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(54) Capacity control valve for variable displacement compressor

(57) A valve element 2 of a capacity control valve for a variable displacement compressor is disposed in a refrigerant passage between a discharge chamber and a crank chamber of the compressor. The valve element 2 can be seated on a valve seat 5a from a crank chamber side. A valve seat-forming member 3 is so formed as to contain the valve seat 5a, a valve hole 5 and a through hole 6 as a communication passage between discharge chamber and crank chamber sides. When a solenoid closes the valve, refrigerant from the discharge chamber side flows through the through hole 6 to the crank chamber side, to circulate lubricating oil within the compressor.

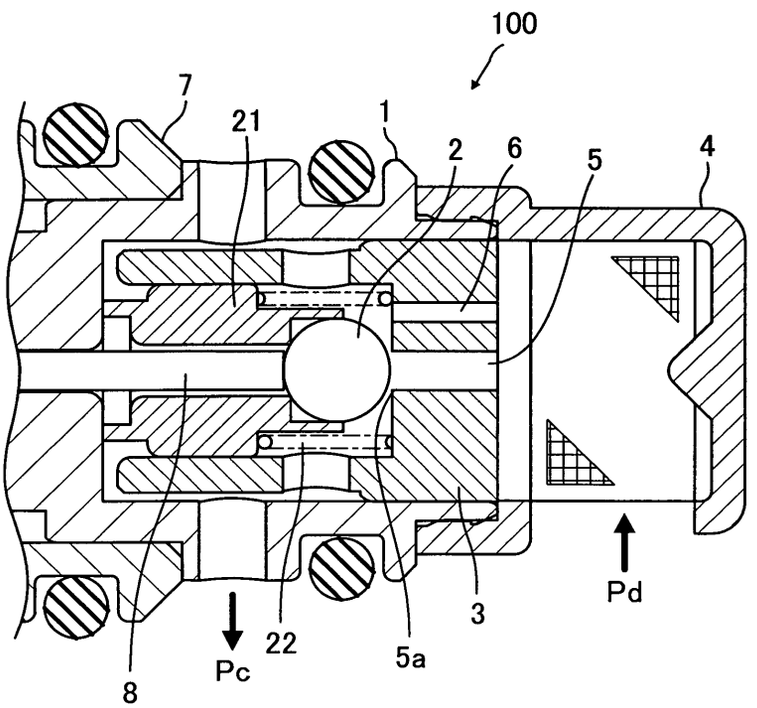

FIG. 2

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Description

[0001] This invention relates to a capacity control valve according to the preamble of claim 1 and of claim 7, particularly for a variable displacement compressor in a refrigeration cycle of an automotive air conditioning system.

[0002] In a known automotive air conditioning system, a variable displacement compressor is employed to obtain adequate cooling capacity without restriction by the rotational speed of the engine driving the compressor. The angle of a piston driving wobble plate is varied to change the delivery quantity of the compressor. The angle is continuously changed by introducing part of the compressed refrigerant into a gastight crank chamber and changing the pressure within the crank chamber.

[0003] The amount of compressed refrigerant introduced into the crank chamber is controlled by a capacity control valve disposed, e.g., in a refrigerant flow path between a discharge chamber and the crank chamber. The valve holds the differential pressure between the discharge chamber pressure and a suction chamber pressure at a predetermined value which is externally set by a value of electric current applied to a solenoid of the valve. The amount of refrigerant discharged from the compressor is not influenced by variations of the engine speed. A variable displacement compressor is known in which a passage extending from a discharge chamber to a crank chamber via the capacity control valve is used as an oil return passage to efficiently introduce lubricating oil contained in the refrigerant into the compressor.

[0004] Another known compressor employs an oil separator returning lubricating oil contained in the refrigerant into the crank chamber. The oil separator may be disposed in an oil return passage, for directly returning refrigerant from the discharge chamber to the crank chamber without introducing the oil burdened refrigerant into an external refrigerant circuit.

[0005] Another known compressor (JP-A-2002-213350) has an oil separator in an extraction passage between the crank chamber and the suction chamber. Separated lubricating oil is introduced into a passage extending from the capacity control valve to the crank chamber. Lubricating oil discharged from the discharge chamber then is returned directly and quickly to the crank chamber.

