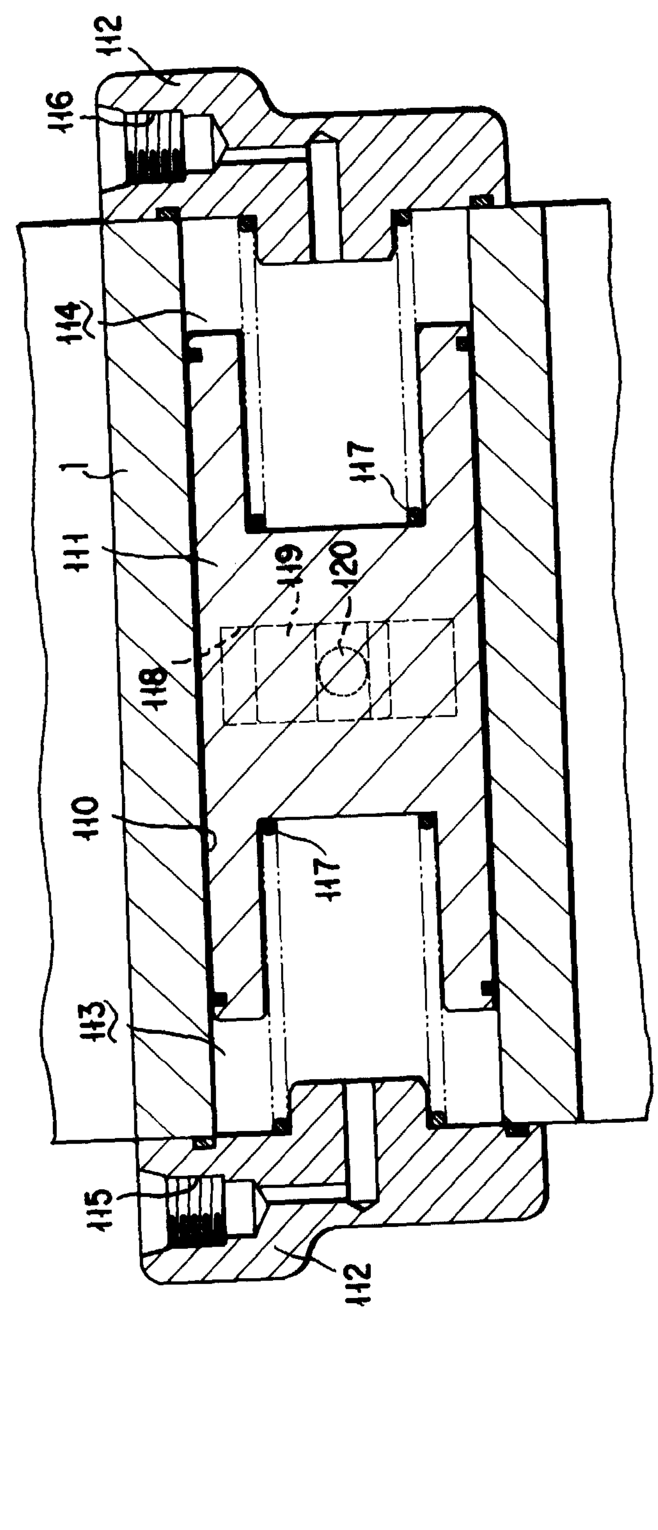


FIG. 49

