



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.04.2009 Bulletin 2009/15

(51) Int Cl.:
F04B 27/10 (2006.01)

(21) Application number: **07791271.5**

(86) International application number:
PCT/JP2007/064555

(22) Date of filing: **25.07.2007**

(87) International publication number:
WO 2008/013190 (31.01.2008 Gazette 2008/05)

(84) Designated Contracting States:
DE FR GB
Designated Extension States:
AL BA HR MK RS

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(30) Priority: **26.07.2006 JP 2006203653**

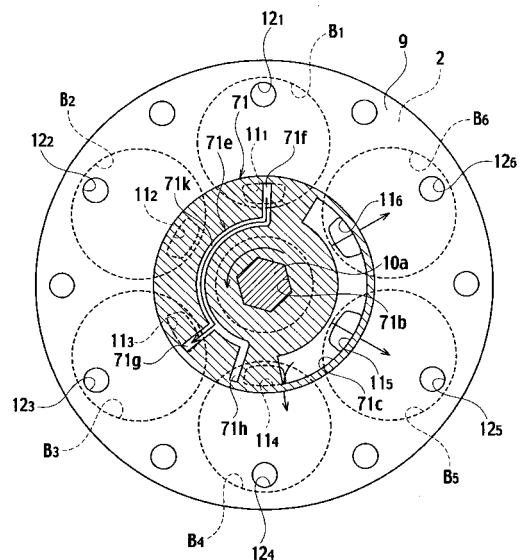
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(54) **COMPRESSOR**

(57) A rotary valve (71) of a compressor is formed with a release path (71e) configured to release a high pressure residual refrigerant which have not been discharged in a compression and discharge stroke from one cylinder bores (B_1) which is in an initial stage of its suction stroke to other cylinder bores (B_3 , B_4) having a lower pressure than the one cylinder bores (B_1). The release path (71e) is formed with an inlet (71f), a first outlet (71g), a second outlet (71h), and a communication part (71k) connecting the inlet and the outlets. During a time period when the inlet (71f) of the release path (71e) is connected to the cylinder bore (B_1) which is in a initial state of its suction stroke, the first outlet (71g) is connected to the cylinder bore (B_3) next to, in an opposite direction to the rotational direction, the cylinder bore (B_4) which is 180 degree opposite to the cylinder bore (B_1), and then, the second outlet (71h) is connected to the cylinder bore (B_4) which is 180 degree opposite to the cylinder bore (B_1).

FIG. 3



Description

TECHNICAL FIELD

[0001] The present invention relates to a compressor.

BACKGROUND ART

[0002] Japanese Patent Publication No. 3079743 discloses a compressor in which pistons are accommodated in cylinder bores arranged around a rotating shaft. The pistons reciprocate according to rotation of the rotating shaft. In this compressor, a rotary valve is provided with a suction path for introducing a refrigerant gas into compression chambers defined by the pistons in the cylinder bores. The rotary valve connects the suction path to the compression chambers sequentially in synchronization with reciprocation of the pistons.

[0003] The rotary valve includes a release passage. The release passage is configured to release a high pressure residual gas that remains in one of the compression chambers in which the piston therein is positioned at approximately an upper dead center thereof to other compression chambers in which the piston therein is positioned at approximately a lower dead center thereof.

[0004] This configuration reduces the high pressure residual gas which remains in the compression chamber after the compression and discharge stroke of the associated piston. That is, the amount of the high pressure residual gas which would otherwise be re-expanded in a suction stroke is decreased. Thereby, a larger amount of the refrigerant gas can be suctioned into the compression chamber during suction strokes, so as to improve the suction efficiency and the compression efficiency of the compressor.

DISCLOSURE OF THE INVENTION

[0005] In general, it is considered that a highly efficient compressor is achieved when high pressure residual gas is released from one of the cylinder bores having a piston positioned at the top dead center (a cylinder bore at an end of an compression and discharge stroke, that is, a cylinder bore at a beginning of the suction stroke) to another of the cylinder bores which is located 180-degree opposite to the one of the cylinder bores (a cylinder bore at the end of the suction stroke, that is, a cylinder bore at the beginning of the compression and discharge stroke). The highly efficient compressor is achieved because these two cylinder bores would have the largest pressure deference.

[0006] However, depending on layouts of the suction path of the rotary valve, the residual gas may be unable to be released from one of the cylinder bores having a piston positioned around the upper dead center to another of the cylinder bores located 180-degree opposite to the one of the cylinder bores. One such example is a structure in which a termination of a connection between

a cylinder bore and a suction path of a rotary valve is set after a time when a piston is positioned at a lower dead center in the cylinder bore (see Japanese Patent No. 3079741). With this structure, the suction path is connected to the cylinder bore right after an end of the piston's suction stroke. Therefore, residual gas can not be released, to one cylinder bore which is in a state right after its suction stroke, from another cylinder bore which is 180-degree opposite to the one cylinder bore (that is, a cylinder bore right after its compression and discharge stroke).

[0007] The present invention was developed in view of the problems described in the related art, an object of the present invention is to provide a compressor capable of releasing a residual gas right after a compression and discharge stroke, regardless of the layout of a suction path of a rotary valve

[0008] An aspect of the present invention is a compressor (1) comprising: an even number of at least four cylinder bores (Bj) evenly spaced from each other in a circumferential direction thereof around a drive shaft (10); a suction chamber (7) separated from the cylinder bores (Bj) by a first partition wall (9, 85) and communicating with the cylinder bores (Bj) through suction holes (11j) formed in the first partition wall; a discharge chamber (8) separated from the cylinder bores (Bj) by a second partition wall (9) and communicating with the cylinder bores (Bj) through discharge holes (12j) formed in the second partition wall; a piston (Pi) reciprocatably provided in each of the cylinder bores (Bj) and configured to reciprocate in the cylinder bores (Bj) in response to rotation of the drive shaft (10) so as to perform a suction stroke and a compression and discharge stroke alternately; and a rotary valve (71) configured to be in rotary slidable contact with the first partition wall while covering the suction holes (11j) and to rotate in synchronizing with the rotation of the drive shaft (10). The rotary valve (71) is formed with: a suction path (71c) configured to open the suction holes (11j) of the cylinder bores (Bj) subjected to the suction strokes so as to connect the cylinder bores (Bj) to the suction chamber (7); and a release path (71e) configured to release a high pressure residual refrigerant which could not be discharged out in the compression and discharge stroke from one of the cylinder bores (Bj) subjected to an initial stage of the suction stroke to others of the cylinder bores (Bj) having lower pressure than the one of the cylinder bores (Bj). The release path (71e) is formed with an inlet (71f), a first outlet (71g) and a second outlet (71h) which are provided on a rotational trajectory to overlap with the suction holes (11j). The release path (71e) is formed with a communication part (71k) provided outside of the rotational trajectory and connecting the inlet and the outlets. A time period when the inlet (71f) of the release path (71e) is connected to a first one of the cylinder bores (Bj) subjected to a initial state of the suction stroke includes: an A-period when the first outlet (71g) is connected to a second one of the cylinder bores (Bj) next to, in a direction opposite to the rotational direc-

tion, a third one of the cylinder bores (Bj) which is located 180 degree opposite to the first one of the cylinder bores (Bj), and after A-period, C-period when the second outlet (71h) is connected to the third one of the cylinder bores (Bj) which is located 180 degree opposite to the first one of the cylinder bores (Bj).

[0009] In this application, a "suction stroke" is defined as a duration when a piston moves from its upper (top) dead center to its lower (bottom) dead center, and a "compression and discharge stroke" is defined as a duration when a piston moves from its lower (bottom) dead center to its upper (top) dead center. An "end of a compression and discharge stroke" and a "beginning of a suction stroke" are defined as a time when a piston is positioned at its upper (top) dead center, an "end of a suction stroke" and a "beginning of a compression and discharge stroke" are defined as a time when a piston is positioned at its lower (bottom) dead center.

[0010] In the suction stroke, a fluid is suctioned through the suction hole from the suction chamber into the cylinder bore. On the other hand, in the compression and discharge stroke, a fluid is compressed within the cylinder bore and the compressed fluid is discharged through the discharge hole from the cylinder bore into the discharge chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

[Fig. 1] Fig. 1 is a sectional view of a compressor according to a first embodiment of the present invention.

[Fig. 2] Fig. 2 is a sectional view taken along with the line Z-Z of Fig. 1, showing a positional relation between suction paths and a release path during a rotation of a rotary valve.

[Fig. 3] Fig. 3 is a sectional view taken along with the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 4] Fig. 4 is a sectional view taken along with the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 5] Fig. 5 is a sectional view taken along with the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 6] Fig. 6 is a sectional view taken along with the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 7] Fig. 7 is a view of superimposed pressure curves of pressures in a cylinder bore B₁, a cylinder bore B₃ and a cylinder bore B₄; the solid line indicates the pressure curve of the cylinder bore B₁; the chain line indicates the pressure curve of the cylinder bore

B₃; and the two-dot chain line indicates the pressure curve of the cylinder bore B₄.

[Fig. 8] Fig. 8 is a view enlarging a term in the view of Fig. 7, showing an initial stage of a suction stroke in the cylinder bore B₁.

[Fig. 9] Fig. 9 is a front view of the rotary valve of the compressor according to the first embodiment.

[Fig. 10] Fig. 10 is a front view of a first modification of the rotary valve of the compressor according to the first embodiment.

[Fig. 11] Fig. 11 is a front view of a second modification of the rotary valve of the compressor according to the first embodiment.

[Fig. 12] Fig. 12 is a sectional view of a compressor according to the second embodiment of the present invention.

[Fig. 13] Fig. 13 is a sectional view taken along the Z-Z of Fig. 12, showing a positional relation between suction paths and a release path during a rotation of a rotary valve.

[Fig. 14] Fig. 14 is a sectional view taken along the line Z-Z of Fig. 12, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 15] Fig. 15 is a sectional view taken along the line Z-Z of Fig. 12, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 16] Fig. 16 is a sectional view taken along the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 17] Fig. 17 is a sectional view taken along the line Z-Z of Fig. 1, showing a positional relation between the suction paths and the release path during the rotation of the rotary valve.

[Fig. 18] Fig. 18 is an expanded view of an outer peripheral surface of the rotary valve of the compressor according to the second embodiment.

[Fig. 19] Fig. 19 is a sectional view of a first modification of the rotary valve of the compressor according to the second embodiment.

[Fig. 20] Fig. 20 is a sectional view of a second modification of the rotary valve of the compressor according to the second embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012] Embodiments of a compressor according to the present invention will be described with reference to the drawings.

(First embodiment)

[0013] A compressor of a first embodiment will be described with reference to Figs. 1 to 9.

[0014] Fig. 1 is a sectional view of the compressor of the first embodiment and Fig. 2 is a sectional view taken

along the line Z-Z of Fig. 1. The compressor 1 of the present embodiment is a swash plate type variable capacity compressor as shown in Fig. 1. The compressor 1 has a cylinder block 2 which has substantially column-shaped cylinder bores Bj (The "j" refers to "1 to 6" in this embodiment) arranged in the circumferential direction at regular intervals (see Fig. 2), a front head 4 which is attached to a front end of the cylinder block 2 and forms therein a crank chamber 5 communicating with the cylinder bores Bj, a valve plate 9 which constitutes a first partition wall and a second partition wall, and a rear head 6 which is attached to a rear end of the cylinder block 2 with the valve plate 9 therebetween so as to form therein a suction chamber 7 and a discharge chamber 8. The cylinder block 2, the front head 4 and the rear head 6 are attached and fastened together with through bolts 13 to constitute an overall housing of the compressor.

[0015] A gasket 53 is provided between the valve plate 9 and the rear head 6 to seal the suction chamber 7 and the discharge chamber 8. A gasket 54 is provided between the valve plate 9 and the cylinder block 2 to seal the cylinder bores Bj.

[0016] The valve plate 9 is formed in a substantially circular disk shape. The valve plate 9 is formed with suction holes 11j (The "j" refers to "1 to 6" in this embodiment.) corresponding to the cylinder bores Bj to communicate the cylinder bores Bj with the suction chamber 7, and discharge holes 12j (The "j" refers to "1 to 6" in this embodiment) corresponding to the cylinder bores Bj to communicate the cylinder bores Bj with the discharge chamber 8.

[0017] On the rear head 6 side of the valve plate 9, a suction valve mechanism 70 is provided to open and close the suction holes 11j and a discharge valve mechanism 60 is provided to open and close the discharge hole 12j, as described below in detail.

[0018] A drive shaft 10 is rotatably supported by radial bearings 15, 19 at center through holes 14, 18 of the front head 4 and the cylinder block 2 so that the drive shaft 10 is rotatable in the crank chamber 5.

[0019] A thrust bearing 20 is provided between an inner surface of the front head 4 and a front end surface of the rotor 21 fixed to the drive shaft 10 in the crank chamber 5. A thrust bearing 16 is provided between a step portion formed on the drive shaft 10 and an adjusting screw 17 fixed to the center through hole 14 of the cylinder block 2. This structure prevents axial movements of the drive shaft 10.

[0020] In the crank chamber 5, a conversion mechanism is provided to convert the rotary motion of the drive shaft 10 into reciprocation motion of the pistons Pj (The "j" refers to "1 to 6" in this embodiment). The conversion mechanism includes the circular disk shaped rotor 21 fixed to the drive shaft 10, a circular disk shaped swash plate 24 axially slidable on and attached at an inclination to the drive shaft 10, and a linkage mechanism 40 connecting the rotor 21 and the swash plate 24 so that the rotor 21 and the swash plate 24 rotate together with al-

lowing an inclination angle of the swash plate 24 to change. The respective pistons Pj are attached to the outer peripheral part of the swash plate 24 with a pair of hemispherical-shaped piston shoes 30, 30. When the swash plate 24 rotates, the pistons Pj reciprocate within the cylinder bores Bj according to the inclination angle of the swash plate 24. As the pistons Pj reciprocate, a refrigerant is suctioned from the suction chamber 7 into the cylinder bores Bj through the suction holes 11j of the valve plate 9 and compressed in the cylinder bores Bj. The compressed refrigerant is discharged to the discharge chamber 8 through the discharge holes 12j of the valve plate 9.