[0006] In the known variable displacement compressor, in which the passage extending from the discharge chamber to the crank chamber via the capacity control valve is used as the oil return passage, it is possible to return lubricating oil to the crank chamber by a simple construction. However, the amount of returned lubricating oil is undesirably influenced by the adjusted state of the valve lift or opening degree of the capacity control valve. When the valve is fully closed no oil is returned to the crank chamber, and hence sufficient lubrication of the compressor cannot be assured. This can cause seizure of the pistons and a stop of the operation of the compressor. When the oil separator is used, the construction of the compressor is much more complicated, and the size of the compressor is undesirably increased by the oil separator.

[0007] It is an object of the invention to provide a capacity control valve for a variable displacement compressor for efficiently returning lubricating oil contained in the refrigerant to the crank chamber by a simple construction.

[0008] To solve the above problem, the present invention provides a capacity control valve according to claim 1 or claim 7.

[0009] Since the communication passage communicating the discharge chamber and the crank chamber is additionally formed in the valve seat-forming member of the valve disposed between the discharge chamber side and the crank chamber side within the compressor, even when the valve element is seated on the valve seat for closing the capacity control valve, lubricating oil returning refrigerant nevertheless is introduced by a simple construction into the crank chamber. The capacity control valve can be manufactured at low costs and seldom suffers a breakdown.

[0010] Embodiments of the invention will be described with reference to the drawings. In the drawings is:

Fig. 1 a longitudinal cross-section of a capacity control valve (first embodiment),

Fig. 2 an enlarged view of a valve element of the capacity control valve shown in Fig. 1,

Fig. 3 a central longitudinal cross-section of another capacity control valve (second embodiment),

Fig. 4 an enlarged view of a valve element of the capacity control valve shown in Fig. 3,

Fig. 5 a central longitudinal cross-section of another capacity control valve (third embodiment), and

Fig. 6 an enlarged view of a valve element of the capacity control valve shown in Fig. 5.

[0011] The capacity control valve 100 of Fig. 1 is arranged in an intermediate portion of a refrigerant flow path extending from a discharge chamber to a crank chamber within a not shown variable displacement compressor e.g. for an automotive air conditioning system. The valve 100 controls the amount of refrigerant introduced into the crank chamber of the compressor to vary the discharge amount of the compressor.

[0012] The capacity control valve 100 includes a spherical valve element 2 in the refrigerant flow path formed in an upper body 1. The flow path communicates at one end with the discharge chamber and at the other

end with the crank chamber. The upper body 1 has an inner space communicating with the crank chamber, and contains a pressed-in valve seat-forming member 3. A strainer 4 covers the upper edge of the upper body 1. The inner space of the strainer 4 communicates with the discharge chamber. A valve hole 5 communicating the discharge chamber-side space and the crank chamber-side space is formed in the valve seat-forming member 3. The crank chamber-side end of the valve hole 5 defines a valve seat 5a for the valve element 2. A through hole 6 extends e.g. in parallel with the valve hole 5 in the valve seat-forming member 3. The through hole 6 as well connects the discharge chamber-side and the crank chamber-side spaces.

[0013] The upper body 1 is press-fitted into an upper opening of a lower body 7. A piston rod 8 having the same diameter as the valve hole 5 (to be more precise, a portion corresponding to the valve seat 5a on which the valve element 2 is seated) is disposed axially movably along the axis of the upper body 1. One end of the piston rod 8 abuts at the valve element 2 on a side remote from the valve hole 5. The other end of the piston rod is exposed in an inner space of the lower body 7. That inner space of the lower body 7 communicates with a suction chamber of the variable displacement compressor. The piston rod 8 receives suction pressure Ps from the suction chamber at the exposed end. A lower opening of the lower body 7 is closed by a cap 9.

[0014] Within the lower body 7, there are arranged a fixed core 10 and a sleeve 11 of a solenoid section. The fixed core 10 has an upper central opening screwed onto a lower protruding portion of the upper body 1. A shaft 12 is axially movably inserted along the axis of the fixed core 10. One end of the shaft 12 abuts the end of the piston rod 8. The other end of the shaft 12 is fitted into a movable core 13. The shaft 12 and the movable core 13 slide axially in unison. The sleeve 11 is surrounded by a solenoid coil including a bobbin 14 and a magnet wire coil 15.

[0015] A spring 16 is disposed between the movable core 13 and the fixed core 10. Another spring 17 is disposed between the end of the movable core 13 remote from the fixed core 10 and the bottom of the sleeve 11.