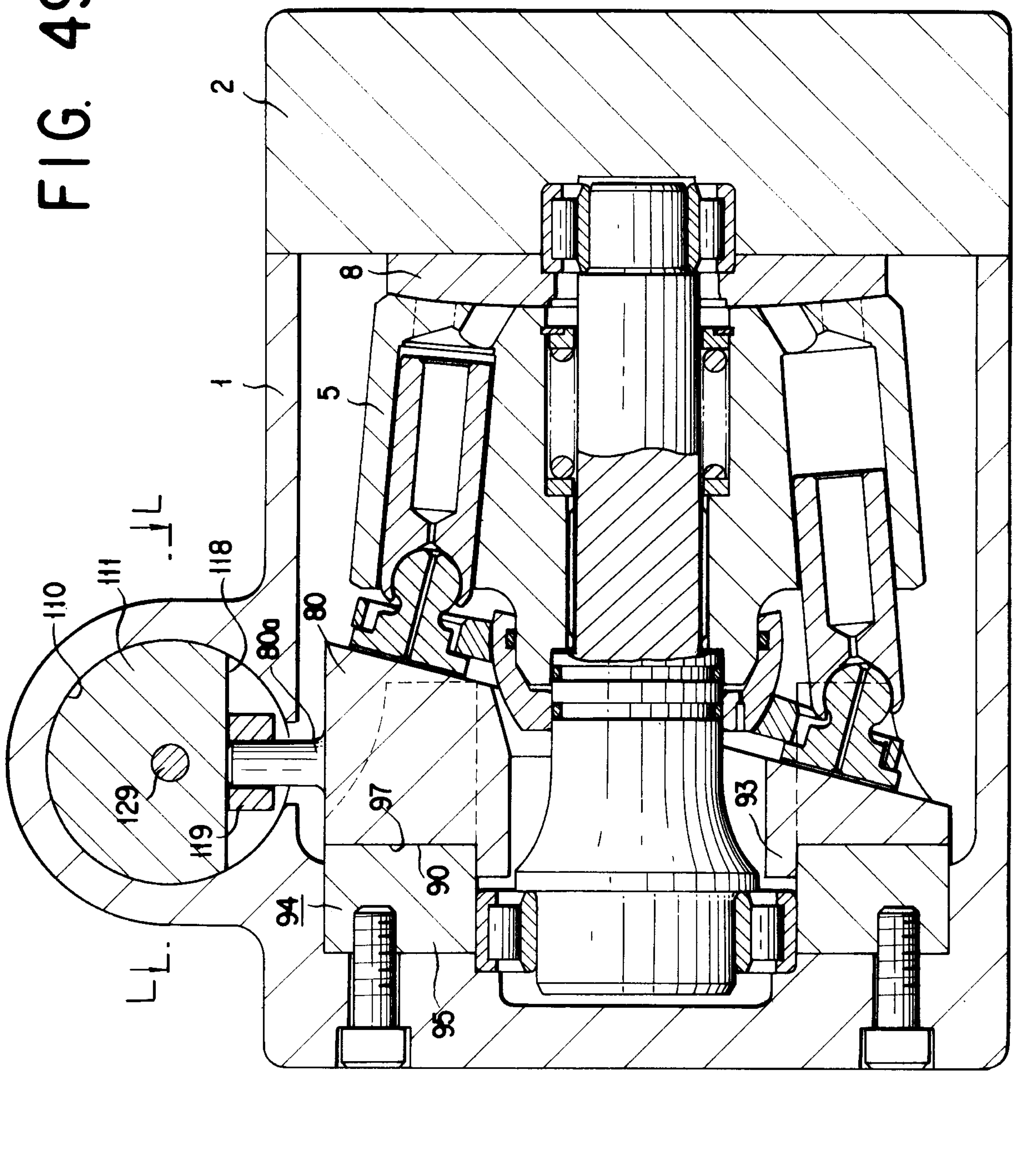
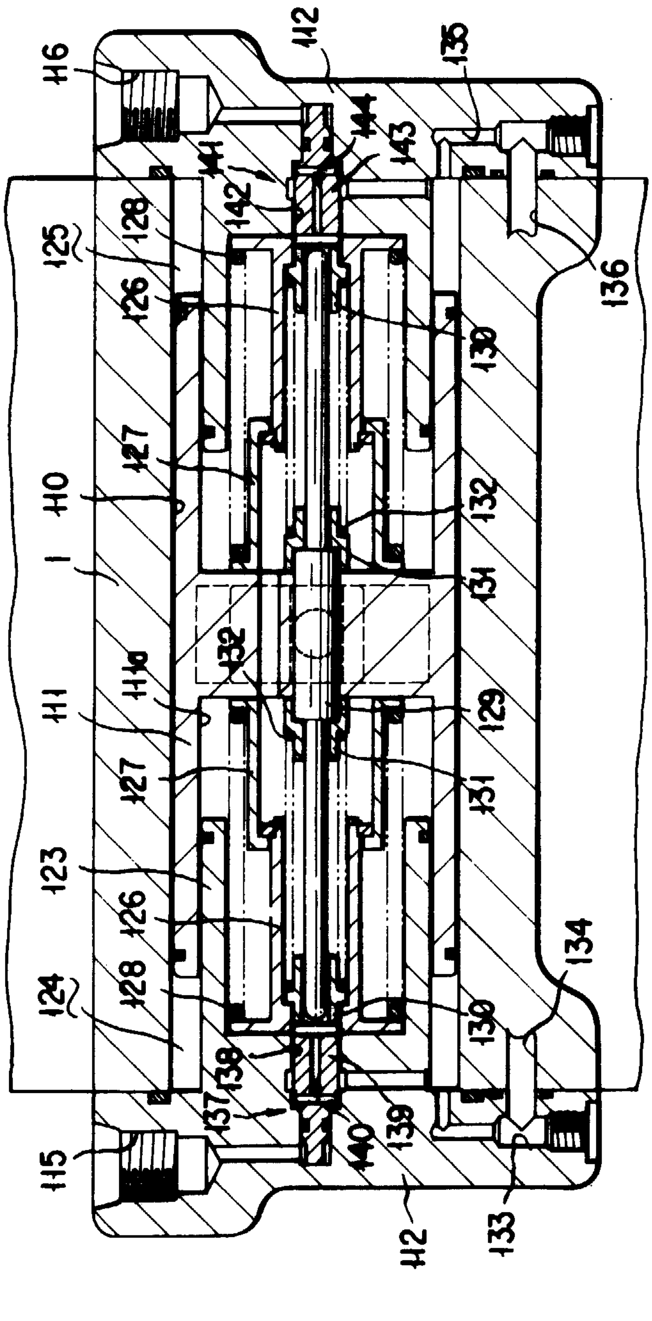