[0021] When the swash plate 24 moves toward the cylinder block 2 against the return spring 52, the inclination angle of the swash plate 24 decreases. On the other hand, the inclination angle of the swash plate 24 is increased when the swash plate 24 moves away from the cylinder block 2 against a return spring 51.

Control of Variable Capacity

[0022] In order to change the amount of discharged refrigerant, the inclination angle of the swash plate 24 is changed so as to change the piston stroke. Concretely, based on a pressure difference (pressure balance) between a crank chamber pressure Pc in back of (below) the pistons Pj and a suction chamber pressure Ps in front of (above) the pistons Pj, the inclination angle of the swash plate 24 is changed so as to change the piston stroke. For this purpose, the variable capacity compressor includes a pressure control mechanism. The pressure control mechanism includes a gas discharge passage (not shown) which communicates the crank chamber 5 with the suction chamber 7, a gas supply passage (not shown) which communicates the crank chamber 5 with the discharge chamber 8, and a control valve 33 provided in the midstream of the gas supply passage to open and close the gas supply passage.

[0023] The gas discharge passage is kept open regardless of opening and closing the gas supply passage controlled by the control valve 33, so that the refrigerant gas in the crank chamber 5 constantly flows to the suction chamber 7 through the gas discharge passage.

[0024] When the control valve 33 opens the gas supply passage, the high-pressure refrigerant flows from the discharge chamber 8 into the crank chamber 5 through the gas supply passage. This increases the pressure in the crank chamber 5. When the pressure in the crank chamber 5 increases, the swash plate 24 decreases its inclination angle as it moves toward the cylinder block 2. As a result, the piston stroke decreases and the amount of discharge of the compressor decreases.

[0025] On the other hand, when the control valve 33 closes the gas supply passage, the pressure difference between the pressure in the suction chamber 7 and the pressure in the crank chamber 5 is equalized. As a result, the inclination angle of the swash plate 24 increases as

the swash plate 24 moves away from the cylinder block 2, so that the piston stroke increases and the amount of discharge of the compressor increases.

Valve System

[0026] Next, valve systems 60, and 70 will be described.

[0027] A discharge valve mechanism 60 will be explained with reference to Fig. 1. The discharge valve mechanism 60 has a discharge valve plate 61. The discharge valve plate 61 is supported between the valve plate 9 and the rear head 6 as shown in Fig. 1. The discharge valve plate 61 is configured in an elastic and flexible thin plate (such as a thin metal plate) and has reed valves 63 located to correspond to the discharge holes 12j. When a pressure in the cylinder bore Bj is equal to or less than a predetermined level, the reed valve 63 keeps the discharge hole 12j closed and, when the pressure in the cylinder bore Bj is greater than the predetermined level, the reed valve 63 is deformed to open the discharge hole 12j. In other words, the reed valve 63 closes the discharge hole 12j during a suction stroke and a compressing stroke but opens the discharge hole 12j during a discharging stroke after the compressing stroke. Stoppers 65 provided on the gasket 53 stop the reed valves 63 at their maximum lift positions.

Next, a suction valve mechanism 70 will be described in further detail with reference to Figs. 1 and 2.

[0028] The suction valve mechanism 70 includes a rotary valve 71, a stopper 73 and a coil spring 75 as a spring member. The rotary valve 71, stopper 73 and coil spring 75 are all disposed in the suction chamber 7 as shown in Fig. 1.

[0029] The rotary valve 71 is configured in a substantially circular disk shape with a center through hole 71b at the center of the rotary valve 71. An axial end 10a of the drive shaft 10 is mounted in the center through hole 71b of the rotary valve 71 and extends through the center through hole 9c of the valve plate 9 into the suction chamber 7. The center through hole 71b of the rotary valve 71 and the axial end 10a of the drive shaft 10 are formed in the same noncircular shape (a hexagonal shape in this embodiment) as shown in Fig. 2 so that the rotary valve 71 is axially slidable with respect to the driving shaft 10 and rotate together with the drive shaft 10.

[0030] Axial movements of the stopper 73 are limited by a bolt 77 which serves as a fastening means at the axial end 10a of the drive shaft 10. The stopper 73 has a pair of arms 73d extending toward and being connected to the rotary valve 71 so that the stopper 73 rotates together with the rotary valve 71. The coil spring 75 is compressed and supported between the stopper 73 and the rotary valve 71 so that the rotary valve 71 is always in close contact with the valve plate 9 as biased to the valve plate 9.

[0031] The rotary valve 71, as shown in Fig. 2, has a suction path 71c penetrating therethrough and formed in

a circular arc hole shape. When the rotary valve 71 rotates, the suction path 71c of the rotary valve 71 sequentially overlaps with the suction holes 11j of the valve plate 9 to open the suction holes 11j in sequence (see Figs. 2 to 6).

[0032] Next, the timing of the valve open period when the suction hole 11j is opened by the suction path 71c will be explained with reference to Figs. 2 to 6. Here, the timing of the valve open period when the suction holes 11j is opened by the suction path 71c is set in synchronization with the suction stroke of the piston Pj.

[0033] Figs. 2 to 6 show a process from when cylinder bore B₁ starts a suction stroke (Fig. 2) to just before the cylinder bore B₁ starts to communicate with the suction path 71c (Fig. 6), in a sequential order.

[0034] In a position shown in Fig. 2, the piston P₁ of the cylinder bore B₁ is positioned at the upper (top) dead center and the piston P₄ of the cylinder bore B₄ located 180 degree opposite to the cylinder bore B₁ is positioned at the lower (bottom) dead center. Thus, in the position shown in Fig. 2, the piston P₁ of the cylinder bore B₁ finishes its compressing and discharging stroke and is going to start its suction stroke, and the piston of the cylinder bore B₄ is going to start its compressing and discharging stroke and finish its suction stroke. Further, the cylinder bores B₂ and B₃ which are located between the cylinder bore B₁ subjected to the upper dead center state and the cylinder bore B₄ subjected to the lower dead center state are subjected to compressing strokes. The cylinder bores B₅ and B₆ which are located between the cylinder bore B₄ subjected to the lower dead center state and the cylinder bore B₁ subjected to the upper dead center state are subjected to suction strokes.

[0035] In such a position shown in Fig. 2, the suction path 71c does not communicate with the suction hole 11₁ of the cylinder bore B₁ subjected to the upper dead center state but communicates with the suction hole 11₄ of the cylinder bore B₄ subjected to the lower dead center state and communicates with the suction holes 11₅, 11₆ of the cylinder bores B₅, B₆ subjected to the suction strokes.

[0036] Thus, regarding the cylinder bore B₁ in Figs. 2 to 6, a start timing of the valve open period in which the suction hole 11₁ (see Fig. 5) is opened by the suction path 71c is set later than the timing at which the piston P₁ in the cylinder bore B₁ is positioned at the upper dead center (Fig. 2). Further, regarding the cylinder bore B₄ in Figs. 2 to 6, an end timing of the valve open period in which the suction hole 11₄ is opened by the suction path 71c (Fig. 4) is set after the timing at which the piston P₄ in the cylinder bore B₄ is positioned at the lower dead center (Fig. 2).

[0037] In other words, regarding the cylinder bore B₁, the piston P₁ is positioned at the upper dead center in Fig. 2, and after that, the valve open period during which the suction hole 11₁ is opened by the suction path 71 starts as shown in Fig. 4. Further, regarding the cylinder bore B₄, the piston P₄ is positioned at the lower dead center in Fig. 2, and after that, the valve open period

during which the suction hole 11₄ is opened by the suction path 71c ends as shown in Fig. 5.

[0038] That is, in each cylinder bore B_j, the start time of the valve open period when the suction hole 11j is opened by the suction path 71c is set after the time at which the piston P_j is positioned at its upper dead center, and the end time of the valve open period when the suction hole 11j is opened by the suction path 71c is set after the time that the piston P_j is positioned at its lower dead center.

[0039] As described above, in each cylinder bores B_j, the end timing of the valve open period when the suction hole 11j is opened by the suction path 71c is set after the time the piston P_j is positioned at the lower dead center. With this structure, suction gas is introduced into the cylinder bore B_j even in an initial stage of the compression and discharge stroke after the suction stroke (when the piston P_j has started to move from the lower dead center toward the upper dead center) because of an inertia of a suction gas flow which was introduced during the suction stroke (while the piston P_j moves from the upper dead center to the lower dead center). This increases the suctioned amount so as to improve the suction efficiency and the compression efficiency of the compressor 1.

Residual Pressure Release Structure

[0040] A residual pressure release structure will be described with reference to Figs. 2 to 9.

[0041] As shown in Figs. 1 to 6 and 9, the rotary valve 71 has a release path 71e.

[0042] The release path 71e is formed as a groove which is a recess on a surface of the rotary valve 71. The release path 71e has an inlet 71f, two outlets 71g, 71h, and a communication part 71k which communicates the inlet 71f and the outlets 71g, 71h. The inlet 71f and outlets 71g, 71h are provided on a rotational trajectory which is to overlap with the suction holes 11j and communicate with the suction holes 11j in sequence as the rotary valve 71 rotates. The communication part 71k is positioned out of the rotational trajectory so as not to overlap with the suction holes 11j.

[0043] The release path 71e is configured to release a high-pressure residual refrigerant, which was not discharged during the compressing and discharging stroke and remained in one of the cylinder bores B_j in the initial stage of the suction stroke, to other of the cylinder bores B_j having a lower pressures than the one.

[0044] The following description will describe how the release path 71e of the rotary valve 71 and the cylinder bores B_j communicate with each other during a period from the time of a beginning of the suction stroke in the cylinder bore B₁ (Fig. 2) to the time just before the cylinder bore B₁ starts to communicate with the suction path 71c (Fig. 6), with reference to Figs. 2 to 6.

[0045] Through Figs. 2 to 6, the cylinder bore B₁ is in the initial stage of the suction stroke (that is, a period

after the compressing and discharging stroke ends and before the suction path 71c communicates with the cylinder bore B₁, in this example). While the release path inlet 71f is communicating with the cylinder bore B₁ (Figs. 3 to 5), the first outlet 71g firstly communicates with the cylinder bore B₃ located just rotationally-prior to the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁ as shown in Fig. 3. Then, as shown in Fig. 5, the second outlet 71h communicates with the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁.

[0046] Hereinafter, "A-period" refers to a period when the first outlet 71g communicates with the cylinder bore B₃ (Fig. 3) and "C-period" refers to a period when the second outlet 71h communicates with the cylinder bore B₄ (Fig. 5). Between the A-period (Fig. 3) and C-period (Fig. 5), a "B-period" (Fig. 4) intervenes for a moment. The "B-period" is a period when the first outlet 71g communicates with the suction hole 11₃ of the cylinder bore B₃ and the second outlet 71h communicates with the suction hole 11₄ of the cylinder bore B₄.

[0047] Figs. 7 and 8 are graphs showing pressure curves of pressures in the cylinder bore B₁, the cylinder bore B₃, and the cylinder bore B₄ which are superimposed on one another. In Figs. 7 and 8, the solid line indicates the pressure curve of the cylinder bore B₁; the chain line indicates the pressure curve of the cylinder bore B₃; and the two-dot chain line indicates the pressure curve of the cylinder bore B₄.

[0048] In Figs. 7 and 8, "θ" indicates a rotation angle of the rotary valve. In Figs. 7 and 8, when the cylinder bore B₁ is subjected to the upper dead center state (when the piston P₁ of the cylinder bore B₁ is positioned at its upper dead center), that is, when the cylinder bore B₄ is subjected to the lower dead center state (when the piston P₄ of the cylinder bore B₄ is positioned at its lower dead center), the rotation angle θ is indicated by 0° (= 360°).

[0049] Fig. 8 is an enlarged view of the initial stage (θ is from about 0° to about 30°) of the suction stroke in the cylinder bore B₁. The arrows in Fig. 8 indicate flows of the high pressure residual gas from the cylinder bore B₁ to the cylinder bores B₃ and B₄. The A-period, B-period and C-period in Fig. 8 correspond to the above described A-period (Fig. 3), B-period (Fig. 4) and C-period (Fig. 5), respectively.

[0050] According to the present embodiment as shown in Fig. 8, regarding the cylinder bore B₁ subjected to the initial stage of the suction stroke, before the C-period (Fig. 5) when the second outlet 71h communicates with the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁, there is an A-period (Fig. 3) when the first outlet 71g communicates with the cylinder bore B₃ next to, in an opposite direction to the rotational direction, the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁. This configuration uses the cylinder bore B₃ located next to the cylinder bore B₄ in the direction opposite to the rotational direction, for the cylinder bore B₁ subjected to the initial stage (A-period to C-period) of the suction stroke. Regardless of the layout of

the suction path 71c, the high pressure residual refrigerant can be released right after the end of the compression and discharge stroke (that is, right after the beginning of the suction stroke). Therefore, a high suction efficiency and compression performance of the compressor can be maintained.

[0051] Although the cylinder bore B_1 has been used as one example in the above explanation in Figs. 2 to 6, the release path 71e communicates with the other cylinder bores B_2 to B_6 in sequence in the same way as the cylinder bore B_1 .

Effects

[0052] Next, effects of the present embodiment will be described.