[0016] An O ring 18 on the periphery of the upper body 1 seals between the portion communicating with the discharge chamber and receiving discharge pressure Pd and the portion communicating with the crank chamber and receiving pressure Pc when the capacity control valve 100 is mounted in the variable displacement compressor. An O ring 19 on the periphery of the lower body 7 seals between the portion receiving the pressure Pc from the crank chamber and the portion communicating with the suction chamber and receiving the suction pressure Ps. An O ring 20 on the periphery of the lower body 7 seals between the portion receiving the suction pressure Ps and the atmosphere.

[0017] The valve seat-forming member 3 in Fig. 2 is formed as to have the valve hole 5 and the through hole 6 e.g. extending in parallel with the valve hole 5. Both holes 5, 6 connect the discharge chamber-side and the crank chamber-side spaces.

[0018] The valve element 2 in Fig. 2 is held by a valve element-holding member 21 disposed in the lower opening of the valve seat-forming member 3 in a manner slidable along the axis of the piston rod 8, for causing the valve element 2 to open and close the valve hole 5. Between the valve-holding member 21 and the bottom portion of the valve seat-forming member 3, which is opposed to the valve element-holding member 21 from a valve element side, there is disposed a spring 22 for urging the valve element element-holding member 21 in valve opening direction.

[0019] Within the capacity control valve 100 of Figs 1 and 2, the discharge pressure Pd introduced from the discharge chamber acts leftward on the valve element 2. The suction pressure Ps from the suction chamber acts rightward on the piston rod 8. An effective pressure-receiving area of the valve element 2 on which the discharge pressure Pd is received is equal to the pressure-receiving area of the piston rod 8 on which the suction passage Ps is received. Therefore, the valve element 2 controlling the flow rate of refrigerant from the discharge chamber to the crank chamber forms a differential pressure valve that senses the differential pressure between the discharge pressure Pd and the suction pressure Ps and operates in response thereto.

[0020] When no current is supplied to the magnet wire coil 15 the discharge pressure Pd pushes the valve element 2 open. The capacity control valve 100 is fully opened. In the variable displacement compressor, the value of the pressure Pc in the crank chamber is held close to the discharge pressure Pd. The difference between the pressures applied to both end faces of each piston (one end face in the crank chamber, the other end face in a cylinder for compressing refrigerant into the discharge chamber) is minimized. The wobble plate in the crank chamber is inclined at such an inclination angle that minimizes the length of the piston stroke, thus controlling the variable displacement compressor to a minimum capacity operation.

[0021] When a maximum control current is supplied to the magnet wire coil 15, the movable core 13 is attracted by the fixed core 10 and moves rightward. The capacity control valve 100 is fully closed. By maintaining communication between the suction chamber side and the crank chamber side via a not shown orifice only refrigerant in the crank chamber is allowed to flow into the suction chamber via the orifice, whereby the pressure Pc within the crank chamber is lowered to a value close to the suction pressure Ps within the suction chamber. The difference between the pressures applied to the opposite end faces of each piston is maximized, whereby the wobble plate is inclined at such an inclination angle that maximizes the length of the piston stroke, thus controlling the variable displacement compressor to a maximum capacity operation.

[0022] During execution of a normal control with a predetermined control current supplied to the magnet wire coil 15 the movable core 13 is attracted toward the fixed core 10 with a magnetic force according to the magnitude or value of the control current. The force generated moves the movable core 13 rightward. This force serves as a set value for the valve element 2 operating as a differential pressure valve. Therefore, the capacity control valve 100 senses the differential pressure between the discharge pressure Pd and the suction pressure Ps, and controls the flow rate of refrigerant flowing from the discharge chamber to the crank chamber such that the differential pressure is maintained at a differential pressure corresponding to the value set by the current supplied to the solenoid section.

[0023] The refrigerant flowing in the capacity control valve 100 and in the variable displacement compressor contains lubricating oil for lubrication of the inside of the variable displacement compressor. The flow path between the discharge chamber and the crank chamber via the capacity control valve 100 also functions as an oil return passage for returning the lubricating oil. Compressed refrigerant discharged from the discharge chamber returns to the crank chamber through the short route without passing through an external refrigerant circuit, which enables the lubricating oil to efficiently internally circulate from the discharge chamber to the crank chamber, and then from the crank chamber to the suction chamber via the mentioned orifice.

[0024] When the valve element 2 is fully seated on the valve seat 5a by energization of the solenoid section, any flow of refrigerant from the discharge chamber to the crank chamber would be stopped, disabling the function of the flow path as the oil return passage. To overcome this problem, according to the present invention, an additional communication passage which allows refrigerant to flow to the crank chamber when the capacity control valve 100 is closed is formed in the valve seat-forming member 3, to thereby maintain oil circulation even when the valve element 2 is seated on the valve seat 5a. The additional communication passage is not controlled by the valve element 2.

