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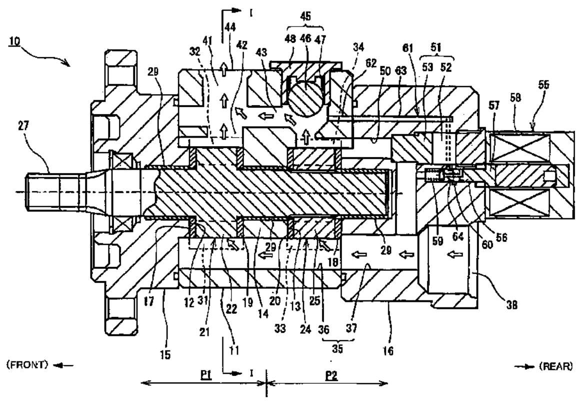
(54) **Valiable displacement type gear pump**

(57) A variable displacement type gear pump has gear chambers, one of which is a specific gear chamber. A suction passage (35,36,37) is formed in the housing so as to communicate with suction-side spaces (31,33). An outlet passage (41) communicates with discharge-side spaces (32,34). A return passage (50) returns the fluid discharged to the discharge-side space of the specific gear chamber to the suction passage. The return passage communicates with the suction passage at a confluence portion located upstream side of the suction-side space. An opening and closing valve (51) opens the return passage in a small displacement operational state. A check valve (45) is located between the discharge-side space of the specific gear chamber and the outlet passage for preventing the fluid discharged from the gear chamber other than the specific gear chamber from flowing into the discharge-side space of the specific gear chamber in the small displacement operational state.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a variable displacement type gear pump. Specifically, the variable displacement type gear pump has plural gear mechanisms including a drive gear and a driven gear, and the plural gear mechanisms are accommodated in plural gear chambers which are independently formed.

[0002] Generally, a gear pump includes a gear mechanism having a drive gear and a driven gear therein. The gear pump introduces fluid from the outside, pressurizes the fluid through a gear mechanism, and discharges the fluid to the outside. In case that hydraulic oil is utilized as the fluid for the gear pump, the gear pump is capable of operating a hydraulic equipment located in a hydraulic circuit. The gear pump has a simple structure, compared to other type pumps. Therefore, the operation and the maintenance are easily performed, and further, the manufacturing cost is low. In addition, the gear pump is not easily affected by foreign matters in the fluid. The gear pump is appropriate for downsizing and reducing weight. Thus, the gear pump is utilized, for example, as a hydraulic pump in an industrial vehicle such as a forklift truck, and is operated by a combustion engine for running the industrial vehicle.

[0003] The discharge flow rate of the gear pump is determined in accordance with the rotational speed of the gear pump, and it is difficult to change the flow rate irrespective to the rotational speed. When the gear pump is operated more than demands, the gear pump generates excessive flow rate, and performs excessive work as a gear pump. A variable displacement type gear pump with plural gear mechanisms has been proposed for achieving discharge displacement. The variable displacement type gear pump is shifted between two states. That is, in one state, a specific gear mechanism in the plural gear mechanisms discharges pressurized fluid to the outside, and in other state, the fluid is returned from the specific gear mechanism to the suction side, thereby achieving the discharge displacement.

[0004] Japanese Unexamined Patent Publication No. 2002-70757 discloses a double gear pump as a variable displacement type gear pump. In the double gear pump, a drive gear and two driven gears engaging with the drive gear are accommodated in a casing, and function as first and second pumps. An inlet and an outlet of the second gear pump are connected through an unload passage. An electromagnetic valve is provided in the unload passage. When the electromagnetic valve is closed, the first pump and the second pump are operated in parallel, thereby increasing the discharge displacement. In this state, the gear pump is in large displacement operational state. When the electromagnetic valve is opened, the second pump is unloaded, thereby decreasing the discharge displacement. In this state, the gear pump is in small displacement operational state.

[0005] In this type of variable displacement gear pump, the first pump and the second pump are located parallelly. The inlet and the outlet of the first pump are located reversely to the inlet and the outlet of the second pump, due to the rotational direction of the drive shaft. That is, the inlet of the first pump and the outlet of the second pump are located at one side of the drive shaft, and the outlet of the first pump and the inlet of the second pump are located at the other side. In the variable displacement type gear pump, a suction passage and a discharge passage are formed by connecting fluid passages at the inlet side and the outlet side of the first and the second pumps.

[0006] However, in the variable displacement type gear pump as disclosed in the above reference, the inlet and the outlet of the first pump are located reversely to the inlet and the outlet of the second pump. The structure is complicated if the pump body includes therein the suction and discharge passages formed by connecting the fluid passages at the inlet side and the outlet side. It is also difficult to form such a pump body with the complicated passages. Further, this kind of variable displacement gear pump increases the size of the whole equipment, since the unload passage is located outside the gear pump for returning the fluid from the second pump to the inlet. Further, the fluid in the unload passage is divided into the first the second pumps, and joins the flow delivered from the inlet of the gear pump at the outlet of each pump so as to be discharged from each outlet, when small displacement operation is continued. Thereby the fluid flowing through the unload passage continuously circulates through a specific part in the body of the gear pump, due to the continuation of the small displacement operation. That may cause a problem that the temperature distribution is uneven in the housing of the gear pump. The unevenness of the temperature distribution in the housing may result in deforming the housing and decreasing the operational efficiency of the gear pump.

[0007] The present invention is directed to provide a variable displacement type gear pump that has a suction passage by connecting passages at the suction side in a housing, and that prevents specific fluid from continuously circulating in a specific passage in a gear pump body, even if continuing small displacement operation.

SUMMARY OF THE INVENTION

[0008] In accordance with the present invention, a variable displacement type gear pump introduces and discharges fluid. The gear pump includes a housing, plural gear chambers having a gear mechanism, a suction-side space, and a discharge-side space. The plural gear chambers are formed in the housing, one of which is a specific gear chamber. The gear mechanism is accommodated in the respective gear chamber. The suction-side space is formed in the respective gear chamber. The discharge-side space is formed in the respective gear chamber. The gear pump further includes a suction passage, an outlet passage, a return passage, an opening and closing valve, and a check valve. The suction passage is formed in the housing so as to communicate with the suction-side spaces. The outlet passage communicates with the discharge-side spaces. The return passage returns the fluid discharged to the discharge-side space of the specific gear chamber to the suction passage. The return passage communicates with the suction passage at a confluence portion located upstream side of the suction-side space. The opening and closing valve is provided in the return passage, and opens the return passage in a small displacement operational state. The check valve is located between the discharge-side space of the specific gear chamber and the outlet passage for preventing the fluid discharged from the gear chamber other than the specific gear chamber from flowing into the discharge-side space of the specific gear chamber in the small displacement operational state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a longitudinal cross-sectional view of a variable displacement type gear pump according to a first preferred embodiment;

Fig. 2 is a cross-sectional view of the gear pump taken along the line I - I in Fig. 1;

Fig. 3 is a cross-sectional view of the gear pump taken along the line II - II in Fig. 2;

Fig. 4 is a cross-sectional view of the gear pump in small displacement operational state;

Fig. 5 is a partial cross-sectional view of a variable displacement type gear pump according to a second preferred embodiment;

Fig. 6 is a partial cross-sectional view of a variable displacement type gear pump according to a third preferred embodiment; and

Fig. 7 is a longitudinal cross-sectional view of a variable displacement type gear pump according to a fourth preferred embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] A first preferred embodiment according to the present invention will be described with reference to Figs. 1 through 4. Fig. 1 shows a variable displacement type gear pump 10 in large displacement operational state. As shown in Fig. 1, the variable displacement type gear pump 10 includes a body 11 which accommodates drive gears 22, 25 and driven gears 23, 26 therein. The body 11 has two spaces which are formed so as to extend from both axial end faces of the body 11. One space is a first gear chamber 12 and the other space is a second gear chamber 13. In this embodiment, the second gear chamber 13 serves as a specific gear chamber. A partition 14 is formed between the first gear chamber 12 and the second gear chamber 13.

[0011] A front housing 15 is joined to one end of the body 11. A rear housing 16 is joined to the other end of the body 11. In this embodiment, the body 11, the front housing 15, the rear housing 16 constitute a housing assembly. The body 11 and the front and the rear housings 15, 16 are joined by through bolts 30 with each other as shown in Fig. 2. It is noted that the front side where the front housing 15 is located corresponds to the left side in the drawings (referring to Figs. 1, 3, and 4). Similarly, the rear side where the rear housing 16 is located corresponds to the right side in the drawings. The front housing 15 closes the first gear chamber 12, and the rear housing 16 closes the second gear chamber 13. A side plate 17 is interposed between the first gear chamber 12 and the end face of the front housing 15, and a side plate 18 is interposed between the second gear chamber 13 and the end face of the rear housing 16, Similarly, a side plate 19 is interposed between the first gear chamber 12 and the partition 14, and a side plate 20 is interposed between the second gear chamber 13 and the partition 14.