[0053] (1) The compressor 1 of the present embodiment includes: four or more even numbers of cylinder bores B_j spaced evenly apart from each other along the circumferential direction around the drive shaft 10; the suction chamber 7 separated from the cylinder bores B_j by the first partition wall (or the valve plate 9 in this embodiment) and communicating with the cylinder bores B_j through the suction holes 11j formed in the first partition wall; the discharge chamber 8 separated from the cylinder bores B_j by the second partition wall (or the valve plate 9 in this embodiment) and communicating with the cylinder bores B_j through discharge holes 12j formed in the second partition wall; the pistons P_j configured to reciprocate in the cylinder bores B_j ; and the conversion mechanism (21, 24, 40, 30) configured to convert the rotation of the drive shaft 10 to the reciprocations of the pistons P_j . The pistons P_j reciprocate in the respective cylinder bores B_j , in order, in conjunction with the rotation of the drive shaft 10 so that each cylinder bore B_j has its suction stroke and its compression and discharge stroke alternately. In the suction stroke, the refrigerant is suctioned from the suction chamber 7 into the cylinder bore B_j through the suction hole 11j. In the compression and discharge stroke, the refrigerant is compressed in the cylinder bores B_j and then the compressed refrigerant is discharged to the discharge chamber 8 through the discharge hole 12j. The compressor 1 further includes the rotary valve 71 disposed to be in rotational, slidable contact with the first partition wall 9 while covering the suction hole 11j and connected to the drive shaft 10 so as to rotate in synchronizing with the rotation of the drive shaft (10). The rotary valve (71) is formed with a suction path (71c) configured to open the suction holes 11j of the cylinder bores B_j subjected to the suction strokes so as to connect the cylinder bores B_j to the suction chamber 7. The rotary valve 71 is formed with the release path 71e to release a high pressure residual refrigerant which was not discharged in the compression and discharge stroke from one of the cylinder bores B_j subjected to an initial stage of the suction stroke to others of the cylinder bores B_j having a lower pressure than the one of the cylinder bores B_j . The release path 71e is formed with the inlet

71f, the first outlet 71g and the second outlet 71h provided on the rotational trajectory to overlap with the suction holes 11j. The release path 71e is formed with the communication part 71k provided outside the rotational trajectory and communicating the inlet with the outlets.

[0054] During the time period when the inlet 71f of the release path 71e communicates with first one of the cylinder bore B_j which is in the initial state of the suction stroke, (A) the first outlet 71g communicates with a second one of the cylinder bores B_j next to, in a direction opposite to the rotational direction (counter-rotational direction), a third one of the cylinder bore B_j located 180 degree opposite to the first one of the cylinder bore B_j ; and after that, (C) the second outlet 71h communicates with the third one of the cylinder bores B_j located at 180 degree opposite to the first one of the cylinder bores B_j .

[0055] Regarding the cylinder bore B_1 as one example, in a time period (Figs. 3 to 5) during which the inlet 71f of the release path 71e communicates with the cylinder bore B_1 subjected to an initial state of its suction stroke (that is, a period after a compression and discharge stroke of the cylinder bore B_1 and before the suction path 71c communicates with the cylinder bore B_1), the first outlet 71g communicates with the cylinder bore B_3 next to, in the counter-rotational direction, the cylinder bore B_4 located 180 degree opposite to the cylinder bore B_1 (a A-period); and then, the second outlet 71h communicates with the cylinder bore B_4 located 180 degree opposite to the cylinder bore B_1 (a C-period).

[0056] As described above, the present embodiment uses the cylinder bore B_3 next to, in the opposite direction to the rotational direction, the cylinder bore B_4 located 180 degree opposite to the cylinder bore B_1 subjected to the initial stage of the suction stroke. Thus, regardless of the layout of the suction path 71c, the high pressure residual refrigerant can be released right after the end of the compression and discharge stroke (that is, right after the beginning of the suction stroke). Therefore, a high suction efficiency and compression performance of compressor can be maintained.

[0057] Although the cylinder bore B_1 has been used as one example in the explanation through Fig. 2 to 6, the release path 71e communicates with the other cylinder bores B_2 to B_6 by turns in the same way.

[0058] (2) According to the present embodiment, the layout of the suction path 71c is designed such that the start timing of the valve open period when the suction hole 11j is opened by the suction path 71c is set later than the timing when the piston P_j in the cylinder bore B_j is positioned at its upper dead center.

[0059] In other words, regarding the cylinder bores B_1 , B_4 which are 180 degree opposite to each other, the ending time (Fig. 4) of the valve open period when the suction hole 11j is opened by the suction path 71c is set after the timing shown in Fig. 2 in which the piston P_4 in the cylinder bore B_4 is positioned at the lower dead center.

[0060] Therefore, the suction gas is introduced into the cylinder bore B_j even after the suction stroke (the initial

stage of the compression and discharge stroke, that is, a stage in which the piston Pj has started to move from the lower dead center toward the upper dead center, by the inertia of the suction gas flow which was introduced during the suction stroke (that is, during a period when the piston Pj moves from the upper dead center to the lower dead center). This process increases the suction amount of gas so as to improve the suction efficiency and the compression efficiency of the compressor 1.

[0061] This structure, however, can not release the residual gas from one of the cylinder bores Bj having piston Pj at the upper dead center to another of the cylinder bore Bj 180 degree opposite to the one of the cylinder bores Bj. In other words, as for the cylinder bores B₁ and B₄ that are 180 degree opposite to each other, the residual gas can not be released from the cylinder bores B₁ (Fig. 3) having piston Pj positioned right after the upper dead center to the cylinder bore B₄ located 180 degree opposite to the cylinder bore B₄. In the same way, although explanations by drawings are omitted here, in the case of the cylinder bores B₂ and B₅ that are 180 degree opposite to each other and the case of the cylinder bores B₁ and B₄ that are 180 degree opposite to each other, when their pistons are positioned right after the upper dead center, a residual gas can not be released. Therefore, the effect (1) will be more effective.

[0062] (3) According to the present embodiment, the A-period and C-period are partially overlapped so that the C-period follows A-period without a break therebetween. This configuration allows release of the residual gas without a break, and thereby, the suction efficiency is further improved.

[0063] (4) The compressor 1 of the present embodiment includes a rotatable drive shaft 10 extending into the suction chamber 7 through the through hole 9c provided in the valve plate 9, and the plate shaped rotary valve 71 connected to the drive shaft 10 within the suction chamber 7 so as to rotate with the drive shaft 10 and configured to open and close the suction holes 11j of the valve plate 9 as rotating with the drive shaft 10; and the stopper 73, which is axially immovable, attached to the drive shaft 10, wherein the rotary valve 71 is axially slidably attached to the drive shaft 10 and biased toward the valve plate 9 by the coil spring 75 serving as a spring supported by the stopper 73.

[0064] In other words, the rotary valve 71 rotates with the drive shaft 10 with being axially slidable with respect to the drive shaft 10 and is biased toward the valve plate 9 by the spring 75. With this structure, the rotary valve 71 is firmly in close contact with the valve plate 9, so that the compressed high pressure medium in the cylinder bores Bj does not substantially leak from the suction holes 11j of the cylinder bores Bj through the gap between the valve plate 9 and the rotary valve 71 into the suction chamber 7. Thereby, the compression efficiency is improved. Moreover, if the pressure within the cylinder bores Bj was to increase excessively, the rotary valve 71 would move away from the valve plate 9 to release the

excessively high pressure medium from the cylinder bores Bj to the suction chamber 7. Therefore, the compressor 1 of the present embodiment has a safety for the excessively high pressure in the cylinder bores Bj.

[0065] Unlike the conventional art (for example, Japanese Patent Application Laid-Open No. 8-144946, Figs. 3, 6, 9 and 12), the coil spring 75 is not in contact with the rear head 6, so that vibration of the rotary valve 71 is not transmitted to the rear head 6 via the coil spring 75. Therefore, the compressor 1 of the present embodiment achieves improved suppression of vibration.

[0066] Moreover, the stopper 73 for the coil spring 75 rotates with the rotary valve 71 as one unit, unlike the conventional art (for example, Japanese Patent Application Laid-Open No. 8-144946, Fig. 3, 6, 9 and 12), so there is no need to have a thrust bearing between the coil spring and the rotary valve or between the coil spring and the stopper. Therefore, cost is reduced since expensive thrust bearings are not required.

[0067] Next, modifications of the first embodiment will be explained. In modifications or embodiments described below, the same reference numerals and symbols will be used to designate the same elements as the elements described in the first embodiment, and redundant description for the elements and its effects will be omitted.

(First modification)

[0068] Fig. 10 is a view of a rotary valve according to a first modification of the first embodiment.

[0069] Although the rotary valve 71 of the first embodiment has the recessed communication part 71k of the release path 71e which is recessed from the surface of the rotary valve 71 in a groove shape (See, Fig. 9), the rotary valve 71 of the first modification shown in Fig. 10 has a communication part 71k which penetrates through the rotary valve 71 to form a hole therein. Such a first modification can achieve the same or similar effect as that of the first embodiment.

(Second modification)

[0070] Fig. 11 is a view of a rotary valve according to a second modification of the first embodiment.

[0071] The rotary valve 71 of the first embodiment has the release path 71e in which one communication part 71k communicates one inlet 71f with two outlets 71g, 71h (See, Fig. 9). However, a rotary valve 71 of the second modification shown in Fig. 11 has a release path 71e with separate communication parts 71k-1, 71k-2 in which one communication part 71k-1 connects an inlet 71f to a first outlet 71g and the other communication part 71k-2 connects the inlet 71f to a second outlet 71h. The communication part 71k-1 and the communication part 71k-2 meet in the middle. In other words, the communication part 71k-1 and the communication part 71k-2 diverge from each other in midstream. Such a second modification can achieve the same or similar effect as that of the

first embodiment.

(Second embodiment)

[0072] Next, a second embodiment according to the present invention will be explained with reference to Figs. 12 to 18.

[0073] The compressor 1 of the first embodiment includes the plate-shaped rotary valve 71 configured to be in slide contact with the valve plate 9. The compressor 1 according to the second embodiment includes a tubular-shaped rotary valve 71A which is slidably received in a center through hole 14 of a cylinder block 2. Other configurations of the second embodiment are the same as that of the first embodiment.

[0074] In particular, as shown in Figs. 12 and 13, a tubular portion 83 projects from a rear end of the cylinder block 2 around a circumferential edge of the center through hole 1, and the tubular portion 83 of the cylinder block extends into a suction chamber 7 of a rear head 6 through a center through hole 9c of the valve plate 9. With this configuration, the center through hole 14 of the cylinder block 2 communicates with the suction chamber 7. The valve plate 9 (or, a second partition wall) is formed with discharge holes 12 and without a suction hole. However, suction holes 11j are formed at a partition wall 85 (or, a first partition wall) by which the center through hole 14 of the cylinder block 2 and the cylinder bores Bj are separated from each other. The tubular rotary valve 71A is rotationally slidably provided in the center through hole 14 of the cylinder block 2 and is connected with a drive shaft 10, so that the rotary valve 71A can rotate with the drive shaft 10 as an integral unit.

[0075] Similar to the first embodiment, the rotary valve 71A is formed with a suction path 71c configured to communicate the suction chamber 7 to the suction holes 11j of the cylinder bores Bj subjected to a suction stroke, in turn, as the rotary valve 71A rotates. Like the first embodiment, the rotary valve 71A is provided with a release path 71e. The release path 71e is formed as a recess from a surface of the rotary valve 71A, and has an inlet 71f, a first outlet 71g, a second outlet 71h, and a communication part 71k connecting the inlet 71f to the outlets 71g, 71h. The inlet 71f and the outlets 71g, 71h are provided on a rotational trajectory which overlaps the suction holes 11j so as to connect with the suction holes 11j in sequential order as the rotary valve 71A rotates. The communication part 71k is outside of the rotational trajectory.

[0076] Figs. 13 to 17 show a connection process between the release path 71e and the cylinder bores B₁, B₄ and B₅ in a sequential order during an initial stage of a suction stroke in the cylinder bore B₁. In a position shown in Fig. 13, a piston P₁ of a cylinder bore B₁ is positioned at its upper dead center and a piston P₄ of a cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁ is positioned at its lower dead center. Thus, in the position shown in Fig. 13, in cylinder bores B₂ and

B₃ which are located between the cylinder bore B₁ subjected to the upper dead center state and the cylinder bore B₄ subjected to the lower dead center state, compressing strokes are performed, and in cylinder bores B₅ and B₆ which are located between the cylinder bore B₄ subjected to the lower dead center state and the cylinder bore B₁ subjected to the upper dead center state, suction strokes are performed.

[0077] In a period (Figs. 14 to 16) during which the release path inlet 71f is connected to the cylinder bore B₁ subjected to the initial stage of the suction stroke, the first outlet 71g communicates with the cylinder bore B₃ next to, in the counter-rotational direction, the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁ as shown in Fig. 14, and after that, the second outlet 71h communicates with the cylinder bore B₄ which is 180 degree opposite to the cylinder bore B₁ as shown in Fig. 16. Hereinafter, "A-period" refers to a period when the first outlet 71g communicates with the cylinder bore B₃ (Fig. 14) and "C-period" refers to a period when the second outlet 71h communicates with the cylinder bore B₄ (Fig. 16). Between the A-period (Fig. 14) and the C-period (Fig. 16), there is a momentary B-period (Fig. 15) when the first outlet 71g communicates with the suction hole 11₃ of the cylinder bore B₃ and the second outlet 71h communicates with the suction hole 11₄ of the cylinder bore B₄.

[0078] With this configuration, the same or similar effect as to the first embodiment can be achieved.

(First modification)

[0079] Fig. 19 is a view of a rotary valve of a first modification of the second embodiment.

[0080] In the rotary valve 71A of the second embodiment, the communication part 71k of the release path 71e is recessed from an outer circumferential surface of the rotary valve 71A and formed in a groove shape (Figs. 13 and 18). The first modification has a communication part 71k which penetrates the rotary valve 71A to form a hole therein. Such a first modification can provide the same or similar effect as that of the second embodiment.

(Second modification)

[0081] Fig. 20 is a view of a rotary valve of a second modification of the second embodiment.

[0082] The rotary valve 71A of the second embodiment is configured which a communication part 71k to connect the inlet 71f with two of the outlets 71g, 71h (Figs. 13, 18). The second modification has separate communication parts 71k-1, 71k-2 in which the communication part 71k-1 connects an inlet 71f of a release path 71e with a first outlet 71g and the communication part 71k-2 connects the inlet 71f with a second outlet 71h. The communication part 71k-1 and the communication part 71k-2 are connected to each other in midstream. Such a second modification can achieve the same or similar effect as

that of the second embodiment.

[0083] It should be appreciated that the present invention is not limited to the above detailed embodiments and modifications.

[0084] For example, although each of the above detailed embodiments has such a structure with six cylinder bores, the present invention can be applied to a structure having an even number of four or more cylinder bores which is space apart from each other in a circumferential direction. In addition, the present invention can be implemented with various other modifications without departing from technical scope of the present invention.