[0025] In Figs 1 and 2, the valve seat-forming member 3 has the through hole 6 as this communication passage. In Fig. 2, the through hole 6 extends e.g. in parallel with the valve hole 5 in the valve seat-forming member 3, for communicating between the discharge chamber-side space and the crank chamber-side space. The through hole 6 is e.g. circular in cross section, and its cross-sectional area may be smaller than the cross-section of the valve hole 5. When the valve hole 5 has a diameter of e.g. approximately 1.0 mm to 1.2 mm, it is desirable that the through hole 6 has a diameter of approximately 0.1 mm to 0.3 mm, namely with a view to reducing influence on the compression performance of the compressor, of ensuring sufficient flow of lubricating oil from the discharge chamber side to the crank chamber side, to facilitate machining, and to easily maintain the required accuracy.

[0026] The through hole 6 establishes a refrigerant flow path from the discharge chamber side to the crank chamber side so as to efficiently return sufficient lubricating oil into the variable displacement compressor even when the capacity control valve 100 is closed.

[0027] Further, the construction described above can be suitably employed particularly when a CO_2 refrigerant difficult to mix with lubricating oil is used. The needed circulation of lubricating oil can be easily ensured without using a complicated device, such as an oil separator, but simply by forming a permanently open hole through the valve seat-forming member 3. The capacity control valve 100 may have a small size and a low failure rate, at low manufacturing costs.

[0028] The capacity control valve 200 in Figs 3 and 4 is distinguished from the first embodiment by the shape of the additional communication passage formed in the valve seat-forming member 23 disposed between the inner space of the strainer 4 communicating with the discharge chamber and the inner space of the upper body 1 communicating with the crank chamber. The valve seat-forming member 23 has a valve hole 25 communicating the discharge chamber-side and the crank chamber-side spaces. A crank chamber-side end of the valve hole 25 functions as a valve seat 25a for the valve element 2. The valve seat 25a has at least one nick 25b formed on one portion of its peripheral edge.

[0029] In Fig. 4 the valve element 2 is seated and held in contact with the valve seat 5a but not in contact with the nick 25b. Hence a gap is created by the nick 25b allowing oil containing refrigerant to flow past the valve seat 25a toward the crank chamber side even when the valve element 2 is seated on the valve seat 25a.

[0030] It is desirable that the nick 25b has a size small enough to minimize influence on the compression performance of the variable displacement compressor and to allow required machining accuracy to be easily achieved, similarly to the communication passage in the first embodiment. When the valve hole 25 has a diameter of approximately 1.0 mm to 1.2 mm, it is desirable to form a nick having an equivalent to the opening area corresponding to that of a drilled hole having a diameter of approximately 0.1 mm to 0.3 mm, as described for the first embodiment.

[0031] The capacity control valve 300 in Figs. 5 and 6 is distinguished from the first and second embodiments by the shape of the additional communication passage formed in the valve seat-forming member 33 disposed between the discharge chamber-side and the crank chamber-side spaces of the valve.

[0032] The valve seat-forming member 33 has a valve hole 35 communicating the discharge chamber-side and the crank chamber-side spaces. A crank chamber-side end of the valve hole 35 functions as the valve seat 35a for the valve element 2. The valve seat-forming member 33 is press-fitted in the upper opening of the upper body 1. An inner wall of the upper opening of the

upper body 1 and an upper outer peripheral surface of the valve seat-forming member 33 are in contact with each other. An e.g. axially extending communication groove 35b is formed on one portion of the upper outer peripheral surface of the valve seat-forming member 33.

[0033] The communication groove 35b in Fig. 6 extends between the space communicating with the discharge chamber and the space communicating with the crank chamber. When the valve element 2 is seated on the valve seat 35a, refrigerant flows from the discharge chamber side to the crank chamber side through the communication groove 35b to supply lubricating oil into the compressor.

[0034] The communication groove 35b e.g. may have a V shape or a curved shape in cross section. It is desirable that the cross-sectional area of a gap created between the communication groove 35b and the inner wall of the upper body 1 is small enough to minimize influence on the compression performance of the variable displacement compressor and allow required machining accuracy to be easily achieved, similarly to the communication passages in the above first and second embodiments.