FIG. 50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115
133

FIG. 51

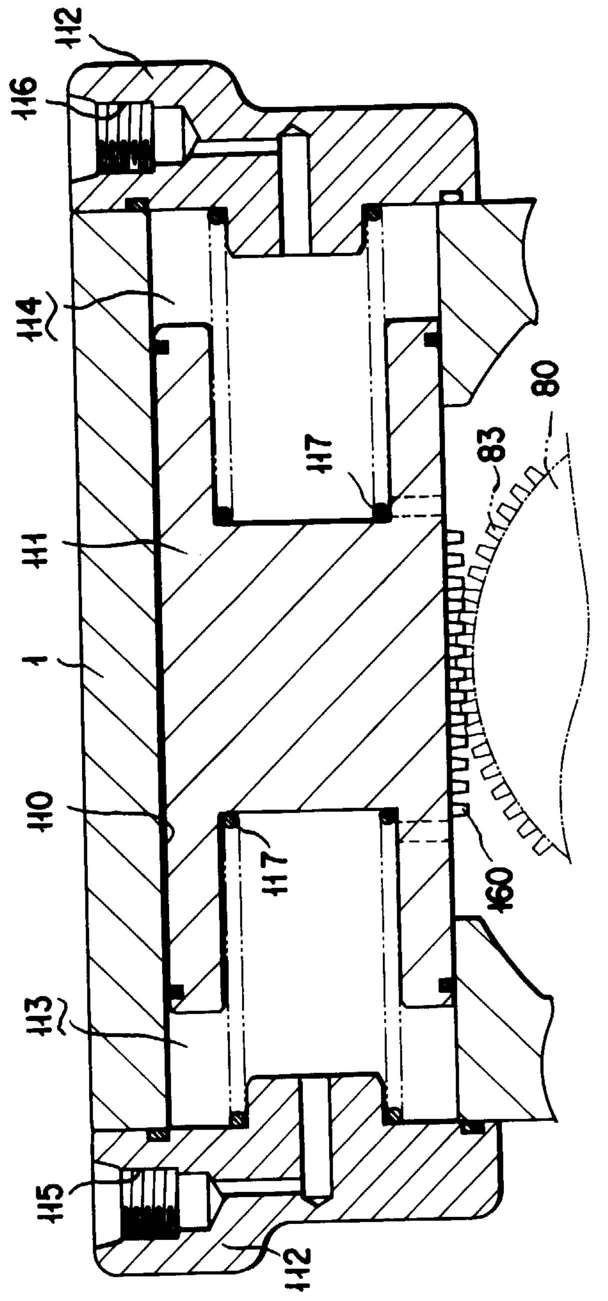
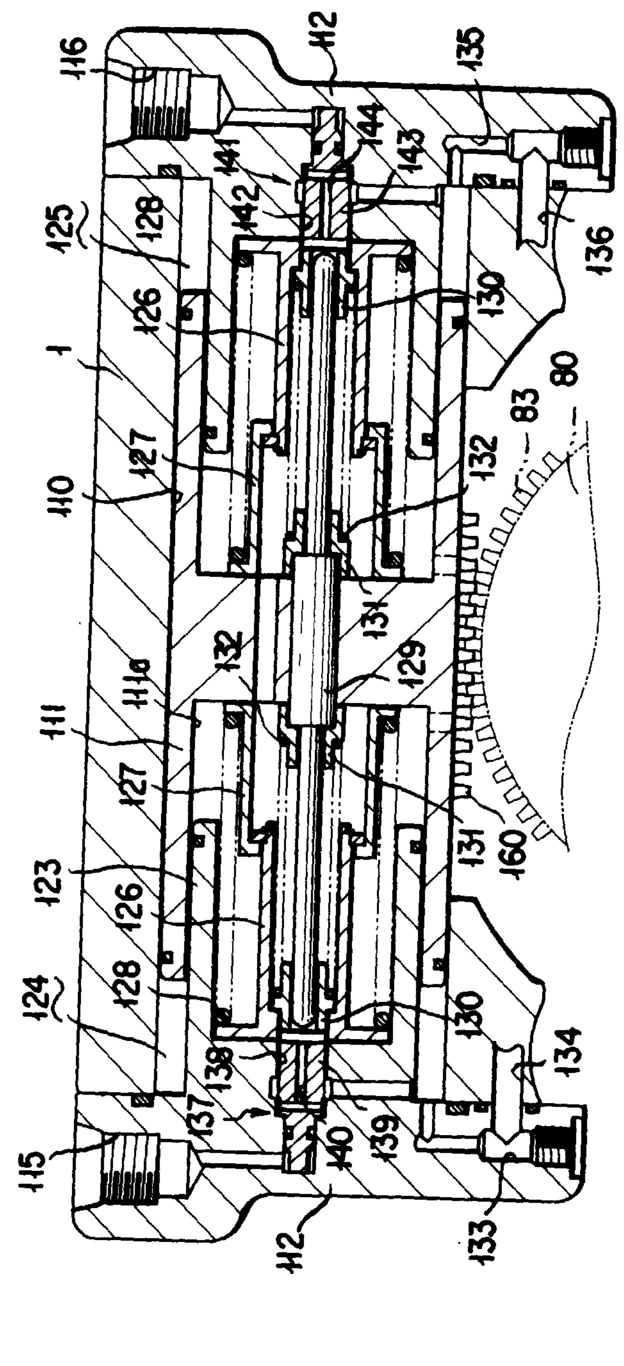


FIG. 52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115
133

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP97/03857

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 F04B1/24

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)

Int. Cl^6 F04B1/24, F04B1/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1925 - 1997
Kokai Jitsuyo Shinan Koho 1971 - 1997
Toroku Jitsuyo Shinan Koho 1994 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 58-200087, A (Moskovskoe Nauchno-proizvodstvennye Objedinenie po stroitelnom i Dorozhnom Mashinostroenie "VNIISTROIDORMASH"), November 21, 1983 (21. 11. 83) (Family: none)	1 - 5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"E" earlier document 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
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"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
December 2, 1997 (02. 12. 97)	January 7, 1998 (07. 01. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)