Claims

1. A compressor (1) comprising:

an even number of at least four of cylinder bores (Bj) evenly spaced from each other in a circumferential direction thereof around a drive shaft (10);

a suction chamber (7) separated from the cylinder bores (Bj) by a first partition wall (9, 85) provided with suction holes (11j) and configured to communicate with the cylinder bores (Bj) through the suction holes;

a discharge chamber (8) separated from the cylinder bores (Bj) by a second partition wall (9) provided with discharge holes (12j) and configured to communicate with the cylinder bores (Bj) through the discharge holes;

a piston (Pj) provided in each of the cylinder bores (Bj) and configured to reciprocate in the cylinder bores (Bj) in response to rotation of the drive shaft (10) so as to perform a suction stroke and a compression and discharge stroke alternately; and

a rotary valve (71) configured to be in rotary slidable contact with the first partition wall while covering the suction holes (11j) and to rotate in synchronizing with the rotation of the drive shaft (10),

the rotary valve (71) includes:

a suction path (71c) configured to open the suction holes (11j) of the cylinder bores (Bj) subjected to the suction strokes so as to connect the cylinder bores (Bj) to the suction chamber (7); and

a release path (71e) configured to release a high pressure residual refrigerant which could not be discharged in the compression and discharge stroke from one of the cylinder bores (Bj) subjected to an initial stage of the suction stroke to others of the cylinder bores (Bj) having a lower pressure than the one of the cylinder bores (Bj), the release path (71e) including: an inlet (71f), a first outlet (71g) and a second outlet (71h)

which are provided on a rotational trajectory to overlap with the suction holes (11j); and a communication part (71k) provided outside of the rotational trajectory and connecting the inlet and the outlets;

wherein, a time period when the inlet (71f) of the release path (71e) is connected to a first one of the cylinder bores (Bj) subjected to an initial state of the suction stroke include: an A-period when the first outlet (71g) is connected to a second one of the cylinder bores (Bj) next to, in a counter-rotational direction, a third one of the cylinder bores (Bj) which is located 180 degree opposite to the first one of the cylinder bores (Bj), and after the A-period, a C-period when the second outlet (71h) is connected to the third one of the cylinder bores (Bj) which is 180 degree opposite to the first one of the cylinder bores (Bj).

2. The compressor according to Claim 1, wherein the A-period and the C-period are partially overlapped so that the C-period follows the A-period without a break therebetween.