[0035] After forming the valve seat-forming member 33, it is possible to form the communication groove 35b on the upper outer peripheral surface of the valve seat-forming member by the same method as it is used for forming a scribe line, and hence manufacturing efficiency is higher than in the above first and second embodiments.

[0036] According to the present invention, it is not required to provide any special device for returning lubricating oil into the compressor, but it is necessary to simply change a portion of the internal construction of the capacity control valve accordingly. The inventive concept may be employed in any capacity control valve that has a valve element in a flow channel from a discharge chamber side to a crank chamber side. This allows to reduce the size of the capacity control valve and of the compressor provided with the capacity control valve, and contributes to reduction of the manufacturing costs of these components.

[0037] In each of the above-described embodiments, the capacity control valve performs control of the differential pressure between the discharge pressure Pd within the discharge chamber and the suction pressure Ps within the suction chamber. However, the same concept also may be applied to a capacity control valve that performs control such that the suction pressure Ps is held constant. Further, any valve element may be used having a shape other than the spherical shape as shown.

Claims

1. A capacity control valve (100, 200, 300) for a variable displacement compressor, for controlling an amount of refrigerant to be introduced from a discharge chamber into a crank chamber of the compressor, to thereby change a capacity of refrigerant discharged by the compressor,
characterized in that an additional communication passage is formed in a valve seat-forming member (3, 23, 33) disposed in a refrigerant passage communicating between the discharge chamber and the crank chamber for constantly connecting a discharge chamber side and a crank chamber side even when the capacity control valve (100, 200, 300) is in a fully closed state.

2. The capacity control valve according to claim 1, **characterized in that** the communication passage is a through hole (6) formed through the valve seat-forming member (3), preferably in parallel with a valve hole (5).

3. The capacity control valve according to claim 1, **characterized in that** the communication passage is a nick (25b) formed on one portion of a valve seat (25a) such that a gap is formed when the valve is closed.

4. The capacity control valve according to claim 1, **characterized by** a holding member (1) having a press-fitting opening communicating between the discharge chamber side and the crank chamber side, and holding the valve seat-forming member (33) press-fitted in the press-fitting opening, and
by the additional communication passage formed by at least one groove (35b) formed on an outer peripheral surface of the valve seat-forming member (33) in a manner extending from the discharge chamber side to the crank chamber side.

5. The capacity control valve according to claim 1, **characterized by** a valve element (2) disposed for opening and closing the refrigerant passage, such that the valve element (2) can be seated on a valve seat (5a, 25a, 35a) formed on the valve seat-forming member (3, 23, 33), from the crank chamber side, and
a solenoid section for applying an axial solenoid force to the valve element (2).

6. The capacity control valve according to claim 5, **characterized by** a piston rod (8) disposed coaxially with the valve element (2), and having one end adjacent to the valve element and the other end having a pressure-receiving area as large as an effective pressure-receiving area of the valve element (2), the piston rod (8) receiving suction pressure (Ps) from a suction chamber on the other end thereof.

7. A capacity control valve (100, 200, 300) for a vari-

able displacement compressor, the capacity control valve comprising a valve seat (5a, 25a, 35a) in a refrigerant passage between a discharge chamber and a crank chamber of the compressor, and a valve element (2) which is movable in relation to the valve seat between a closed state and opening states of varying opening degrees including a fully open state of the capacity control valve, **characterized in that**

in addition to the valve seat (5a, 25a, 35a) at least one permanently open communication passage (6, 25b, 35b) is deviating the valve seat (5a, 25a, 35a) between a discharge chamber side and a crank chamber side of the valve seat, and that the cross-section of the communication passage is smaller than the free flow cross-section between the valve element (2) and the valve seat (25a, 5a, 35a) in the fully opened state of the capacity control valve.