[0012] The drive gear 22 and the driven gear 23 at the front side are externally engaged with each other so as to form a first gear mechanism 21. The first gear mechanism 21 is accommodated in the first gear chamber 12 as shown in Figs. 2 and 3. The drive gear 25 and the driven gear 26 at the rear side are externally engaged with each other so as to form a second gear mechanism 24. The second gear mechanism 24 is accommodated in the second gear chamber 13 as shown in Fig. 3. The front drive gear 22 accommodated in the first gear chamber 12 is formed integrally with a drive shaft 27. The drive gear 22 is coaxial with the drive shaft 27. The rear drive gear 25 is fitted to the drive shaft 27 by way of spline coupling or serration coupling. The drive gear 25 is coaxial with the drive shaft 27. That is, the drive gears 22, 25 are formed so as to have a common rotational axis.

[0013] The drive shaft 27 extends through the side plates 17, 18, 19, 20 and the partition 14 into the front housing 15 and the rear housing 16. The drive shaft 27 is rotatably supported by the body 11, the front housing 15, and the rear housing 16 through a bearing 29. One end of the drive shaft 27 extends out of the front housing 15 so as to be connected to an external drive source which is not shown, and receives driving force from the external drive source.

[0014] The front driven gear 23 is formed integrally with a driven shaft 28, and is coaxial with the driven shaft 28. The rear driven gear 26 is fitted to the driven shaft 28 by way of spline coupling or serration coupling. The driven gear 26 is coaxial with the driven shaft 28. Similar to the drive shaft 27, the driven shaft 28 extends into the front housing 15 and the rear housing 16. The driven shaft 28 is supported by the body 11, the front housing 15 and the rear housing 16 through an another bearing 29. The driven gears 23, 26 are formed so as to have a common rotational axis. Unlike the drive shaft 27, the end of the driven shaft 28 does not extend out of the front housing 15.

[0015] As shown in Fig. 2, the first gear chamber 12 includes a suction-side space 31 and a discharge-side space 32 defined by the inner surface of the first gear chamber 12, the drive gear 22, and the driven gear 23. The suction-side space 31 is formed at the suction side for introducing oil as a fluid. The discharge-side space 32 is formed at the discharge side for discharging the oil. Similar to the first gear chamber 12, a suction-side space 33 and a discharge-side space 34 are defined in the second gear chamber 13 as shown in Fig. 1.

[0016] A front suction passage 36 is formed in the body 11 along the rotational axes of the drive shaft 27 and the driven shaft 28. The oil is introduced into the first and the second gear chambers 12, 13 through the front suction passage 36. A rear suction passage 37 is formed in the rear housing 16 and communicates with the front suction passage 36. The rear suction passage 37 has an inlet 38 which is open at the axial end face of the rear housing 16. The inlet 38 is in communication with the outside. The front suction passage 36 and the rear suction passage 37 have circular cross-sectional surfaces, respectively. The front and rear suction passages 36, 37 are linearly connected with each other. The front suction passage 36 and the rear suction passage 37 constitute a suction passage 35. The suction passage 35 is communicated with the suction-side spaces 31, 33. The oil from the outside of the variable displacement type gear pump 10 flows into the first and the second gear chambers 12, 13 through the suction passage 35.

[0017] A front discharge passage 42 and a rear discharge passage 43 are formed in the body 11 for discharging the oil pressurized in the gear chambers 12, 13 to the outside. The front discharge passage 42 extends from the discharge-side space 32 of the first gear chamber 12. The rear discharge passage 43 extends from the discharge-side space 34 of the second gear chamber 13. The front and rear discharge passages 42, 43 are connected with each other so as to flow into a single outlet passage 41 downstream thereof inside the body 11. Thereby the outlet passage 41 communicates with the discharge-side spaces 32, 34 through the front and rear discharge passages 42, 43. Further, the outlet passage 41 has an outlet 44 which is in communication with the outside. The oil is discharged to the outside of the gear pump 10 through the outlet passage 41 and the outlet 44, and is supplied to a hydraulic circuit which is connected to a hydraulic device, which is not shown. A check valve 45 is provided in the rear discharge passage 43 in the body 11 and is located between the discharge-side space 34 of the specific gear chamber 13 and the outlet passage 41. The check valve 45 serves to prevent the oil discharged from the gear chamber 12, which is other than the specific gear chamber 13 (second gear chamber 13), from flowing into the discharge-side space 34 of the specific gear chamber 13 in a small displacement state.

[0018] The check valve 45 includes a ball-shaped valve body 46, a coil spring 47, and a support member 48. The valve body 46 opens and closes the rear discharge passage 43. The coil spring 47 is an urging device for urging the valve body 46. The support member 48 supports the coil spring 47. The coil spring 47 applies urging force to the valve body 46 in the direction to close the rear discharge passage 43. The valve body 46 is moved in the direction to open the rear discharge passage 43 against the urging force of the coil spring 47 when the pressure in the rear discharge passage 43 is equal to or greater than a predetermined value. The valve body 46 closes the rear discharge passage 43 by the urging force of the coil spring 47 when the pressure in the rear discharge passage 43 is below the predetermined value. The urging force of the coil spring 47 may be set small, since the valve body 46 is urged to a seat surface in the support member 48 by the pressure difference. The form of the valve body 46 is not limited to the ball-shape, and may be a conical shape.

[0019] The rear housing 16 includes a return passage 50. The return passage 50 communicates with the rear discharge passage 43, and also communicates with the rear suction passage 37. That is, the return passage 50 communicates with the suction passage 35 and the discharge-side space 34 of the second gear chamber 13 so as to return the oil discharged to the discharge-side space 34 to the suction passage 35. An opening and closing valve 51 is provided in the return passage 50 to open and close the return passage 50. The valve 51 has a piston mechanism in which a cylindrical piston 53 is slidably accommodated in a hollow cylinder 52 with a bottom.

[0020] The valve 51 opens and closes the return passage 50 by the sliding movement of the piston 53 in the cylinder 52. The sliding movement of the piston 53 is performed by the pressure difference applied to the both end faces of the piston 53. That is, the sliding movement of the piston 53 is performed by the pressure difference between the pressure in the space at the side of the return passage 50 and the pressure in the space in the cylinder 52 at the opposite side of the piston 53.

[0021] In this embodiment, the pressure difference applied on the both end faces of the piston 53 is controlled by the actuation of an electromagnetic valve 55 in the rear housing 16. The electromagnetic valve 55 includes a spool 57, a coil 58, and a coil spring 59. The spool 57 slides in a spool hole 56 formed in the rear housing 16.

The coil 58 moves the spool 57 frontward. The coil spring 59 is an urging device for urging the spool 57. It is noted that "upstream side of the return passage 50" corresponds to the part of the return passage 50 between the valve 51 and the rear discharge passage 43. Similarly, "downstream side of the return passage 50" corresponds to the part of the return passage 50 between the valve 51 and the rear suction passage 37. The spool hole 56 is in communication with the downstream side of the return passage 50. The spool 57 includes a suction-pressure communication passage 60 for communicating the return passage 50 to the cylinder 52. When the coil 58 is excited, the spool 57 is moved frontward. When the coil 58 is de-excited, the spool 57 is moved rearward by the coil spring 59.

[0022] A discharge-pressure communication passage 61 is formed in the body 11 and the rear housing 16 for supplying the oil under discharge pressure from the rear discharge passage 43 to the spool hole 56. The discharge-pressure communication passage 61 includes passages 62, 63 and a groove 64. The groove 64 is formed at the outer periphery of the spool 57. When the coil 58 is de-excited and the spool 57 is at the rear position, the discharge pressure in the rear discharge passage 43 is applied to the cylinder 52 through the discharge-pressure communication passage 61. When the coil 58 is excited and the spool 57 is in the front position, the suction-pressure communication passage 60 releases oil under discharge pressure in the cylinder 52 to the return passage 50. When the pressure in the cylinder 52 becomes to suction pressure due to the excitation of the coil 58, the piston 53 opens the return passage 50. When the pressure in the cylinder 52 becomes to discharge pressure due to the de-excitation of the coil 58, the piston 53 closes the return passage 50.