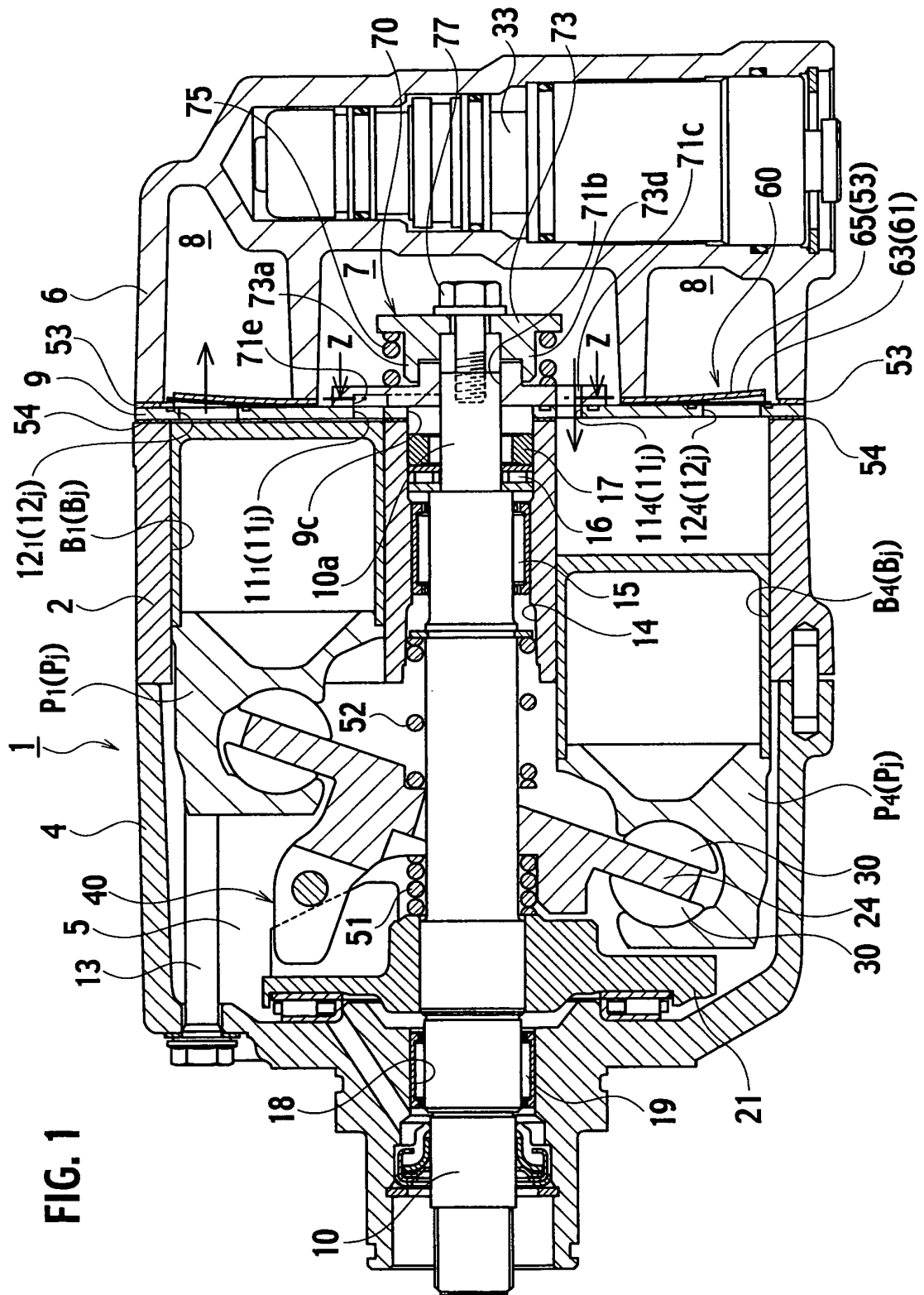


FIG. 2

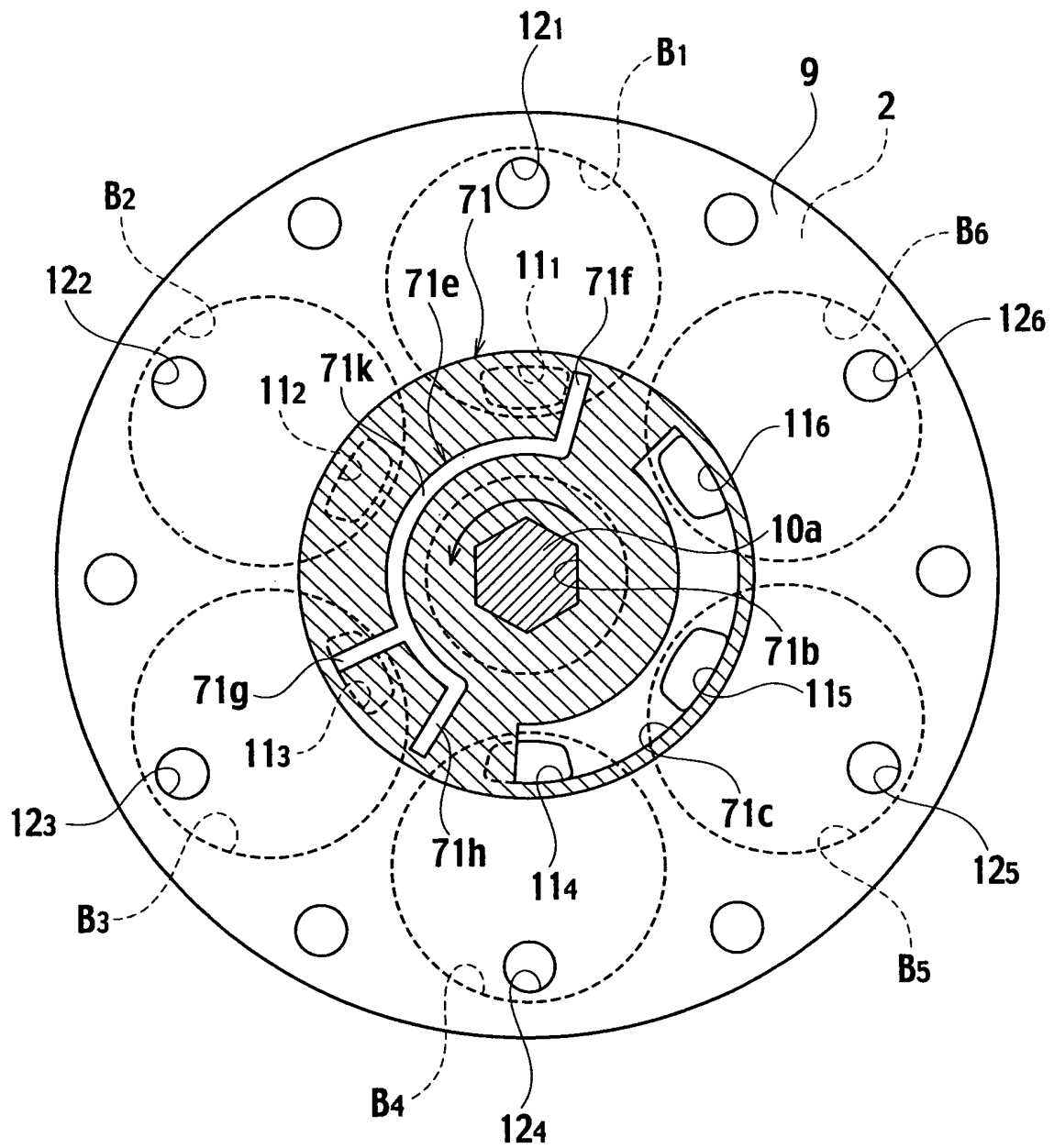


FIG. 3

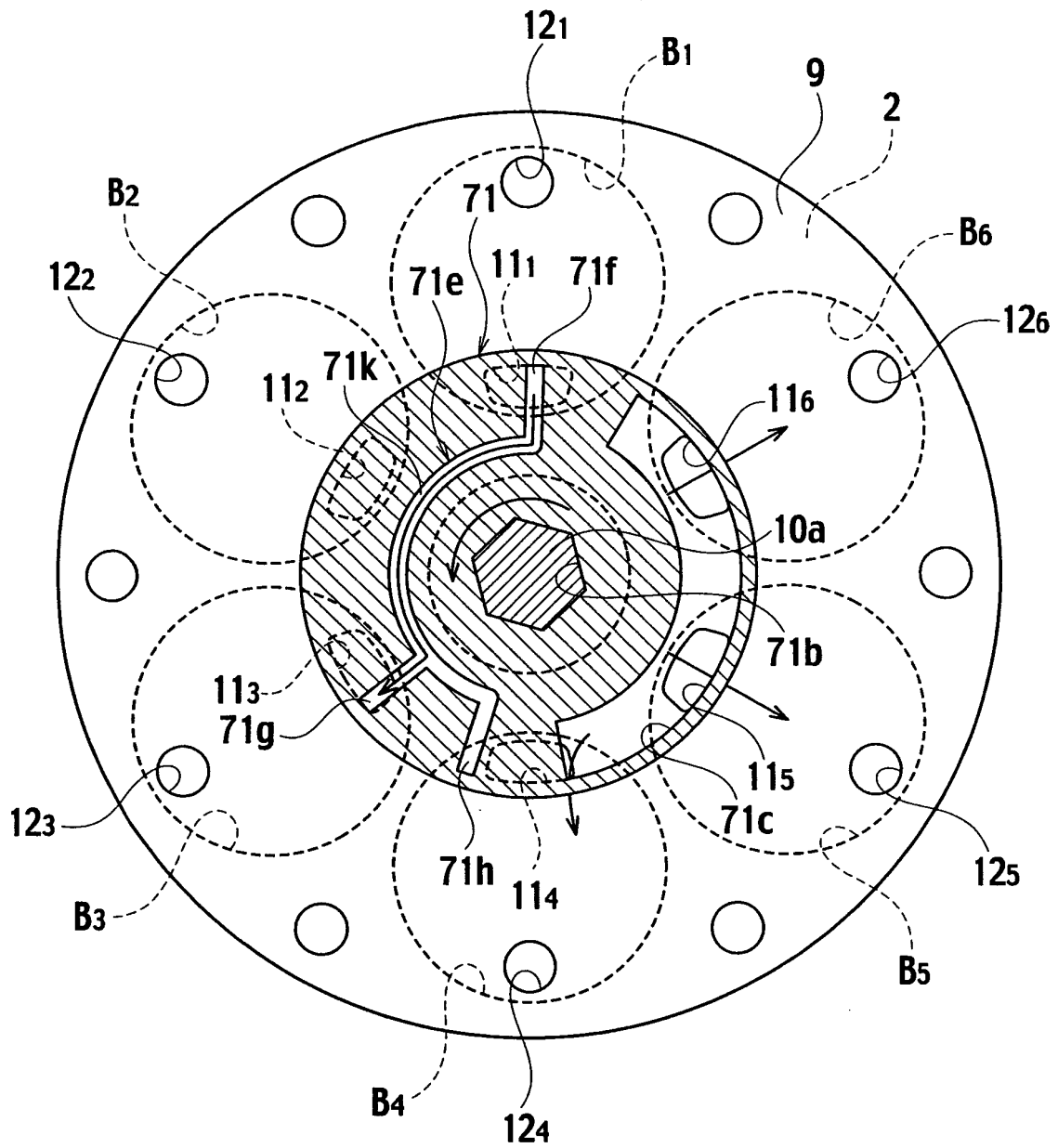


FIG. 4

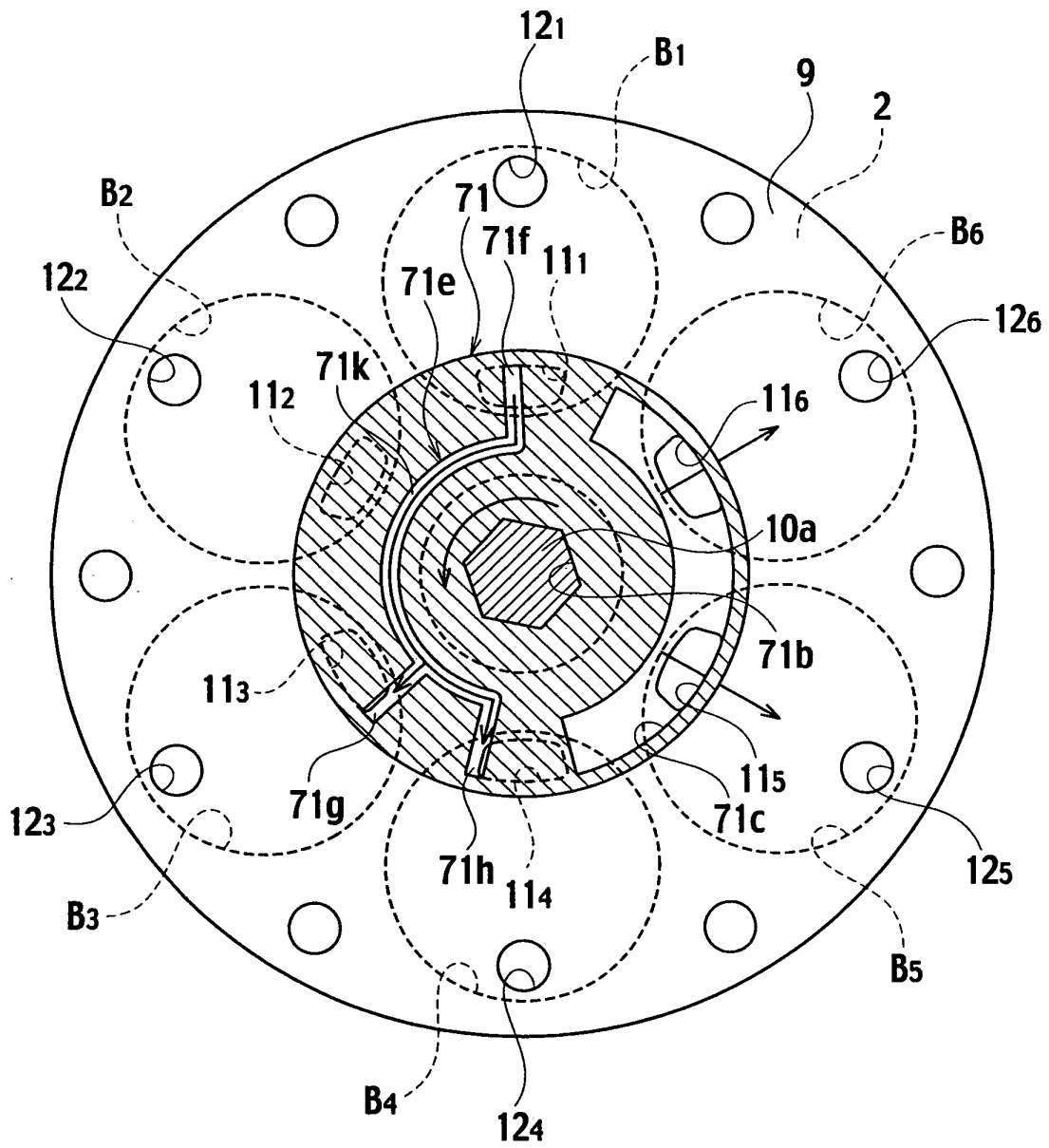


FIG. 5

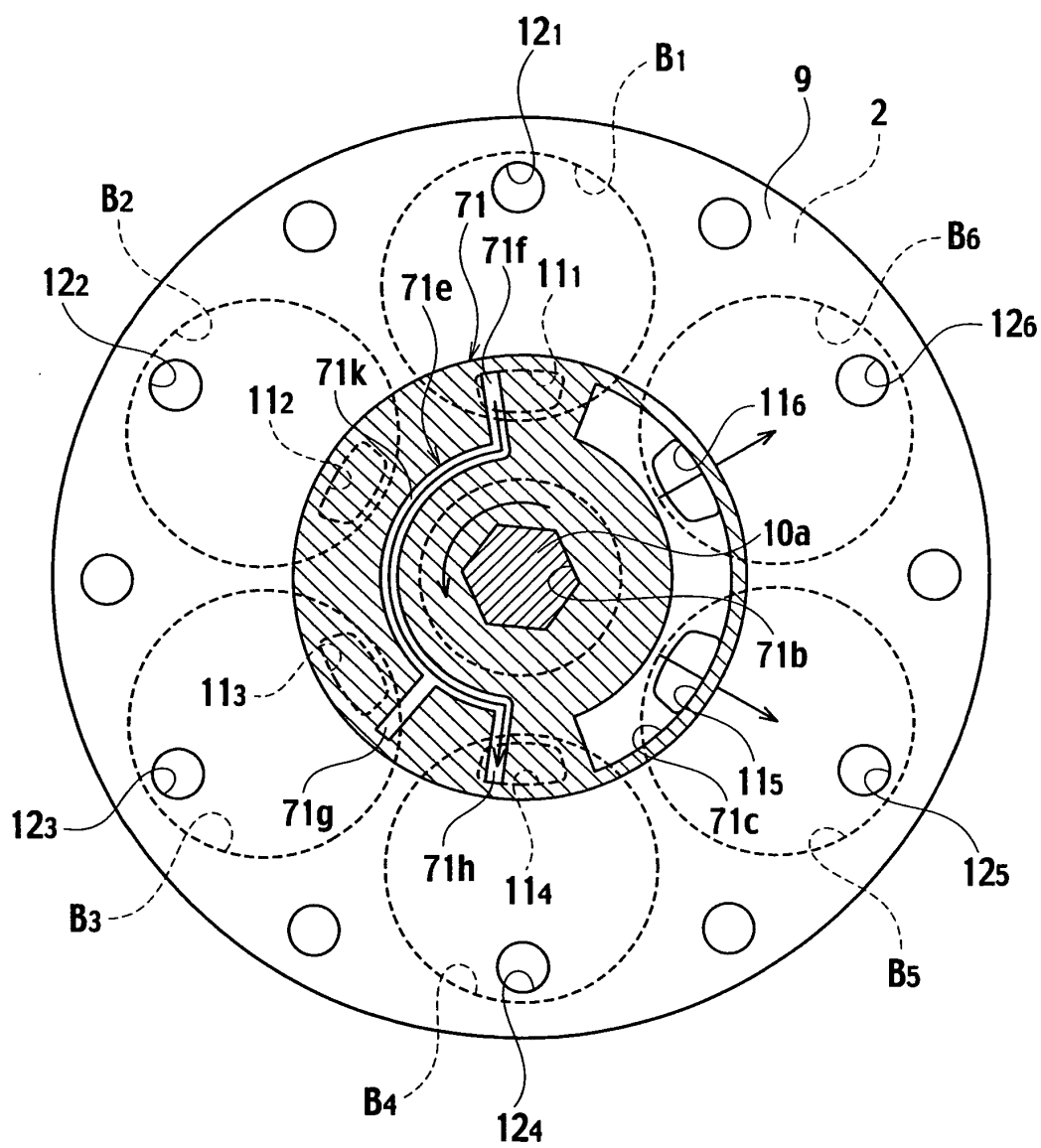


FIG. 6