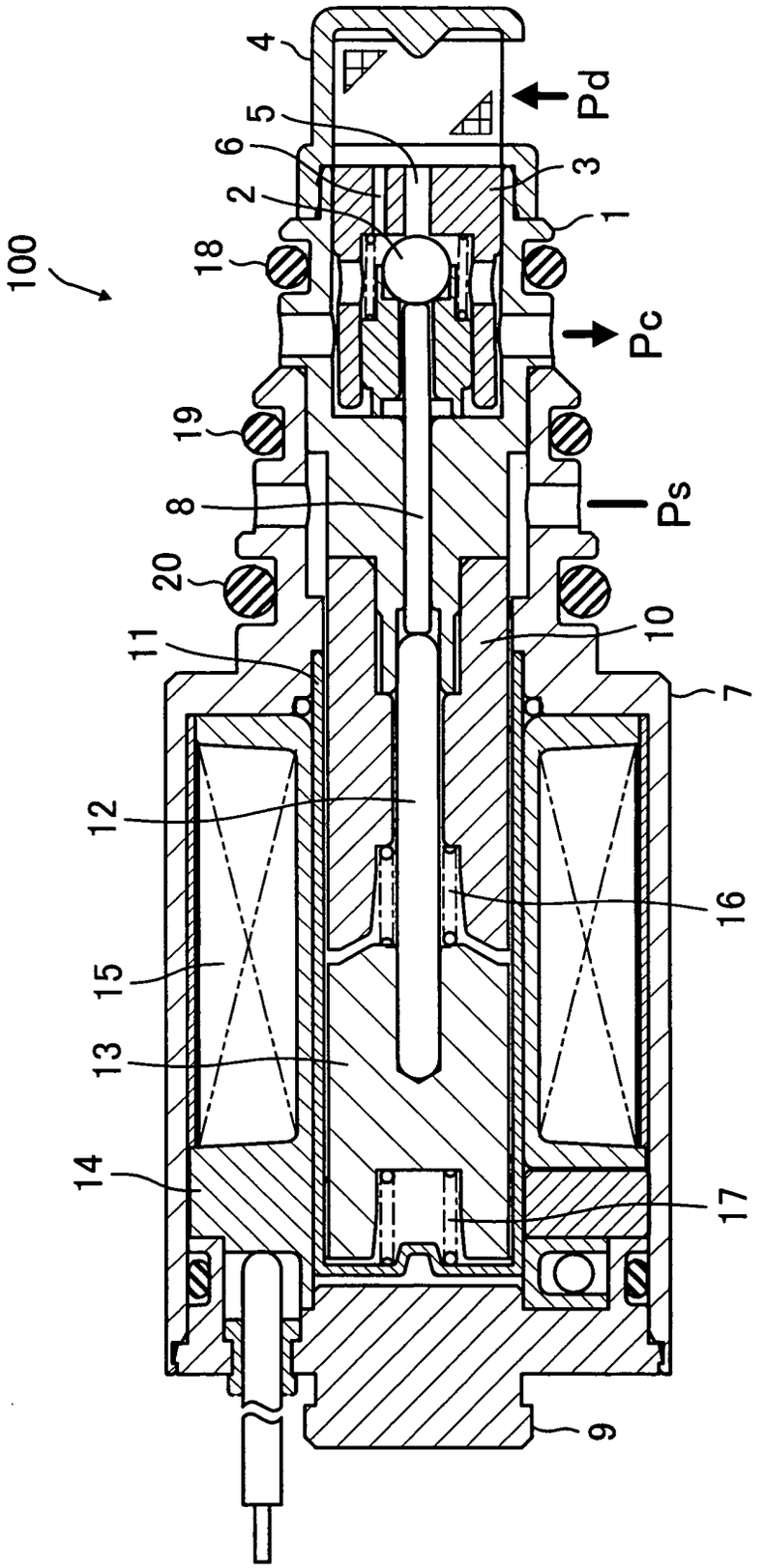

FIG. 1