[0023] The following will describe the operation of the variable displacement type gear pump 10 of the first preferred embodiment according to the present invention. As shown in Fig. 1, the first gear mechanism 21 and the first gear chamber 12 at the front side constitute a front gear pump portion P1. The second gear mechanism 24 and the second gear chamber 13 at the rear side constitute a rear gear pump portion P2. The front gear pump portion P1 and the rear gear pump portion P2 respectively have 50 percent of the entire discharge displacement of the variable displacement type gear pump 10.

[0024] The following will describe the operation of the drive gear 22 and the driven gear 23 in the front gear pump portion P1. When the driving force is applied to the drive shaft 27 from the outside, the drive gear 22 is rotated in one direction as shown in Fig. 2. According to the rotation of the drive gear 22, the driven gear 23 engaging with the drive gear 22 is rotated with the driven shaft 28 in the direction opposite to the rotational direction of the drive gear 22. When the drive gear 22 and the driven gear 23 are rotated while being engaged with each other, oil is introduced into the suction-side space 31 from the suction passage 35.

[0025] The oil introduced in the suction-side space 31 is confined in a space defined by teeth of the drive gear 22 and the inner surface of the first gear chamber 12, and also in a space defined by teeth of the driven gear 23 and the inner surface of the first gear chamber 12. The oil confined in the spaces is transferred along the inner surface of the first gear chamber 12 in the rotational direction of the drive gear 22 and the rotational direction of the driven gear 23, respectively. The oil confined in the spaces is discharged to the discharge-side space 32. The oil in the discharge-side space 32 is discharged to the outside of the gear pump 10 through the front discharge passage 42, the outlet passage 41, and the outlet 44, and delivered to a hydraulic device not shown to operate the hydraulic device. The discharge pressure is increased in accordance with the load of the hydraulic device.

[0026] In the front gear pump portion P1, when the driving force is applied to the drive shaft 27 from the outside, the drive gear 22 and the driven gear 23 in the first gear chamber 12 are driven, and the oil is discharged to the discharge-side space 32. The discharged oil is supplied to the front discharge passage 42. In the rear gear pump portion P2, when the driving force is applied to the drive shaft 27 from the outside, the drive gear 25 and the driven gear 26 in the second gear chamber 13 are driven, and the oil is discharged to the discharge-side space 34.

[0027] When the coil 58 of the electromagnetic valve 55 is not excited, the spool 57 is located in the rear position, by receiving the urging force of the coil spring 59. When the spool 57 is located in the rear position, the discharge-pressure communication passage 61 is communicated with the cylinder 52 of the valve 51. The communication between the suction-pressure communication passage 60 and the cylinder 52 is shut off. Therefore, the oil is introduced from the rear discharge passage 43 through the discharge-pressure communication passage 61, and the cylinder 52 is filled with the oil under the discharge pressure. In the state where the piston 53 does not close the return passage 50 yet, the pressure in the return passage 50 communicating with the suction passage 35 is lower than the pressure in the cylinder 52, and the piston 53 is moved in the direction to close the return passage 50.

[0028] When the piston 53 closes the return passage 50, the pressure in the discharge-side space 34 receiving the oil discharged from the rear gear pump portion P2 is increased, and the valve body 46 of the check valve 45 opens the rear discharge passage 43. Thereby the oil discharged from the rear gear pump portion P2 is supplied to the rear discharge passage 43 and the return passage 50. As shown in Fig. 1, the oil flows from the rear discharge passage 43 to the outlet passage 41, and does not flow to the suction passage 35 through the return passage 50. In this state, the oil discharged from the front gear pump portion P1 and the rear gear pump portion P2 joins together, and is delivered to the outside of the variable displacement type gear pump 10 through the outlet passage 41. Therefore, in this state, the discharge displacement of the variable displacement type gear pump 10 is 100 percent, and the gear pump 10 is in the large displacement operational state. When the gear pump 10 is utilized in a material handling device of a forklift truck, the large displacement operational state of 100 percent may be set to correspond to the load lifting-up state. The piston 53 has a larger diameter at the side adjacent to the cylinder 52 (rear side), and is reliably urged frontward to close the return passage 50, even when the pressures at the front and rear sides of the piston 53 are equal with each other.

[0029] Then, when the coil 58 of the electromagnetic valve 55 is excited, the spool 57 receives the frontward force overcoming the urging force of the coil spring 59, and is moved frontward. When the spool 57 is located in the front position, the communication between the discharge-pressure communication passage 61 and the cylinder 52 is shut off. In this state, the spool hole 56, the suction-pressure communication passage 60, and the cylinder 52 are communicated with each other. Thereby the pressure in the cylinder 52 of the valve 51 is decreased from the discharge pressure to the suction pressure. Since the upstream side of the return passage 50 equals the discharge pressure, the piston 53 is moved into the cylinder 52 by receiving the pressure difference when the pressure in the cylinder 52 becomes the suction pressure. By the retreat of the piston 53 into the cylinder 52, the return passage 50 becomes to the opened state.

[0030] Since the pressure at the upstream side of the return passage 50 is decreased, the valve body 46 closes the rear discharge passage 43 by the urging force of the coil spring 47 of the check valve 45. As shown in Fig. 4, when the check valve 45 closes the rear discharge passage 43 and the valve 51 opens the return passage 50, only the oil discharged from the front gear pump portion P1 is delivered to the outside through the outlet passage 41. The oil discharged from the rear gear pump portion P2 is supplied to the return passage 50. Then the oil joins the upstream side of the suction passage 35 at a confluence portion, that is, between the inlet 38 of the suction passage 35 and the suction-side space 33. In other words, the confluence portion is located upstream side of the suction-side spaces 31, 33 which communicate with the suction passage 35 in the gear pump 10. Therefore, in this state, the discharge displacement of the variable displacement type gear pump 10 gets to 50 percent, and is in the small displacement operational state. In this embodiment, the state where the electromagnetic valve 55 is activated is set as the 50-percent discharge displacement. However, the location of the groove 64 and the suction-pressure communication passage 60 in the spool 57 may be modified so that a state activating the electromagnetic valve 55 is set as 100-percent discharge displacement, while a state deactivating the electromagnetic valve 55 is set as 50-percent discharge displacement.

[0031] When the variable displacement type gear pump 10 is operated in the small displacement state, the oil from the return passage 50 joins the upstream side of the suction passage 35 at the confluence portion. The oil in the suction passage 35 is supplied to the front gear pump portion P1 and the rear gear pump portion P2. The oil in the suction passage 35 is in the state where newly introduced oil from the inlet 38 is mixed with the returned oil from the return passage 50. That is, even if the small displacement operation is continued, the oil flowing through the return passage 50 does not continuously circulate in the rear gear pump portion P2 and the return passage 50. The suction passage 35 is formed in the body 11 along the rotational axes of the drive shaft 27 and the driven shaft 28, and it is not required to form a suction passage 35 outside of the body 11.

[0032] The first preferred embodiment has the following advantageous effects.

(1) Even if the variable displacement type gear pump 10 continues small displacement operation, the returned oil from the return passage 50 is mixed with newly introduced oil at the upstream side of the suction passage 35. Therefore, the specific oil in the return passage 50 does not continue to circulate through a specific passage in the front gear pump portion P1 and the rear gear pump portion P2. Therefore, unevenness of temperature distribution in the body 11 and the housings 15, 16 is prevented or suppressed.

(2) The suction passage 35 is formed in the housing assembly along the rotational axes of the drive shaft 27 and the driven shaft 28, and it is not required to form a suction passage outside of the housing assembly. Therefore, the variable displacement type gear pump 10 does not need to prepare an additional piping member for providing a suction passage outside of the gear pump 10. The gear pump 10 does not need an oil piping outside of the housing assembly, and the pressure loss hardly occurs in the suction passage 35, since the suction passage 35 is linear shape along the rotational axes of the drive shaft 27 and the driven shaft 28.

(3) Since the return passage 50 is formed in the body 11 and the rear housing 16, the variable displacement type gear pump 10 does not need a return passage outside of the gear pump 10. Therefore, the gear pump 10 does not need an additional piping member for providing a return passage outside of the gear pump 10. Further, since the outlet passage 41 is formed in the body 11 so as to communicate with the front and rear discharge passages 42, 43, the gear pump 10 does not need an outlet passage downstream of the confluence portion of the discharge passages 42, 43 outside of the gear pump 10.

(4) With the operation of the electromagnetic valve

55, the return passage 50 is opened and closed by the valve 51. In accordance with the opening and closing of the return passage 50 by the valve 51, the rear discharge passage 43 is opened and closed by the check valve 45, and the discharge displacement of the gear pump 10 is controlled.