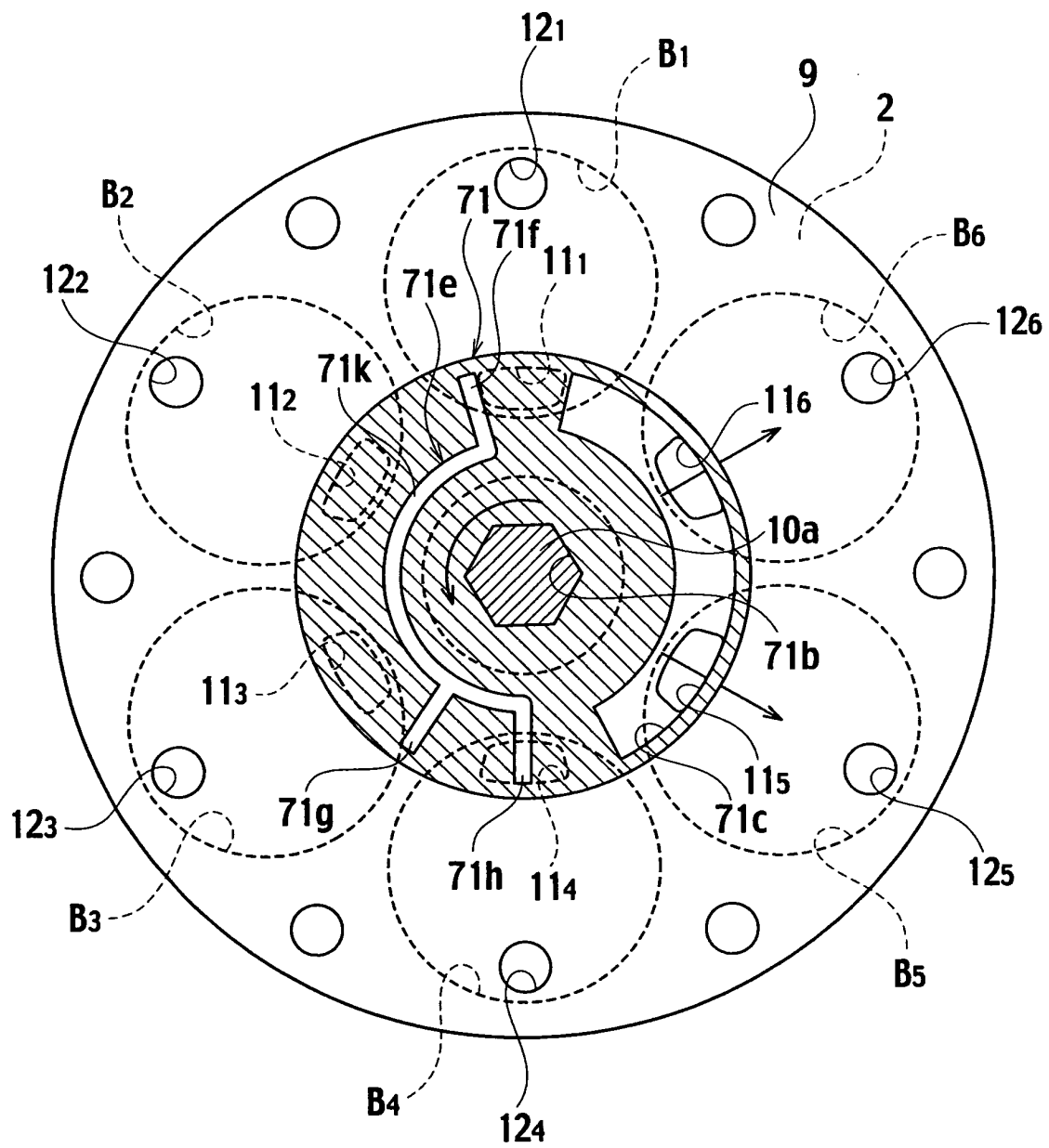


FIG. 7

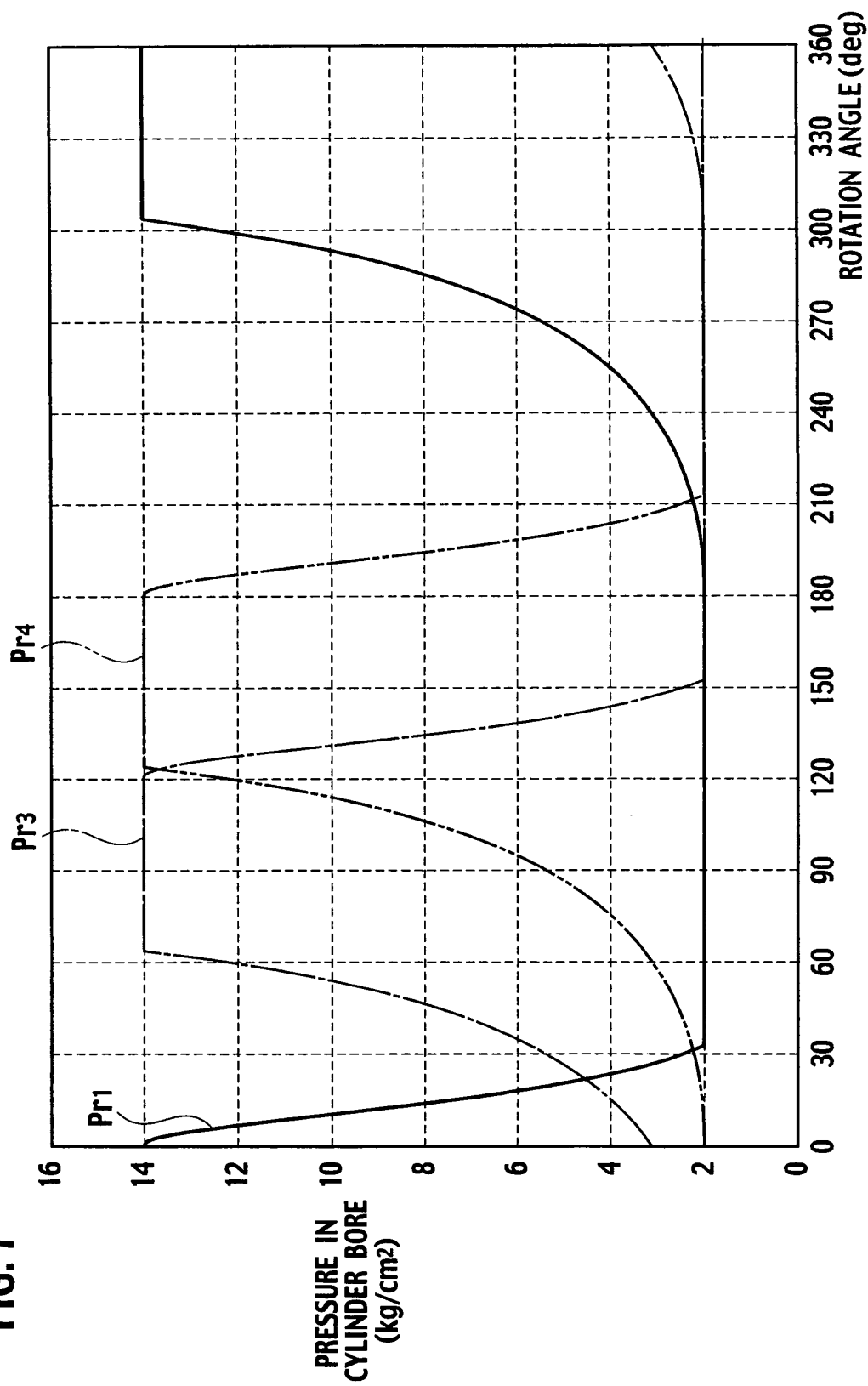


FIG. 8

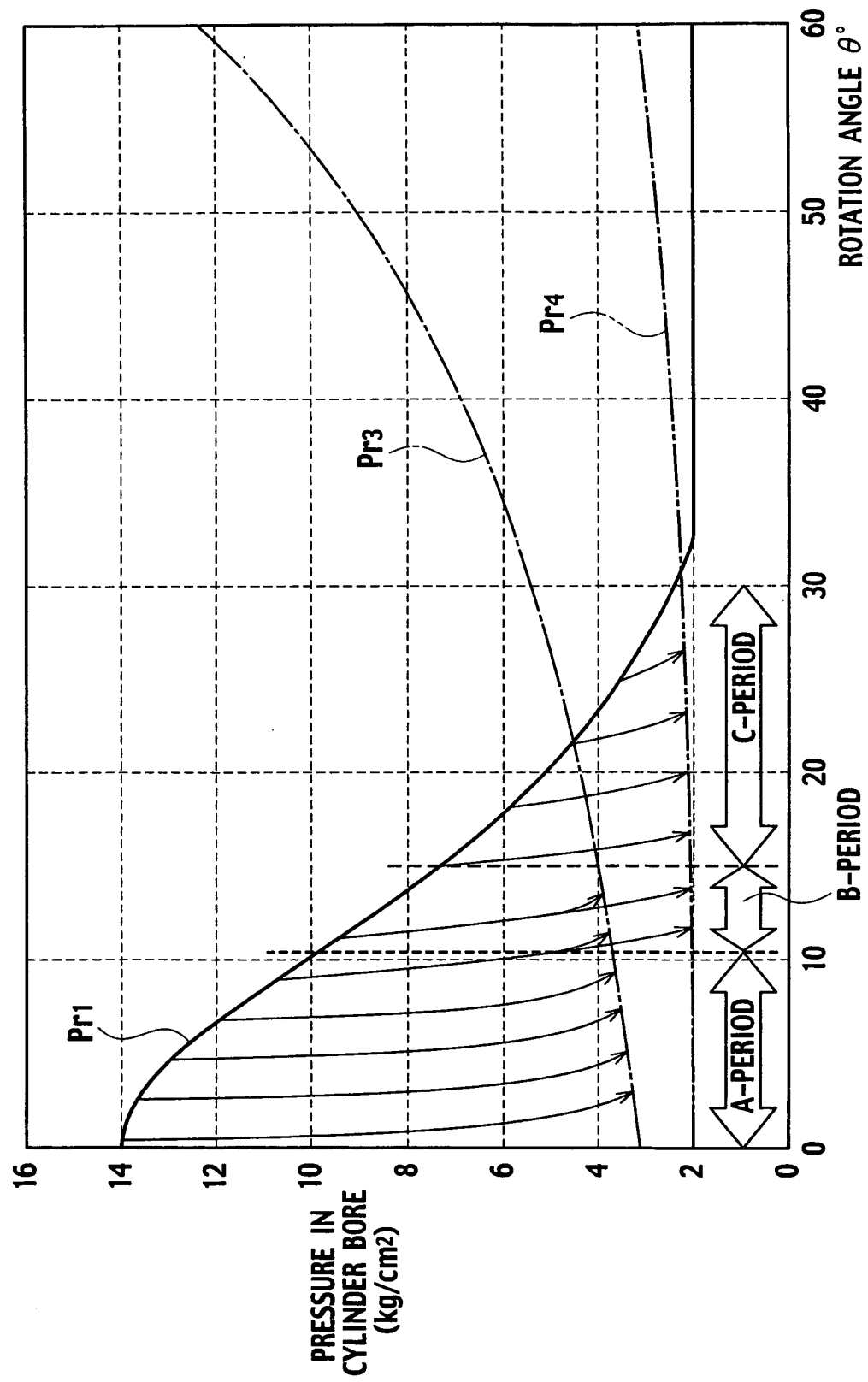


FIG. 9

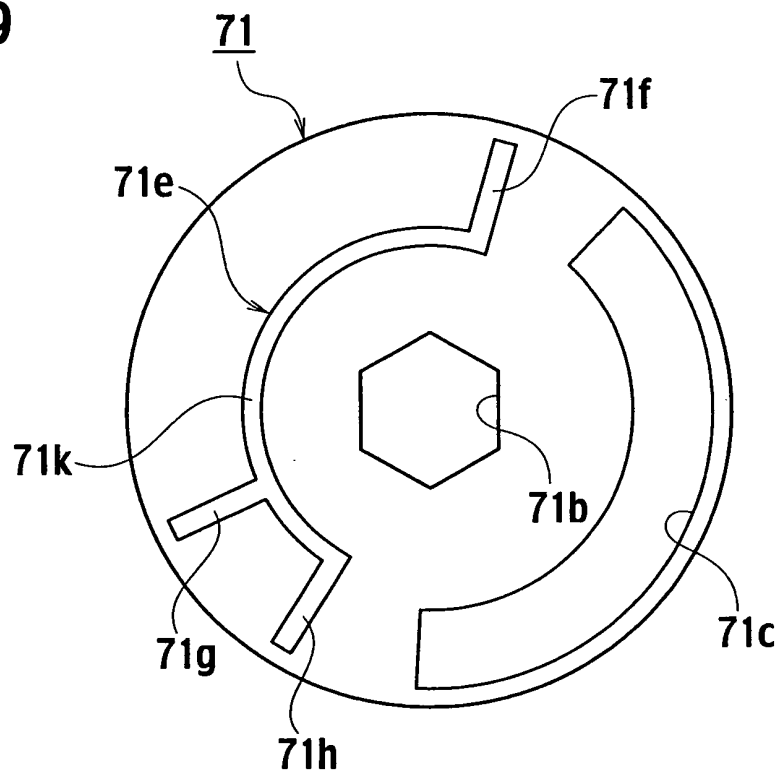


FIG. 10

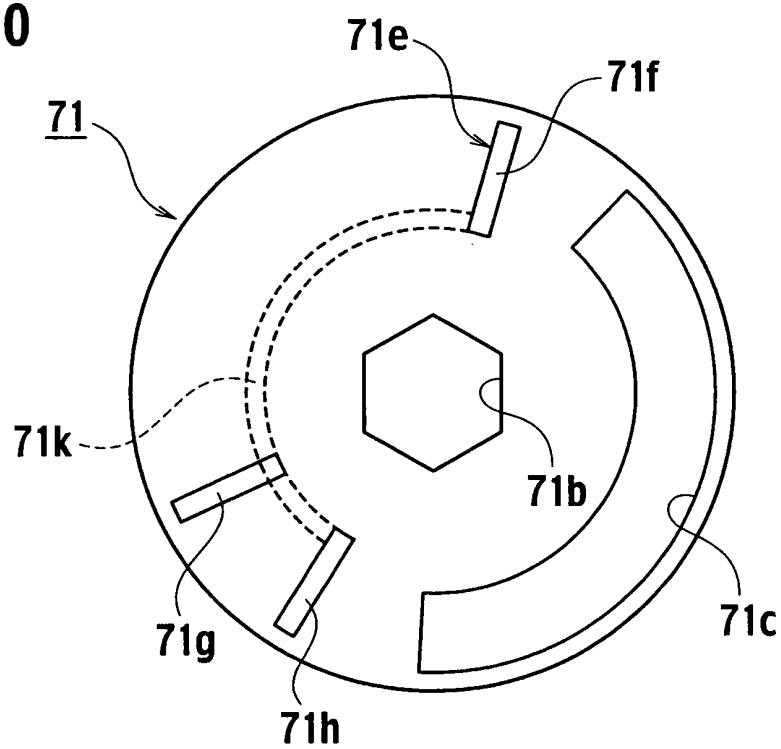
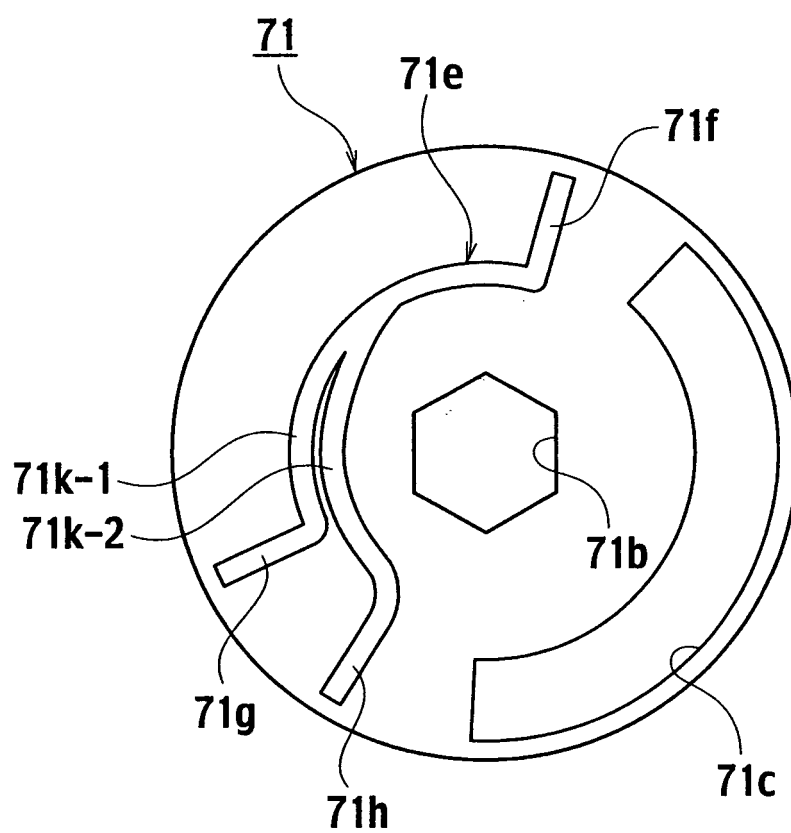