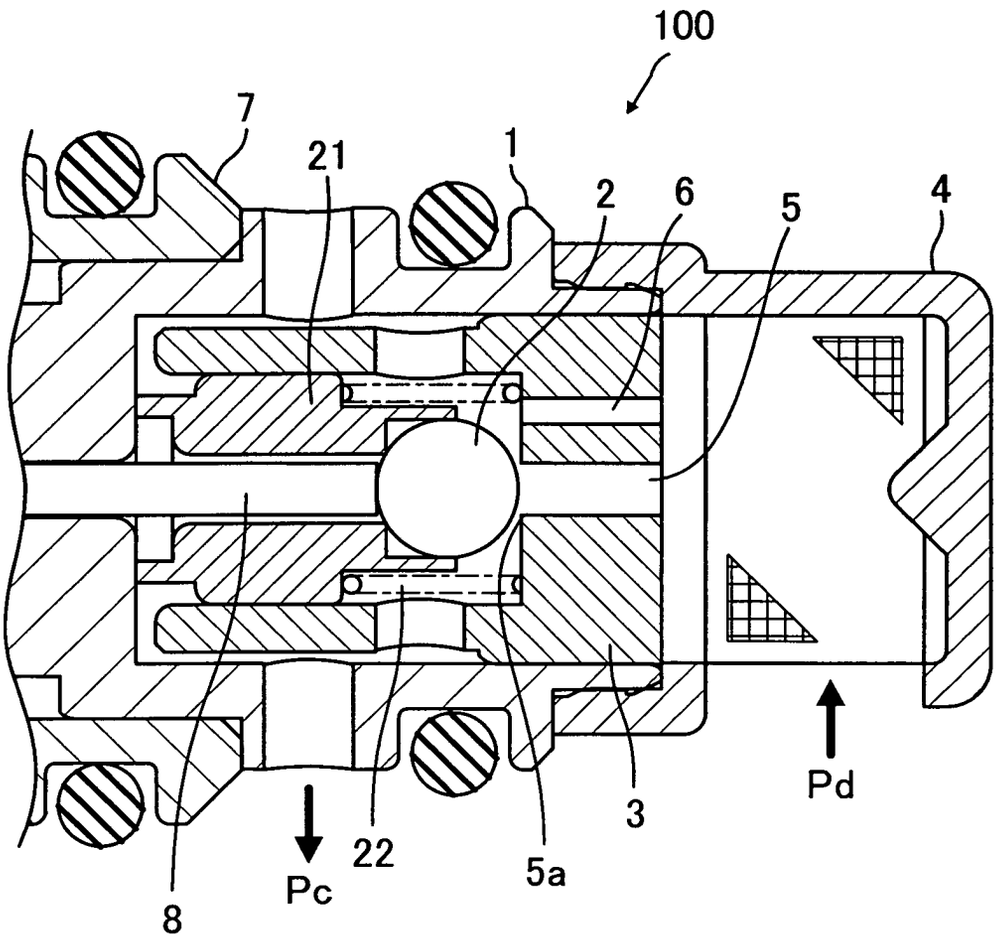

FIG. 2

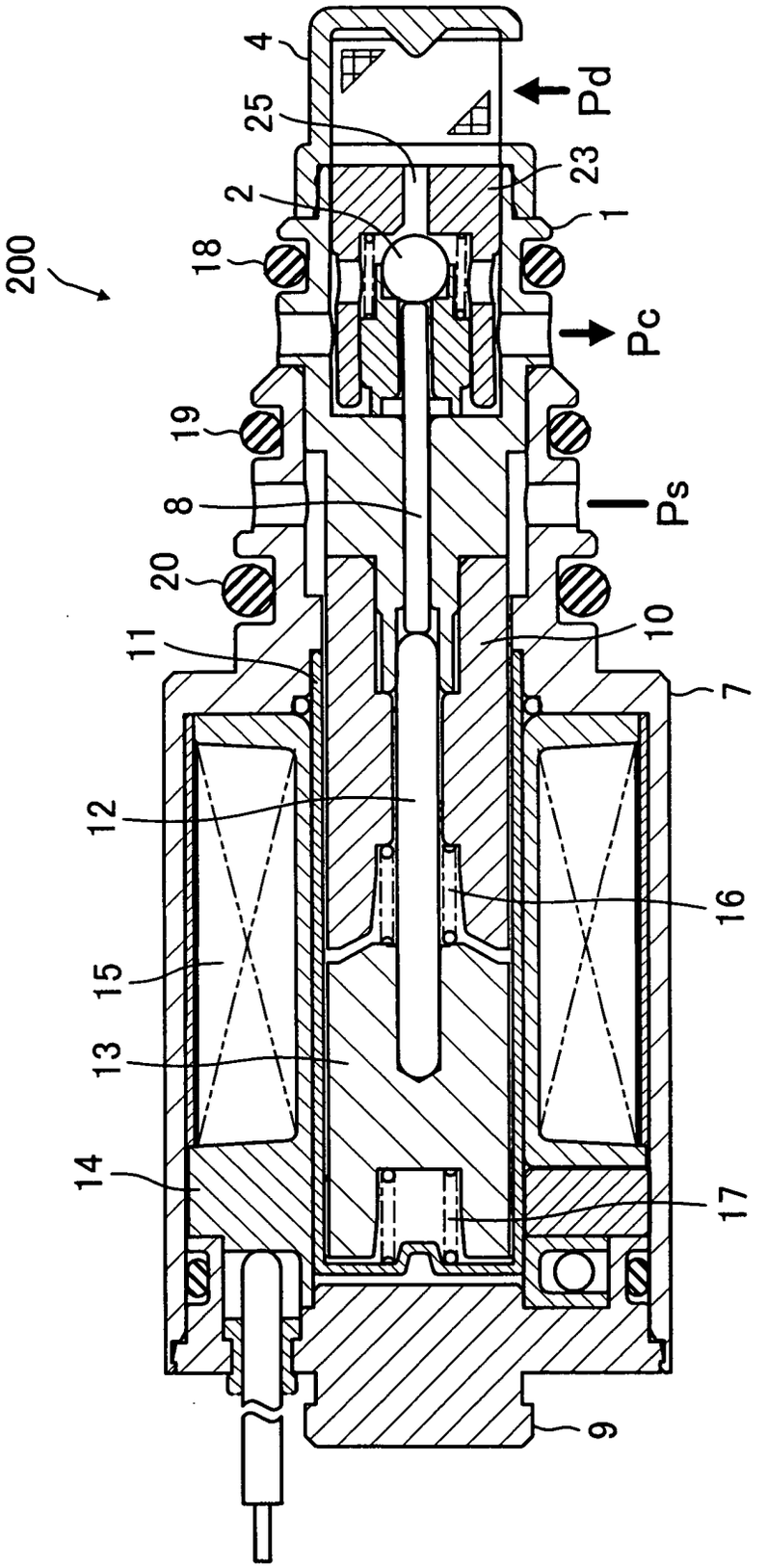