[0033] The second preferred embodiment will be described according to Fig. 5. The gear pump of the second preferred embodiment differs from that of the first embodiment in that the structure of the return passage is modified, and the rest of the structure of the gear pump of the second embodiment is substantially the same as the first embodiment. Therefore, like or same parts or elements will be referred to by the same reference numerals as those in the first embodiment, and the description thereof will be omitted.

[0034] As shown in Fig. 5, a variable displacement type gear pump 71 has a return passage 72. The return passage 72 connects the rear discharge passage 43 and the rear suction passage 37. The downstream side of the return passage 72 is formed substantially linearly in the radial direction in the roar housing 16. The return passage 72 communicates with the upstream side of the suction passage 35 at a confluence portion. A guide portion 73 is formed at the confluence portion, or at the vicinity of the end of the return passage 72 in the rear housing 16 so as to incline the return passage 72 frontward. The inclination at the vicinity of the end of the return passage 72 by the guide portion 73 is in the direction to increase the flow speed of the newly introduced oil in the suction passage 35 by introducing the oil from the return passage 72 into the suction passage 35.

[0035] According to the variable displacement type gear pump 71 of this embodiment, the oil discharged from the rear gear pump portion P2 at the small displacement operation flows through the return passage 72. The oil flowing through the return passage 72 joins the newly introduced oil flowing through the suction passage 35. At this time, the oil in the return passage 72 flows in the direction perpendicular to the oil flow in the suction passage 35, and then is guided by the guide portion 73 so as to flow frontward. The oil guided by the guide portion 73 joins the oil in the suction passage 35 so as to flow in the direction to increase the speed of the oil flow. In this embodiment, the guide portion 73 guides the oil of the return passage 72 into the suction passage 35 so as to increase the speed of the oil flow in the suction passage 35 at the small displacement operation. Thereby the oil flowing in the return passage 72 can be effectively mixed with the newly introduced oil into the suction passage 35.

[0036] The following will describe a third preferred embodiment with reference to Fig. 6. Fig. 6 is a partially enlarged cross-sectional view of a variable displacement type gear pump 81 according to the third preferred embodiment, and taken along a return passage 82 in the rear housing 16. The gear pump of the third preferred embodiment differs from that of the first embodiment in that the structure of the return passage is modified, and the rest of the structure of the gear pump of the third embodiment is substantially the same as the first embodiment. Therefore, like or same parts or elements will be referred to by the same reference numerals as those in the first embodiment, and the description thereof will be omitted.

[0037] As shown in Fig. 6, the suction passage 35 in the variable displacement type gear pump 81 has a circular cross-sectional surface. Specifically, the rear suction passage 37 in the rear housing 16 has a circular cross-sectional surface. The rear discharge passage 43 and the suction passage 35 are connected by the return passage 82. The return passage 82 communicates with the suction passage 35 at a confluence portion located the upstream side of the suction passage 35. The confluence portion of the return passage 82 is formed by connecting the return passage 82 in the tangent direction with respect to the circular cross-sectional surface of the rear suction passage 37, as shown in Fig. 6. With the construction where the return passage 82 is connected to the rear suction passage 37 in the tangent direction, the oil flowing through the return passage 82 enhances the swirling flow of the oil flowing through the suction passage 35.

[0038] According to the variable displacement type gear pump 81 of this embodiment, the return passage 82 is connected to the suction passage 35 in the tangent direction with respect to the circular cross-sectional surface of the suction passage 35. The oil flowing through the return passage 82 at the small displacement operation is introduced into the suction passage 35 along the inner circumferential surface of the suction passage 35. The oil joining together while being guided along the inner circumferential surface of the suction passage 35 enhances the swirling flow in the suction passage 35. With the swirling flow in the suction passage 35, the newly introduced oil in the suction passage 35 is effectively mixed with the oil from the return passage 82.

[0039] The following will describe a variable displacement type gear pump of a fourth preferred embodiment according to the present invention with reference to Figs. 7. The gear pump of the fourth preferred embodiment differs from that of the first embodiment in that the structure of the return passage is modified, and the rest of the structure of the gear pump of the fourth embodiment is substantially the same as the first embodiment. Therefore, like or same parts or elements will be referred to by the same reference numerals as those in the first embodiment, and the description thereof will be omitted.

[0040] Fig. 7 shows a variable displacement type gear pump 91 in small displacement operational state. The gear pump 91 has a return passage 92 which connects the rear discharge passage 43 and the rear suction passage 37. The return passage 92 is connected to the upstream side of the suction passage 35 so as to form a confluence portion. The confluence portion of the return passage 92 with the suction passage 35 has a parallel guide portion 94 at the end of the return passage 92 adjacent the suction passage 35. The parallel guide portion 94 is formed so as to guide the oil flow from the return passage 92 frontward and parallel to the suction passage 35. The oil from the return passage 92 joins parallely the oil flowing through the suction passage 35.

[0041] When the coil 58 of the electromagnetic valve 55 is not excited, the piston 53 is moved in the direction to close the return passage 92. When the piston 53 closes the return passage 92, the pressure in the discharge-side space 34 increases, and the valve body 46 of the check valve 45 opens the rear discharge passage 43. Therefore, the oil discharged from the rear gear pump portion P2 is supplied to the rear discharge passage 43 and the return passage 92. The oil flows from the rear discharge passage 43 to the outlet passage 41. The oil from the front gear pump portion P1 joins the oil flow from the rear gear pump portion P2. In this state, the discharge displacement of the variable displacement type gear pump 91 is 100 percent, and is in the large displacement operational state.

[0042] When the coil 58 of the electromagnetic valve 55 is excited, the piston 53 is retreated into the cylinder 52, and the return passage 92 is in the fully opened state. Further, the pressure at the upstream side of the return passage 92 decreases, and the valve body 46 closes the rear discharge passage 43 due to the urging force of the coil spring 47 of the check valve 45. In the state where the check valve 45 closes the rear discharge passage 43 and the valve 51 opens the return passage 92, only the oil discharged from the front gear pump portion P1 is discharged to the outside through the outlet passage 41. The oil discharged from the rear gear pump portion P2 is supplied to the return passage 92, and joins the upstream side of the suction passage 35. Therefore, in this case, the discharge displacement of the variable displacement type gear pump 91 is 50 percent, and is in the small displacement operational state.

[0043] When the variable displacement type gear pump 91 is in the small displacement operational state, the oil from the return passage 92 joins the upstream side of the suction passage 35. The oil flow from the return passage 92 is parallel to the oil flow in the suction passage 35. Since the oil flow from the return passage 92 does not have a velocity component in the traverse direction with respect to the suction passage 35, the dynamic pressure of the oil from the return passage 92 is effectively introduced into the suction-side space 31 for increasing the pressure therein.

[0044] By increasing the pressure in the suction-side space 31 at maximum, the pressure difference between the discharge-side space 32 and the suction-side space 31 at the front side is going to be decreased, compared to a case without the guide portion 94. The decreased pressure difference between the spaces 31, 32 affects the load applied on the front gear pump portion P1 being reduced.

[0045] Generally, oil is trapped in a trap region at the engaging portion of the drive gear 22 and the driven gear 23 by the engagement of the gears 22, 23 at the front side. At the small displacement operation, the pressure difference between the discharge-side space 32 and the suction-side space 31 at the front side is going to be reduced, compared to a case where energy loss is occurred due to the confluence. Thereby the oil leakage from the trap region to the suction passage 35 is reduced, compared to a case where the pressure difference between the spaces 31, 32 is large. Similarly, oil leakage from the clearance between the gears 22, 23 and the first gear chamber 12 at the front side into the suction passage 35 is small, compared to a case where the pressure difference between the spaces 31, 32 is large. The reduction of oil leakage is effective in increasing the volume efficiency. Further, due to the pressure difference between the spaces 31, 32, the load applied from the drive shaft 27 and the driven shaft 28 to the bearings 29 is reduced. Thereby the sliding friction between the shafts 27, 28 and the bearings 29 is reduced and the mechanical efficiency is improved.

[0046] Generally, when a gear pump is driven, oil in an oil storage tank in atmospheric state is introduced into a suction passage of the gear pump. The oil at the time of being introduced into the suction passage is affected by the pressure loss due to the piping, and becomes low-pressure state lower than the atmospheric pressure. Specifically, when the gear pump is far from the storage tank and requires a long piping, the piping has severe pressure loss. When oil is in low-pressure state lower than the atmospheric pressure, cavitation may occur in the oil. The generated cavitation bubbles may be collapsed to cause shock when the pressure in the gear pump is increased, and thereby cause problems such as noise, vibration, and erosion of the pump parts. At the small displacement operation, the outflow of the oil from the return passage 92 joins the oil in the suction passage 35 flowing in the same direction, and the pressure of the oil in the suction passage 35 downstream side of the confluence portion is increased. Due to the pressure increase of the oil in the suction passage 35, the cavitation in the oil is in advance prevented.