FIG. 11



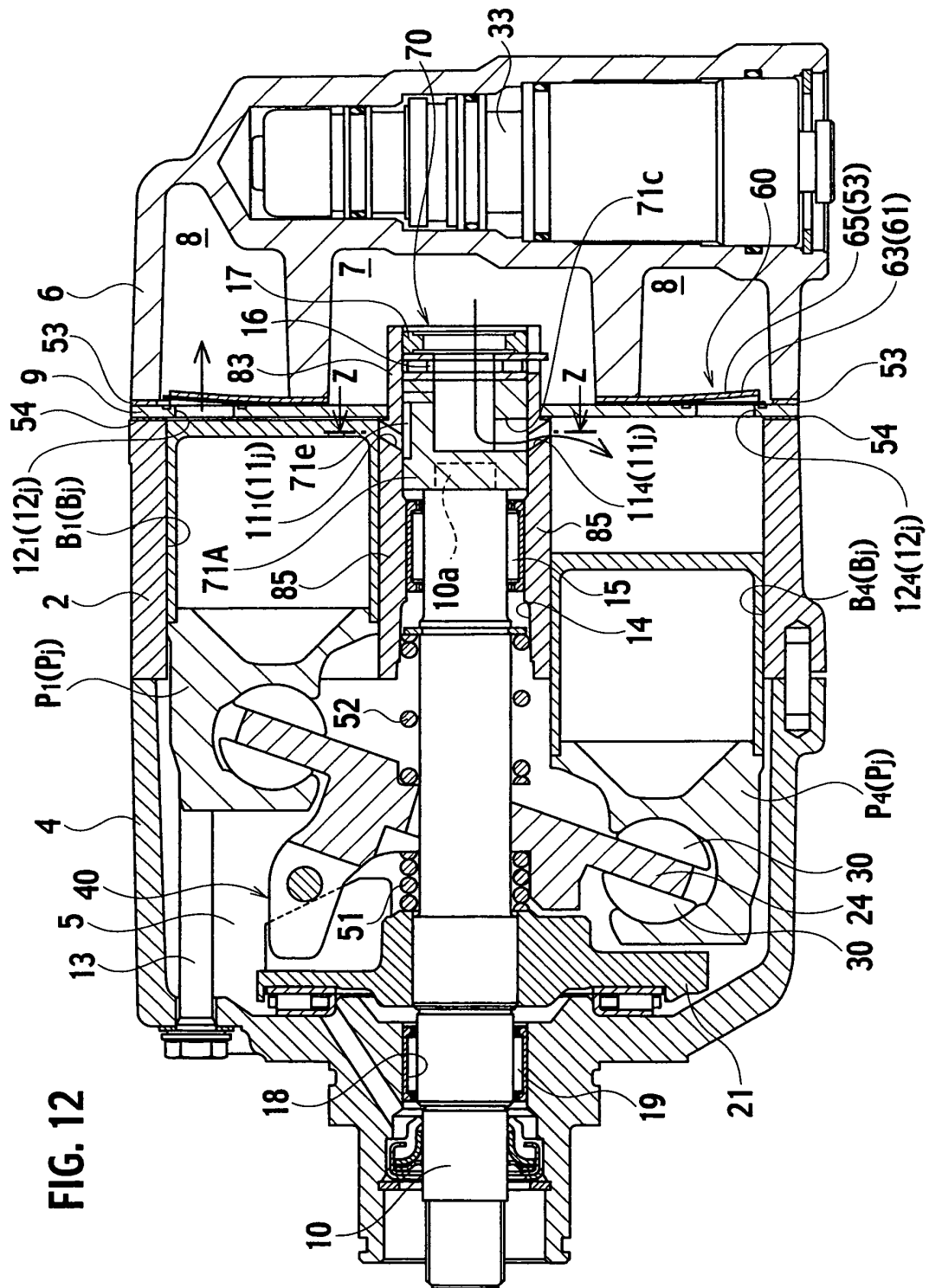


FIG. 13

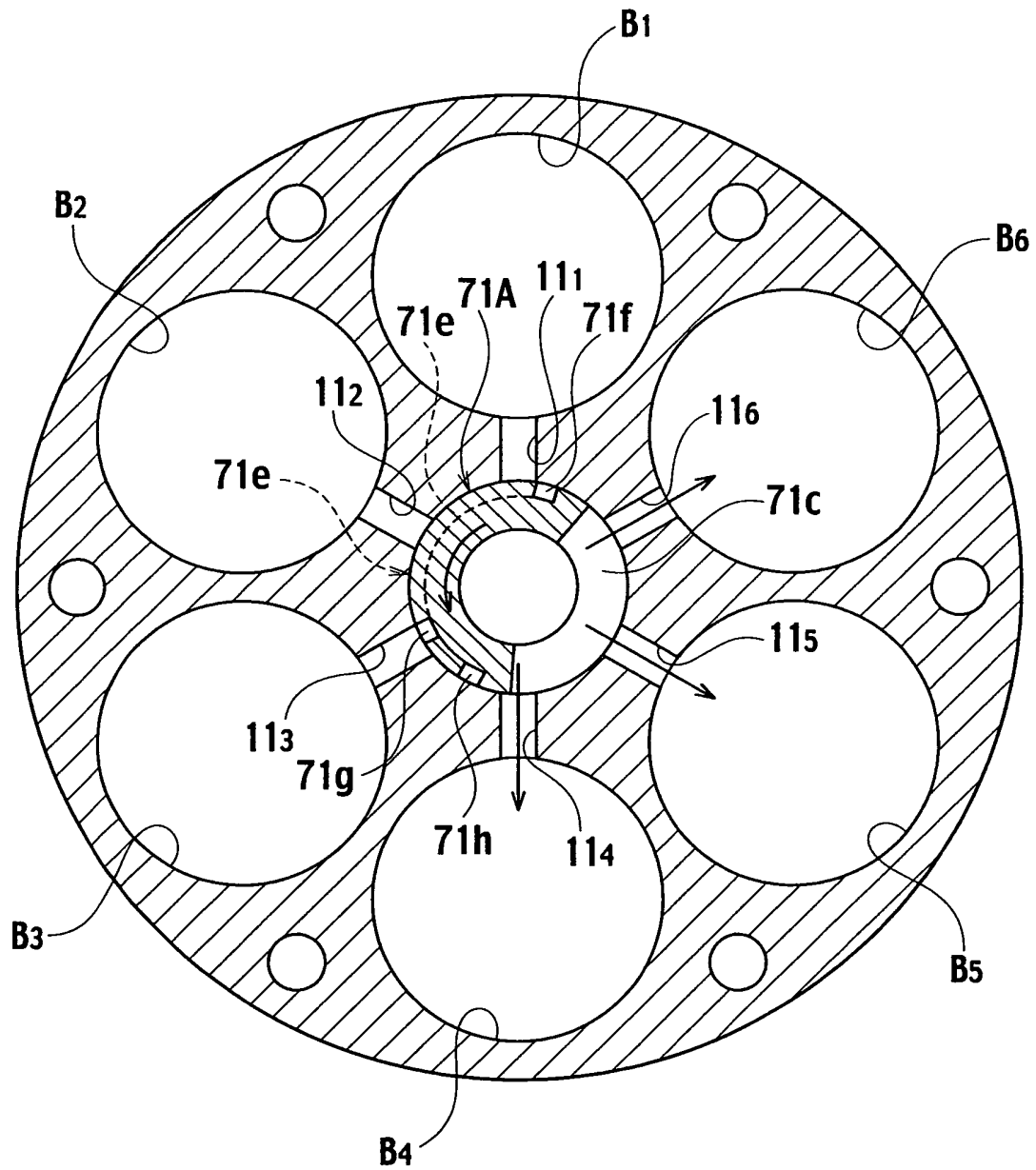


FIG. 14

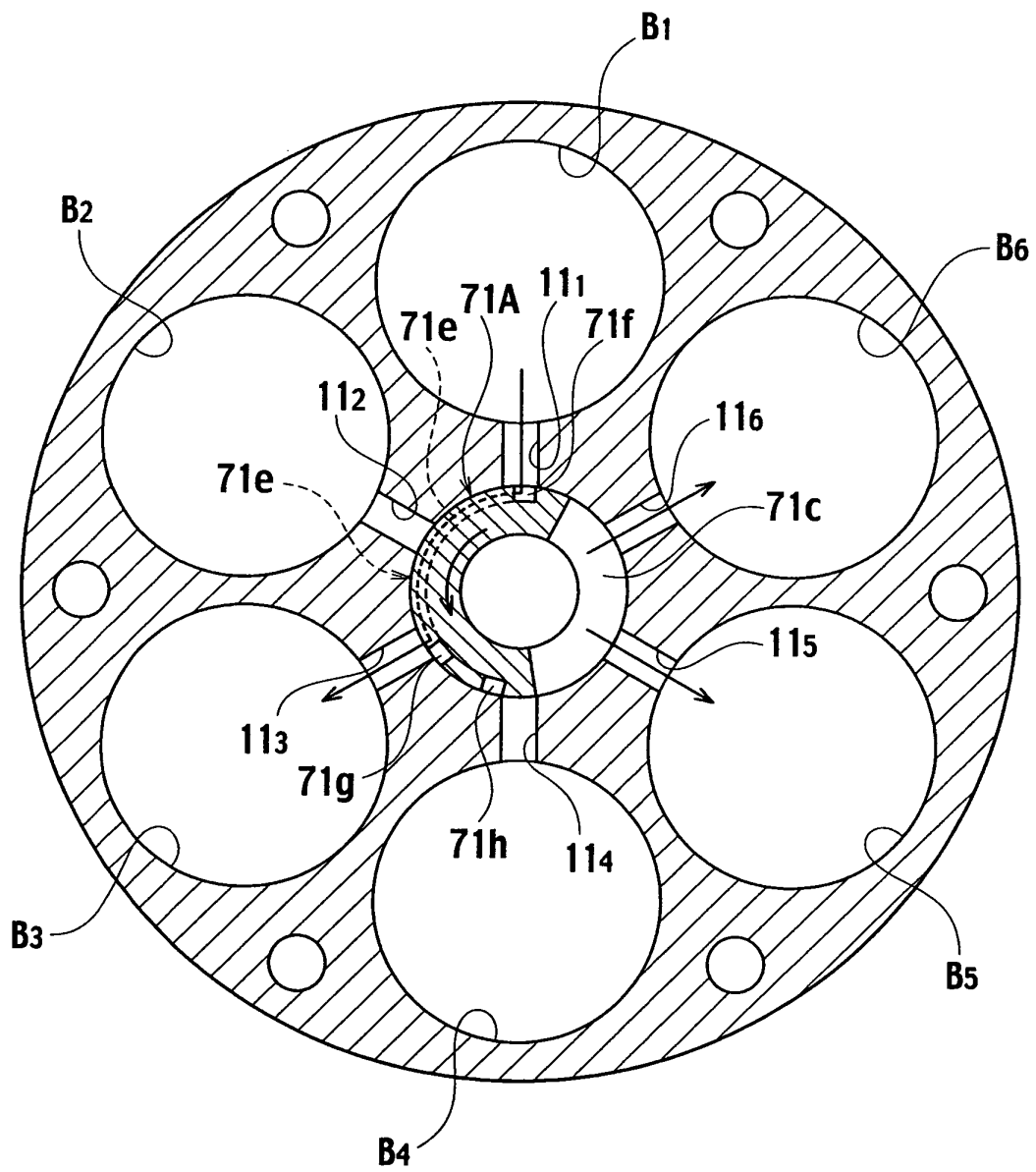


FIG. 15

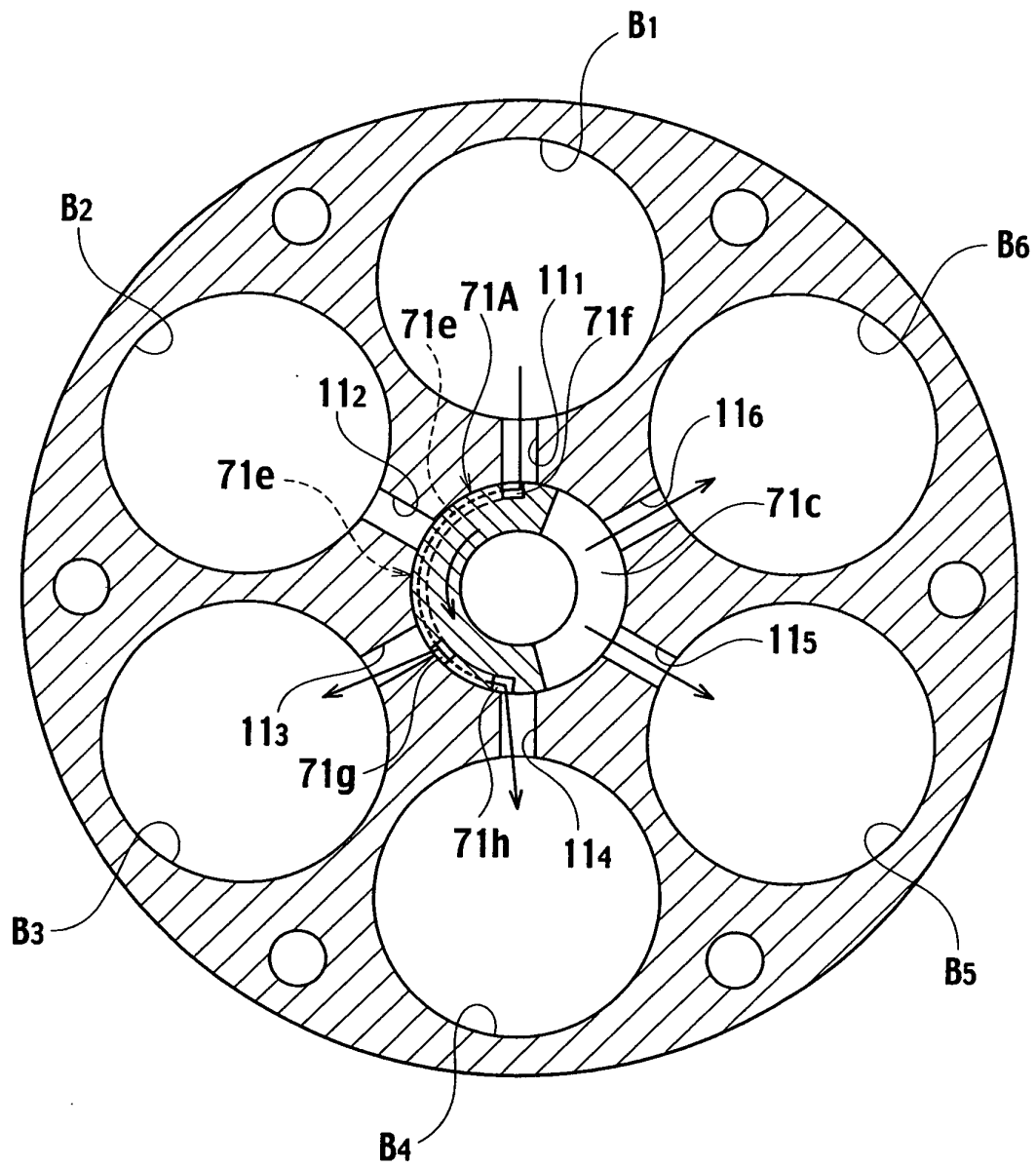


FIG. 16

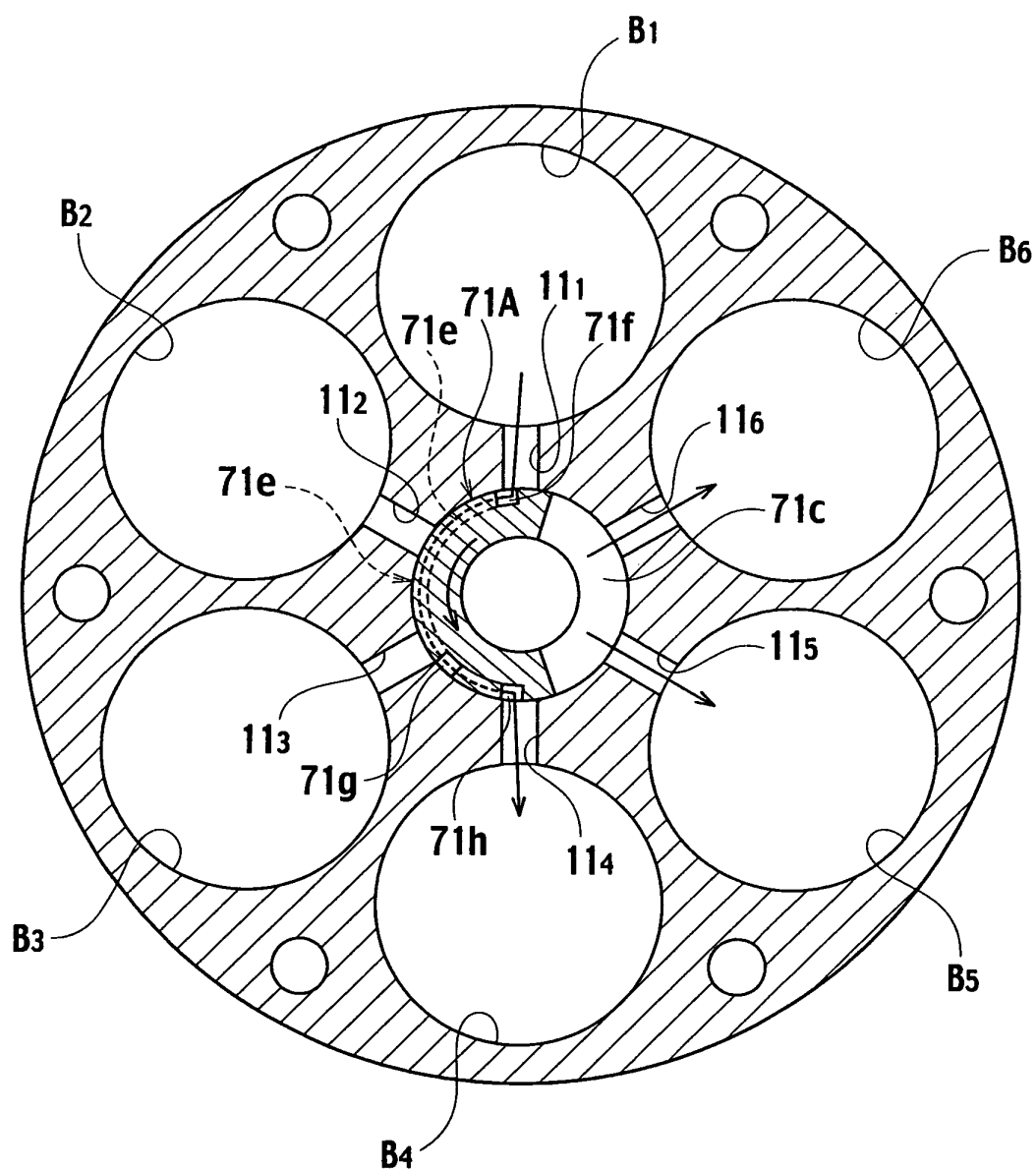


FIG. 17

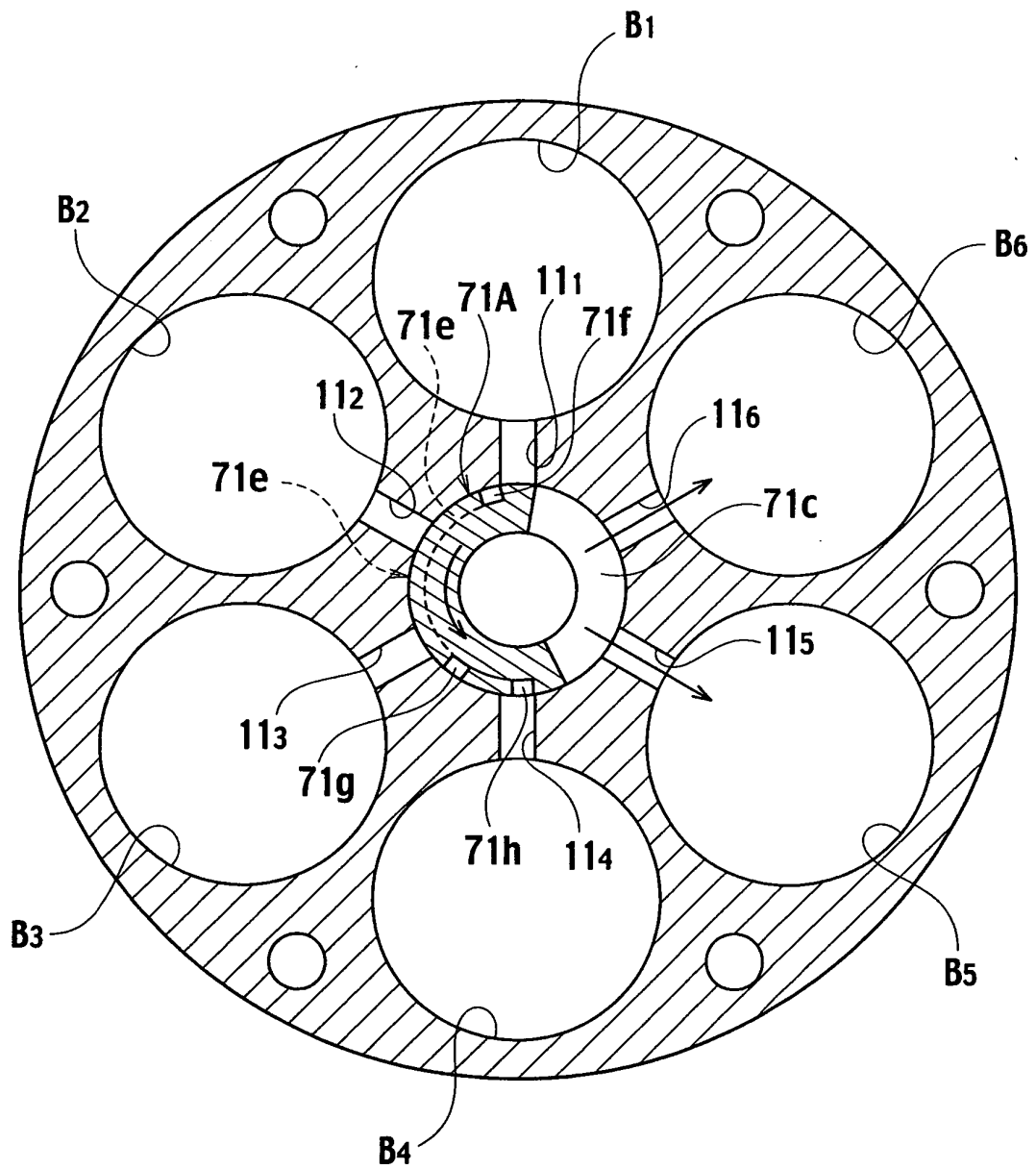


FIG. 18

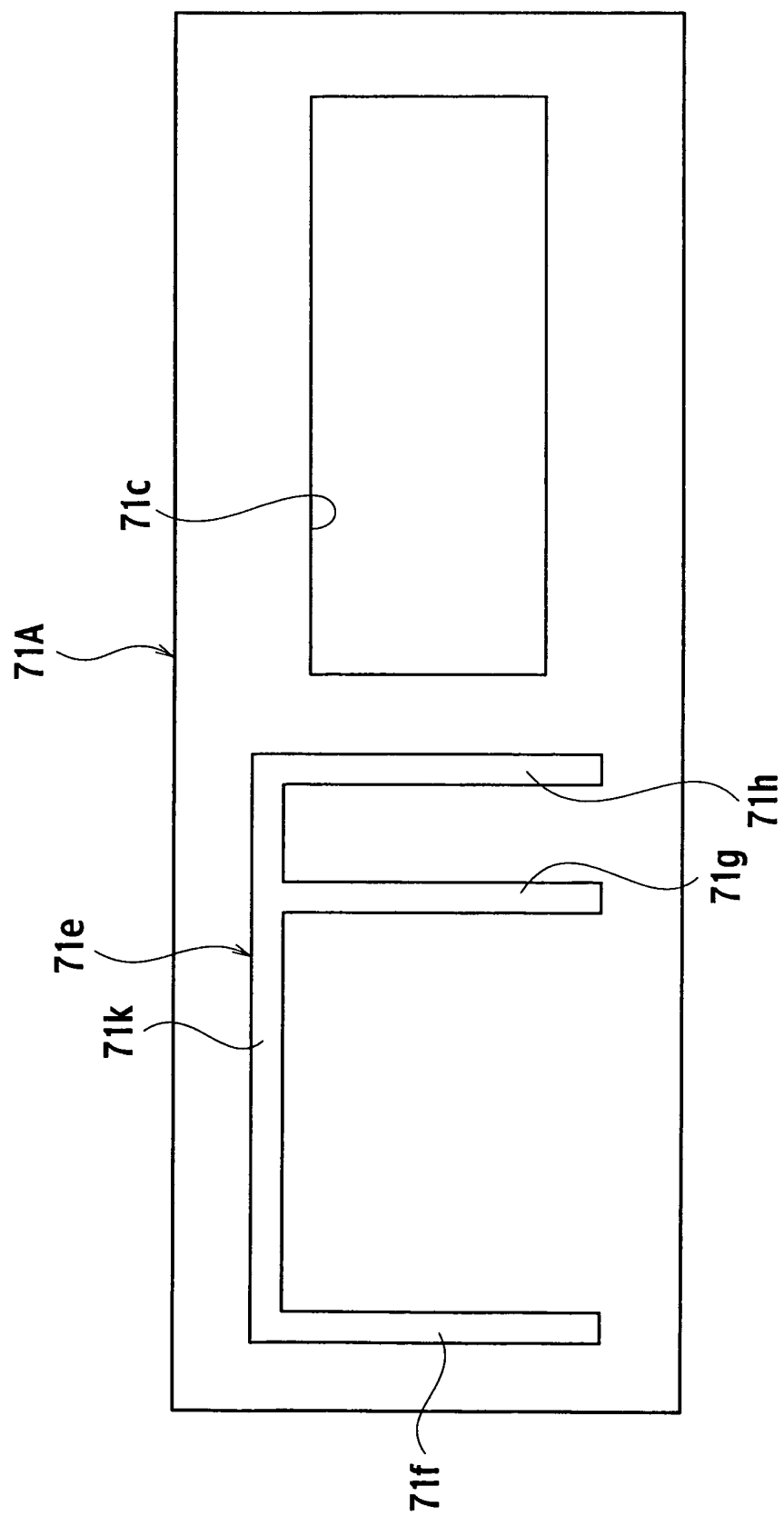


FIG. 19

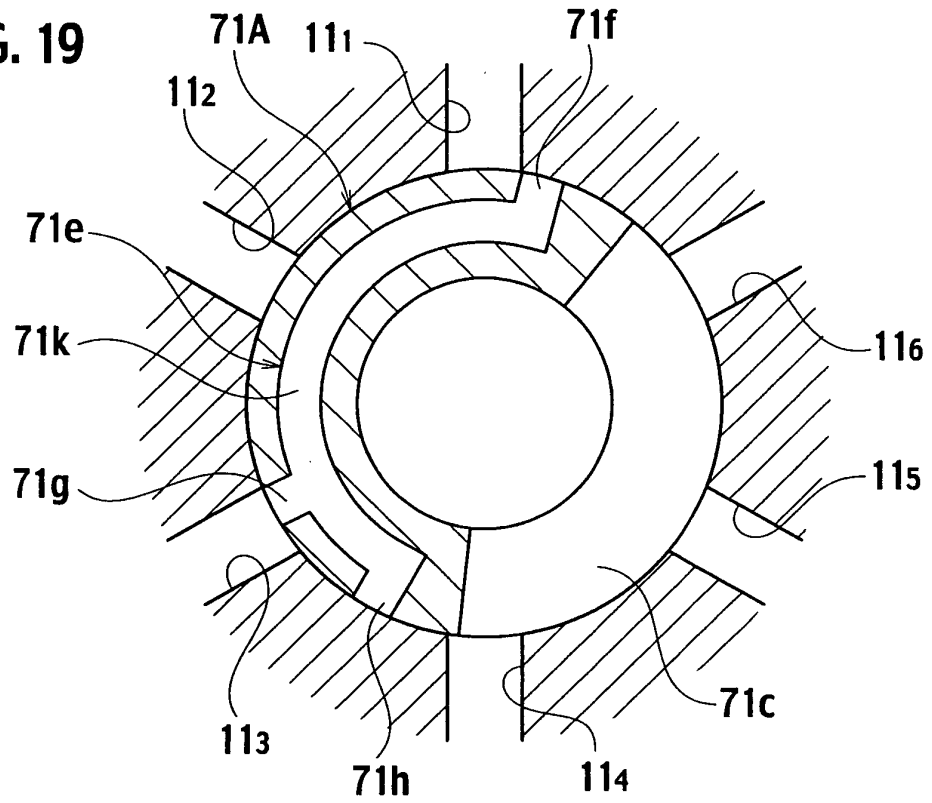
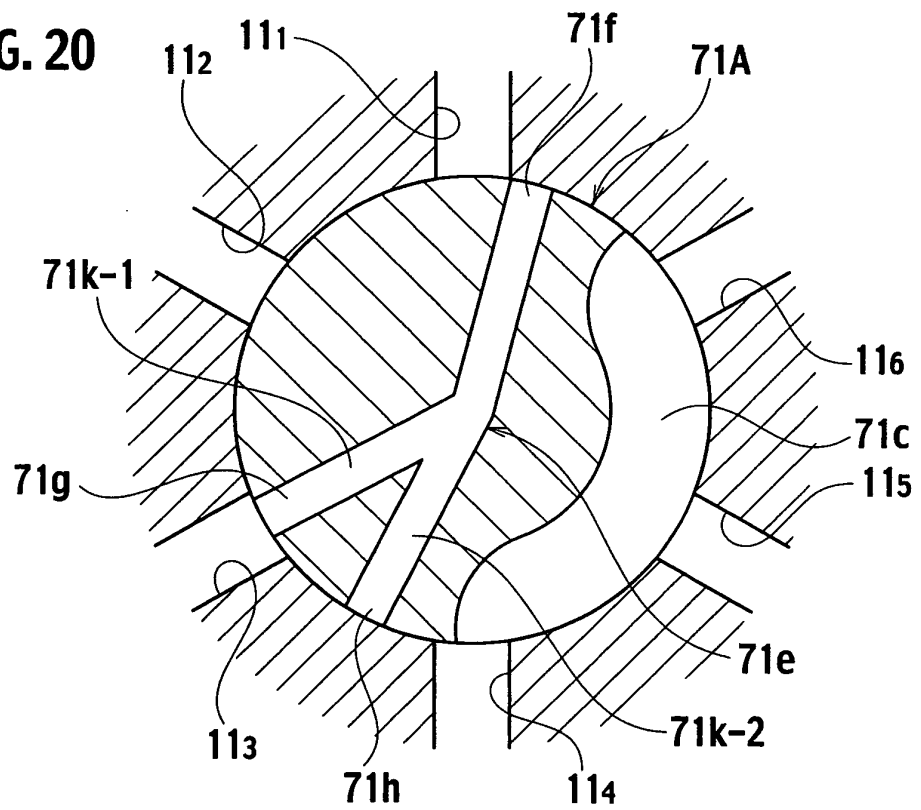


FIG. 20



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/064555

A. CLASSIFICATION OF SUBJECT MATTER F04B27/10(2006.01) i		
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) F04B27/10		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007 Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007		
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.
X A	JP 6-221264 A (Toyoda Automatic Loom Works, Ltd.), 09 August, 1994 (09.08.94), Par. Nos. [0020] to [0021]; Figs. 1 to 5 & DE 4401836 A1 & KR 970004383 B1 & US 5380168 A	1 2
A	JP 6-129350 A (Toyoda Automatic Loom Works, Ltd.), 10 May, 1994 (10.05.94), Par. Nos. [0030] to [0032]; Figs. 8 to 9 (Family: none)	1-2
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 21 August, 2007 (21.08.07)		Date of mailing of the international search report 04 September, 2007 (04.09.07)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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- JP 3079741 B [0006]
- JP 8144946 A [0065] [0066]