[0047] The fourth preferred embodiment has the following advantageous effects.

(5) In the gear pump 91, the flow direction of the outflow from the return passage 92 is coincident with that of the suction passage 35 at the vicinity of the confluence portion. Therefore, the oil in the front suction-side space 31 is pressurized maximally due to the confluence of the oil flowing through the return passage 92. Thereby, the pressure difference between the discharge-side space 32 and the suction-side space 31 at the front side decreases, compared to a case where the flow directions are not coincident at the vicinity of the confluence portion. The pressure difference between the spaces 31, 32 is reduced, and the work load of the front gear pump portion P1

is reduced.

(6) In the gear pump 91, the pressure difference between the discharge-side space 32 and the suction-side space 31 at the front side is reduced, compared to a case where the flow directions at the vicinity of the confluence portion is not coincident. The gear pump 91 reduces oil leakage from the trap region formed by the engagement of the gears 22, 23 at the front side, and from the first gear chamber 12, compared to a case having large pressure difference between the spaces 31, 32. Thereby the volume efficiency as a gear pump is improved. Further, the load applied from the drive shaft 27 and the driven shaft 28 to the bearings 29 is reduced, and the sliding friction between the shafts 27, 28 and the bearings 29 is reduced thereby improving the mechanical efficiency.

(7) At the small displacement operation, the outflow of the oil from the return passage 92 joins parallelly the oil flow in the suction passage 35. Thereby the dynamic pressure of the oil in the suction passage 35 downstream side of the confluence portion is effectively increased, and the cavitation in the oil of the suction passage 35 is in advance prevented. Thereby, noise, vibration, and erosion of the pump parts are prevented.

[0048] The present invention is not limited to the above-described embodiments and may be modified into following alternative embodiments within the scope of the invention.

[0049] In the first through fourth preferred embodiments, when the maximum displacement of the variable displacement type gear pump is set as 100 percent, and the displacement of each of the front and rear gear pump portions is set as 50 percent. However, the performance of the gear pump portions is not limited to 50 percent. The performance of the each gear pump portion is set appropriately, for example, as 70 percent and 30 percent, depending on the condition.

[0050] In the first through fourth preferred embodiments, two gear pump portions, that Is, the front gear portion and the rear gear portion are provided, however, the number of gear pump portion may be more than two. In this case, the oil discharged from at least one gear pump portion may be returned through the return passage at the small displacement operation.

[0051] In the first through fourth preferred embodiments, the suction passage has the circular cross-sectional surface over the entire longitudinal direction. However, the suction passage may not have a circular cross-sectional surface in the first, second, and fourth embodiments. The cross-sectional surface of the suction passage may be, for example, polygonal, elliptical, or oblong shape. In the third embodiment, the cross-sectional surface of the suction passage may be formed only at the vicinity of the confluence portion with the return passage. Specifically, if the downstream side of the confluence portion has a circular cross-sectional surface, it is appropriate for enhancing the swirling flow of oil in the suction passage.

[0052] In the first through fourth preferred embodiments, the discharge passages are provided so as to connect the discharge-side spaces of the gear chambers and the outlet passage. The discharge-side space of each gear chamber may be connected directly to the outlet passage without a discharge passage. In this case, a check valve is required to shut off the outlet passage connecting the gear chambers.

[0053] In the first through fourth embodiments, the return passage is formed so as to pass through the rear side of the rear ends of the drive shaft and the driven shaft. However, the location of the return passage is not limited to the above position. For example, the return passage may pass around at least one of the outer peripheries of the drive shaft and the driven shaft. In this case, the return passage may be preferably formed between the rear gear chamber and the rear ends of the drive shaft and the driven shaft, in order to form the confluence portion of the return passage with the suction passage at the upstream side of the suction passage.

[0054] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

Claims

1. A variable displacement type gear pump (10, 71, 81, 91) for introducing and discharging fluid, comprising:

a housing (11, 15, 16);
plural gear chambers (12, 13) formed in the housing (11, 15, 16), one of which is a specific gear chamber (13);
a gear mechanism (21, 24) accommodated in the respective gear chamber (12, 13);
a suction-side space (31, 33) formed in the respective gear chamber (12, 13);
a suction passage (35, 36, 37) communicating with the suction-side spaces (31, 33);
a discharge-side space (32, 34) formed in the respective gear chamber (12, 13);
an outlet passage (41) communicating with the discharge-side spaces (32, 34);
a return passage (50, 72, 82, 92) returning the fluid discharged to the discharge-side space (34) of the specific gear chamber (13) to the suction passage (35, 36, 37);
an opening and closing valve (51) provided in the return passage (50, 72, 82, 92) and opening the return passage (50, 72, 82, 92) in a small

displacement operational state; and
a check valve (45) located between the discharge-side space (34) of the specific gear chamber (13) and the outlet passage (41) for preventing the fluid discharged from the gear chamber (12) other than the specific gear chamber (13) from flowing into the discharge-side space (34) of the specific gear chamber (13) in the small displacement operational state,
characterized in that the suction passage (35, 36, 37) is formed in the housing (11, 15, 16), and the return passage (50, 72, 82, 92) communicates with the suction passage (35, 36, 37) at a confluence portion located upstream side of the suction-side space (31, 33).

2. The variable displacement type gear pump (10, 71, 81, 91) according to claim 1, **characterized in that** the gear mechanism (21, 24) includes a drive shaft (27), wherein the suction passage (35, 36, 37) is formed along a rotational axis of the drive shaft (27), wherein the suction passage (35, 36, 37) has an inlet (38), wherein the inlet (38) is open at an end face of the housing (16) so as to face in the direction of the rotational axis.

3. The variable displacement type gear pump (10, 71, 81, 91) according to any one of claims 1 and 2, **characterized in that** the return passage (50, 72, 82, 92), the outlet passage (41), and the check valve (45) are formed in the housing (11, 15, 16).

4. The variable displacement type gear pump (81) according to any one of claims1 through 3, wherein the suction passage (35, 36, 37) has a circular cross-sectional surface, wherein the return passage (82) communicates with the suction passage (35, 36, 37) in a tangent direction with respect to the circular cross-sectional surface at the confluence portion.

5. The variable displacement type gear pump (71) according to any one of claims 1 through 3, **characterized in that** the return passage (72) communicates with the suction passage (35, 36, 37) at the confluence portion in an inclined manner with respect to a flow direction of the suction passage (35, 36, 37), wherein the inclination is in a direction to increase the speed of the fluid in the suction passage (35, 36, 37).

6. The variable displacement type gear pump (91) according to any one of claims 1 through 3, **characterized in that** the confluence portion has a guide portion (94) at an end of the return passage (92) adjacent to the suction passage (35, 36, 37), wherein a flow direction of outflow from the return passage (92) is coincident with a flow direction of the suction passage (35, 36, 37).

FIG. 1

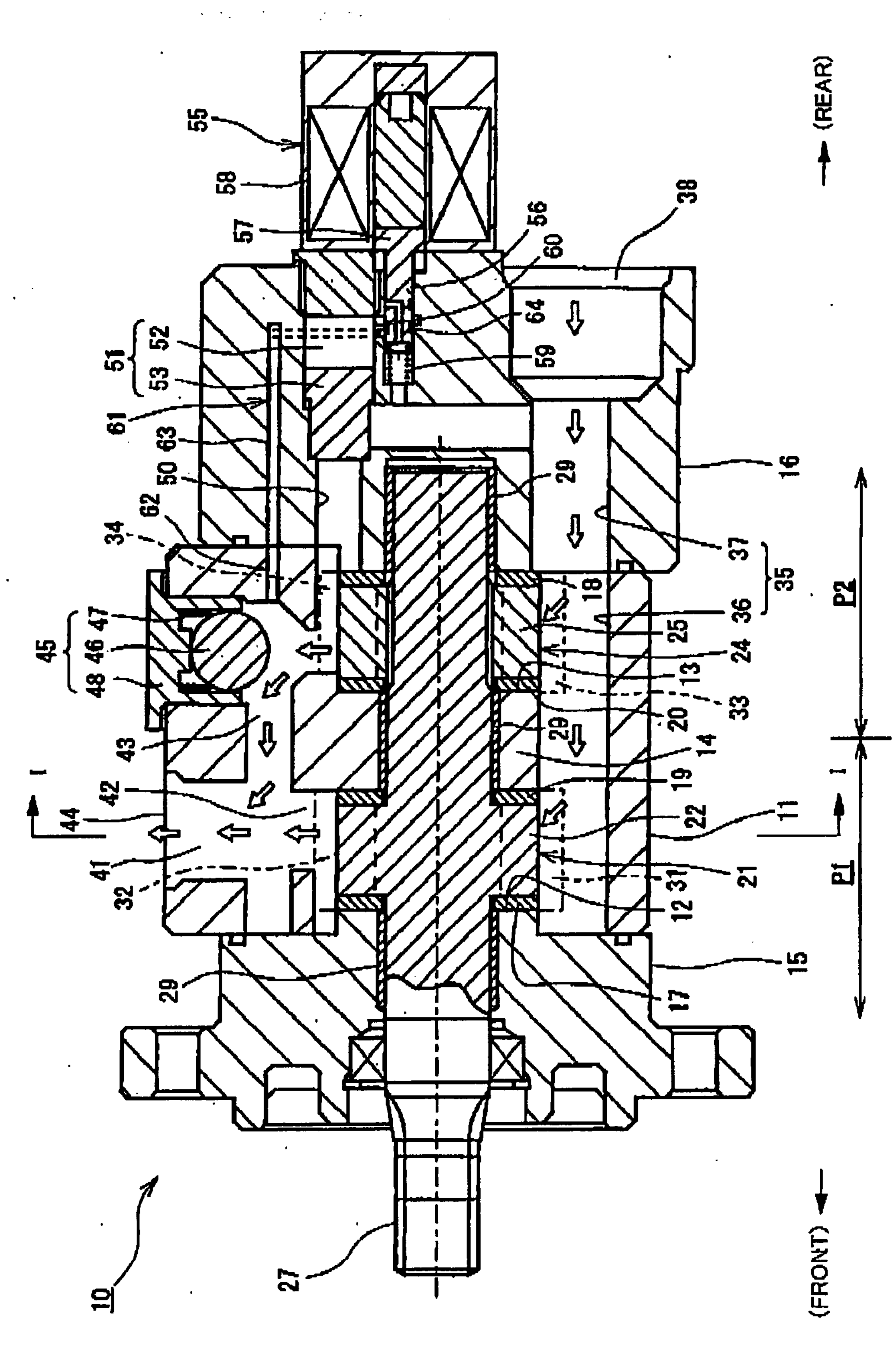
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FIG. 2

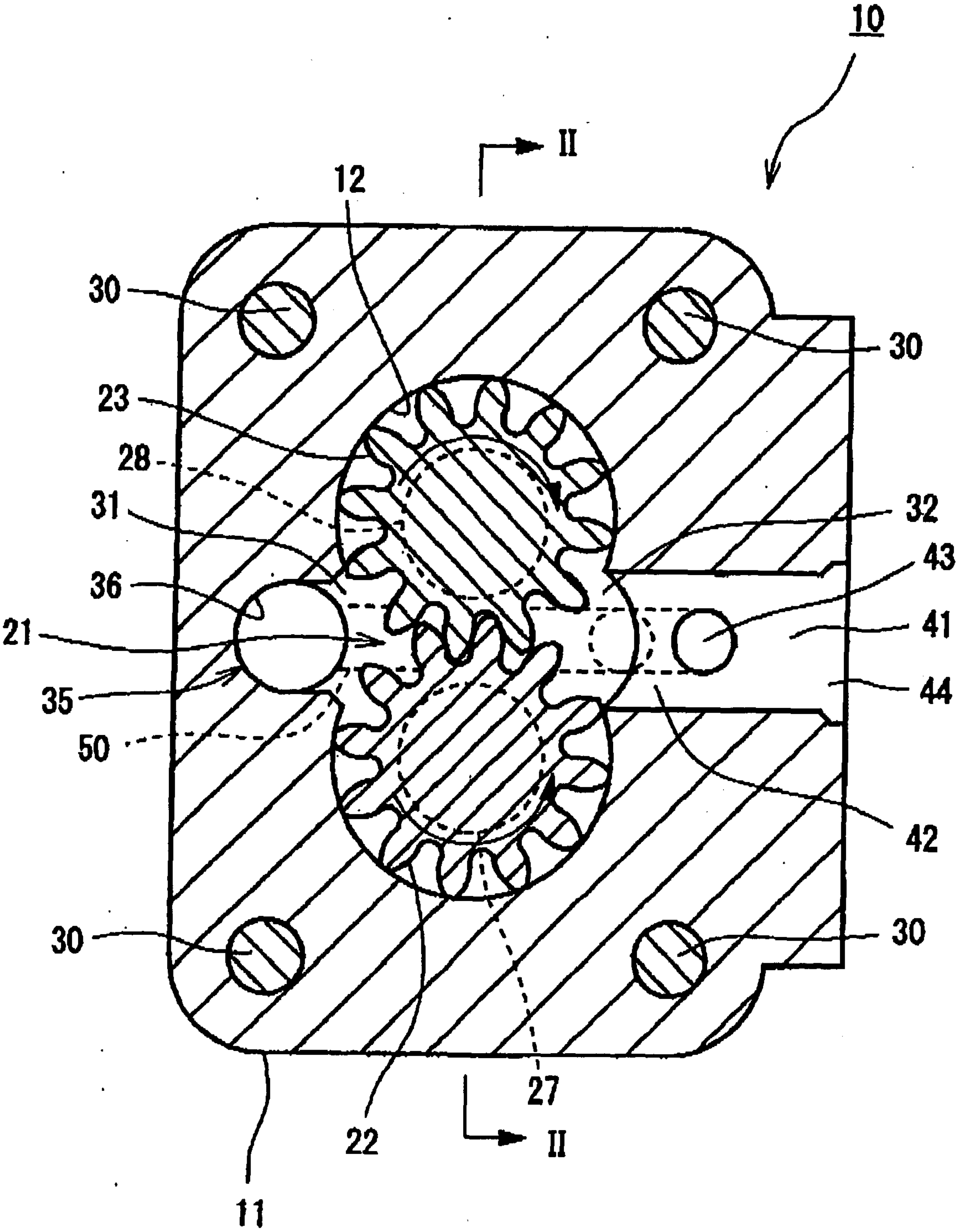

FIG. 3

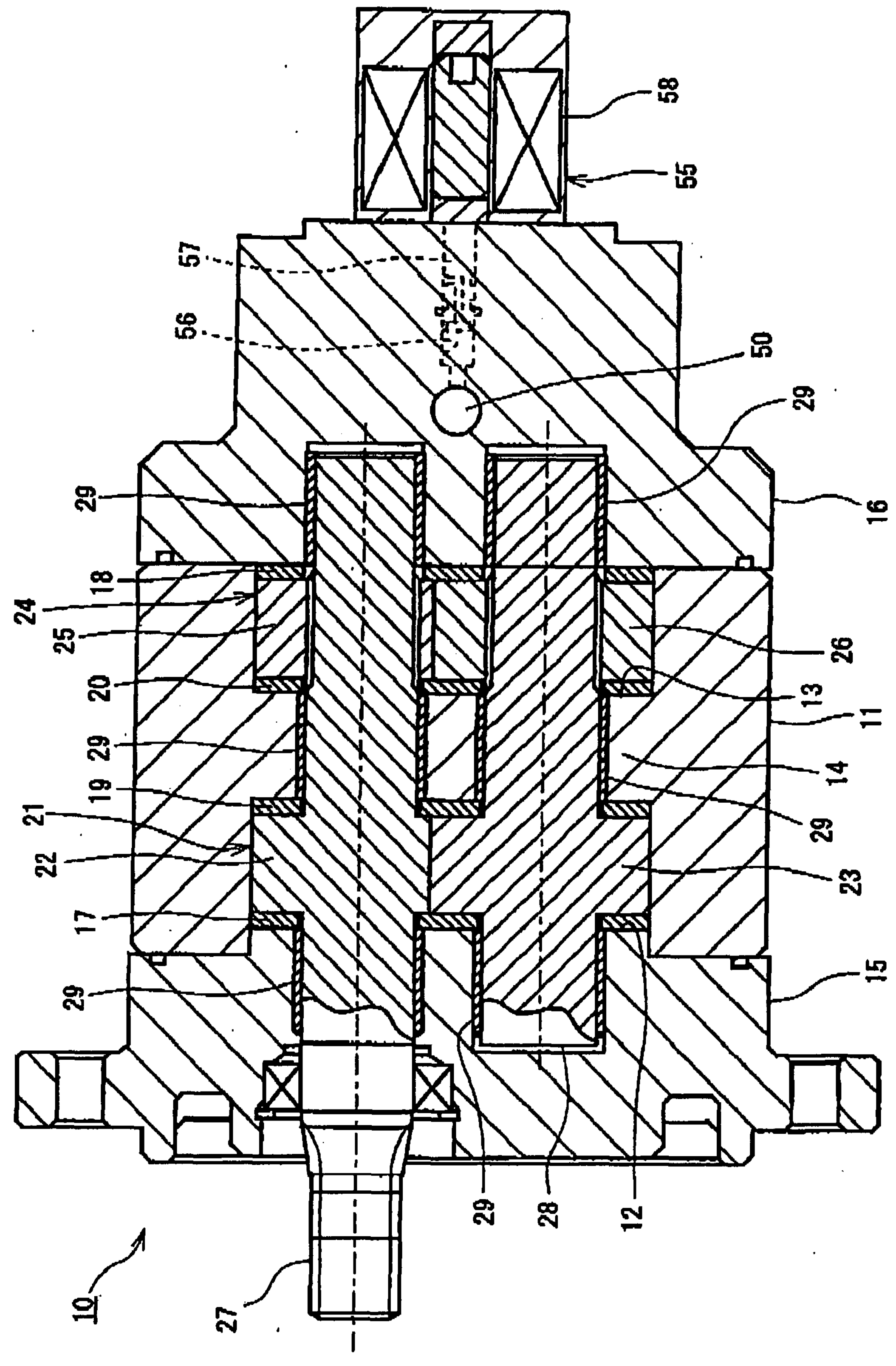
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FIG. 4

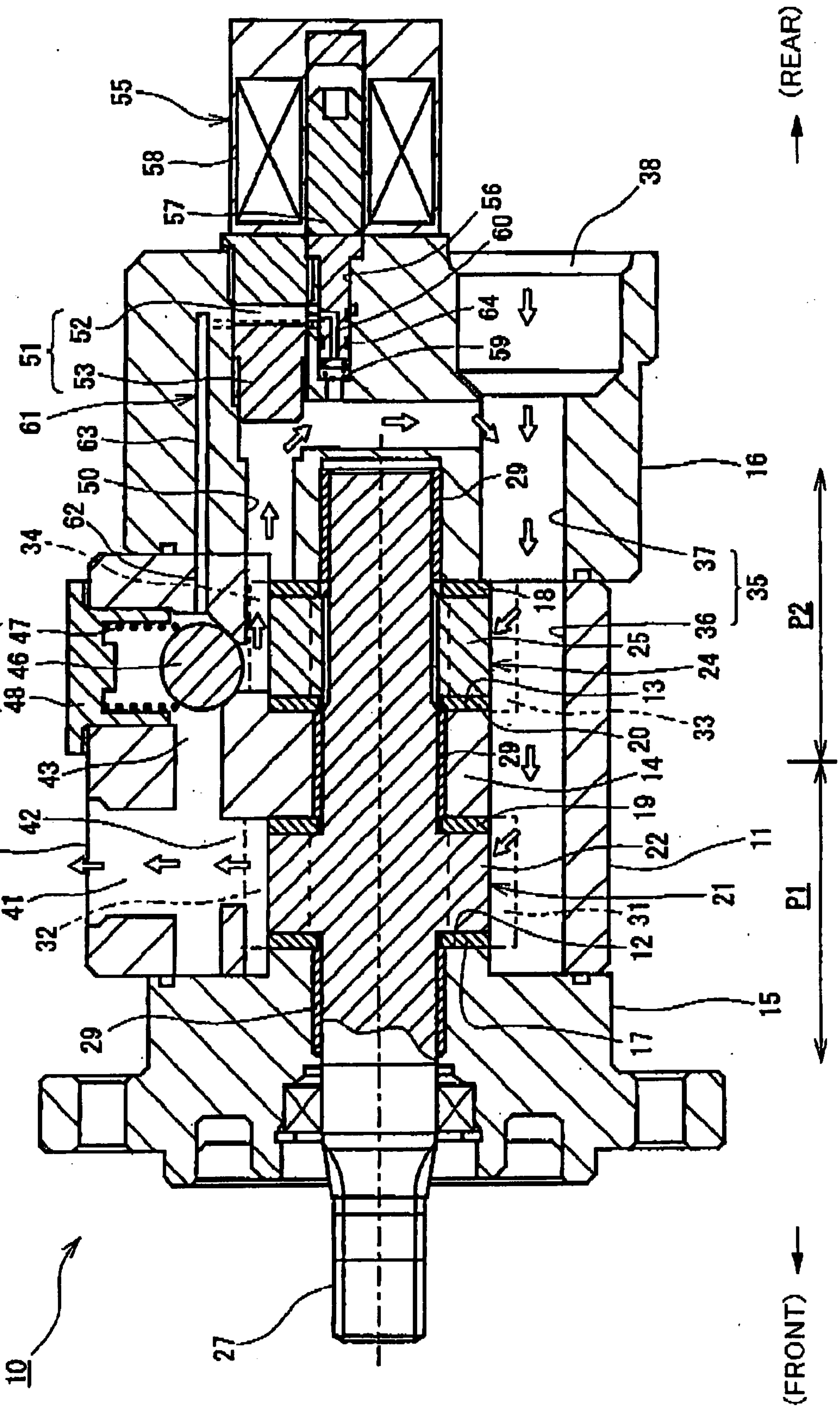


FIG. 5

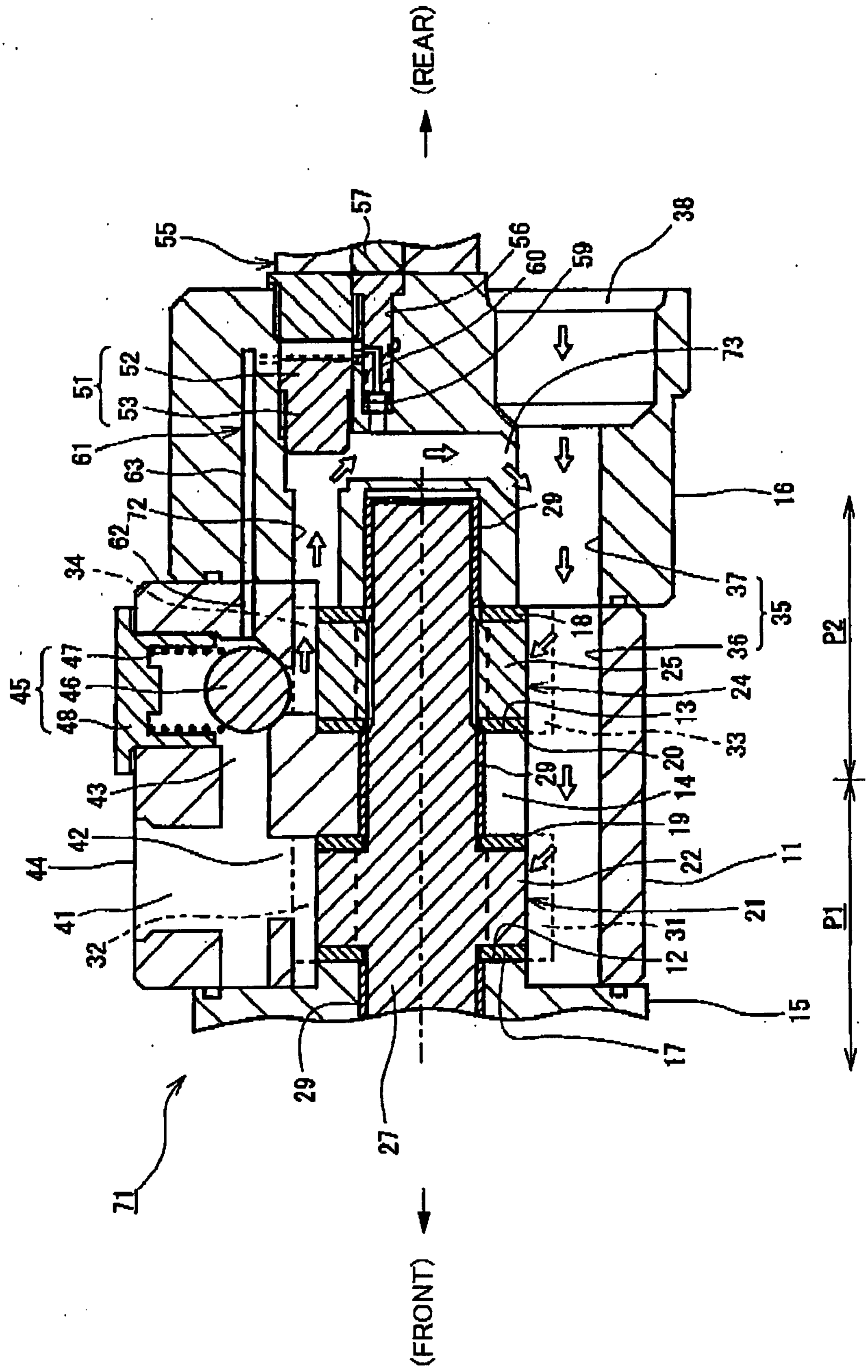


FIG. 6

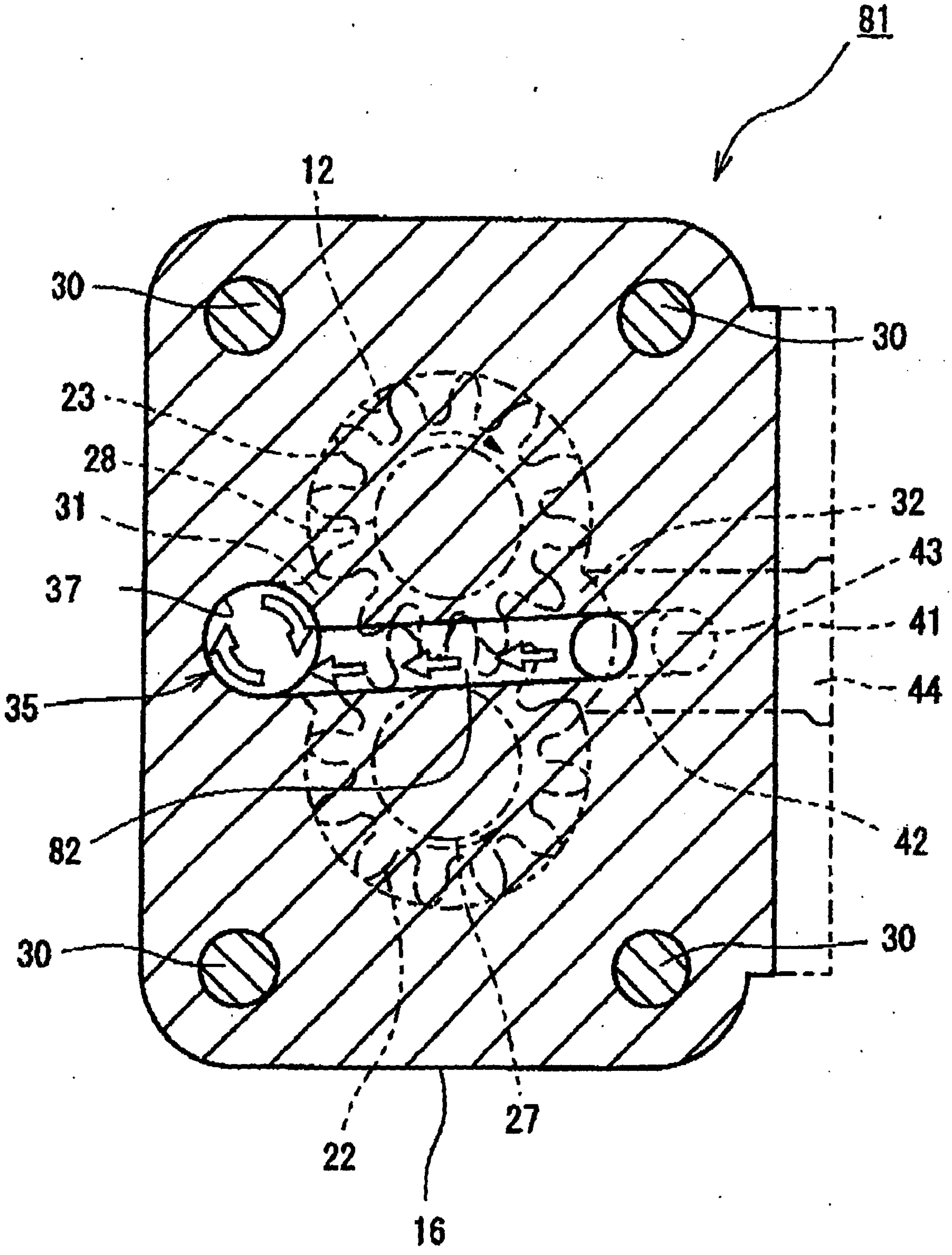
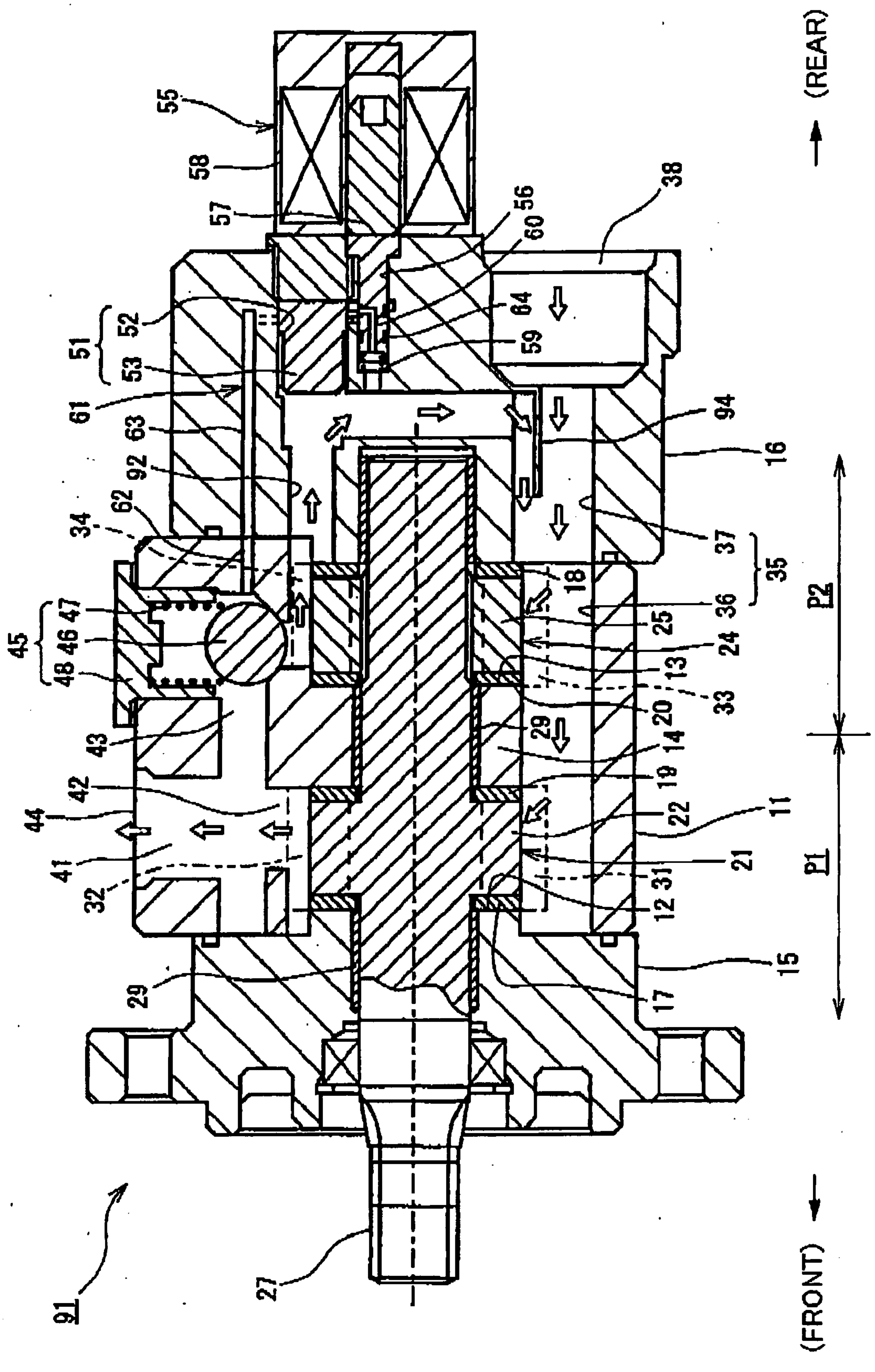


FIG. 7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REFERENCES CITED IN THE DESCRIPTION

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