FIG. 3

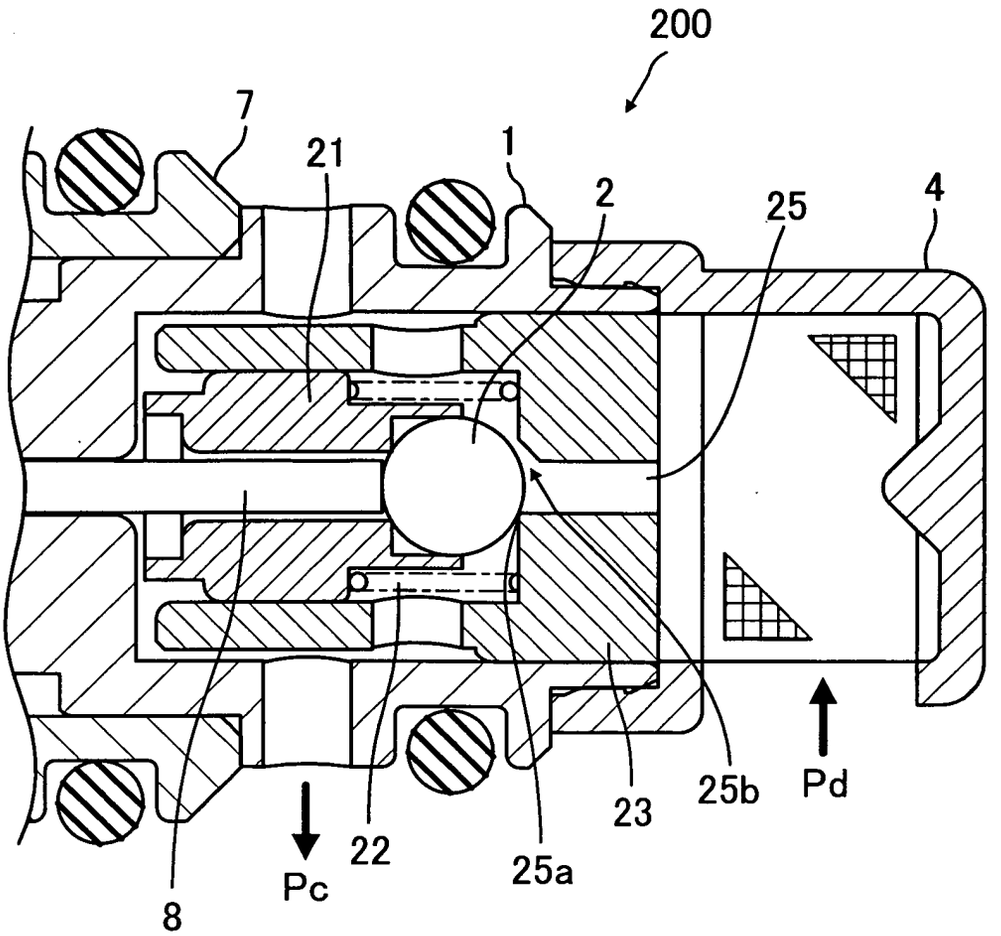

FIG. 4

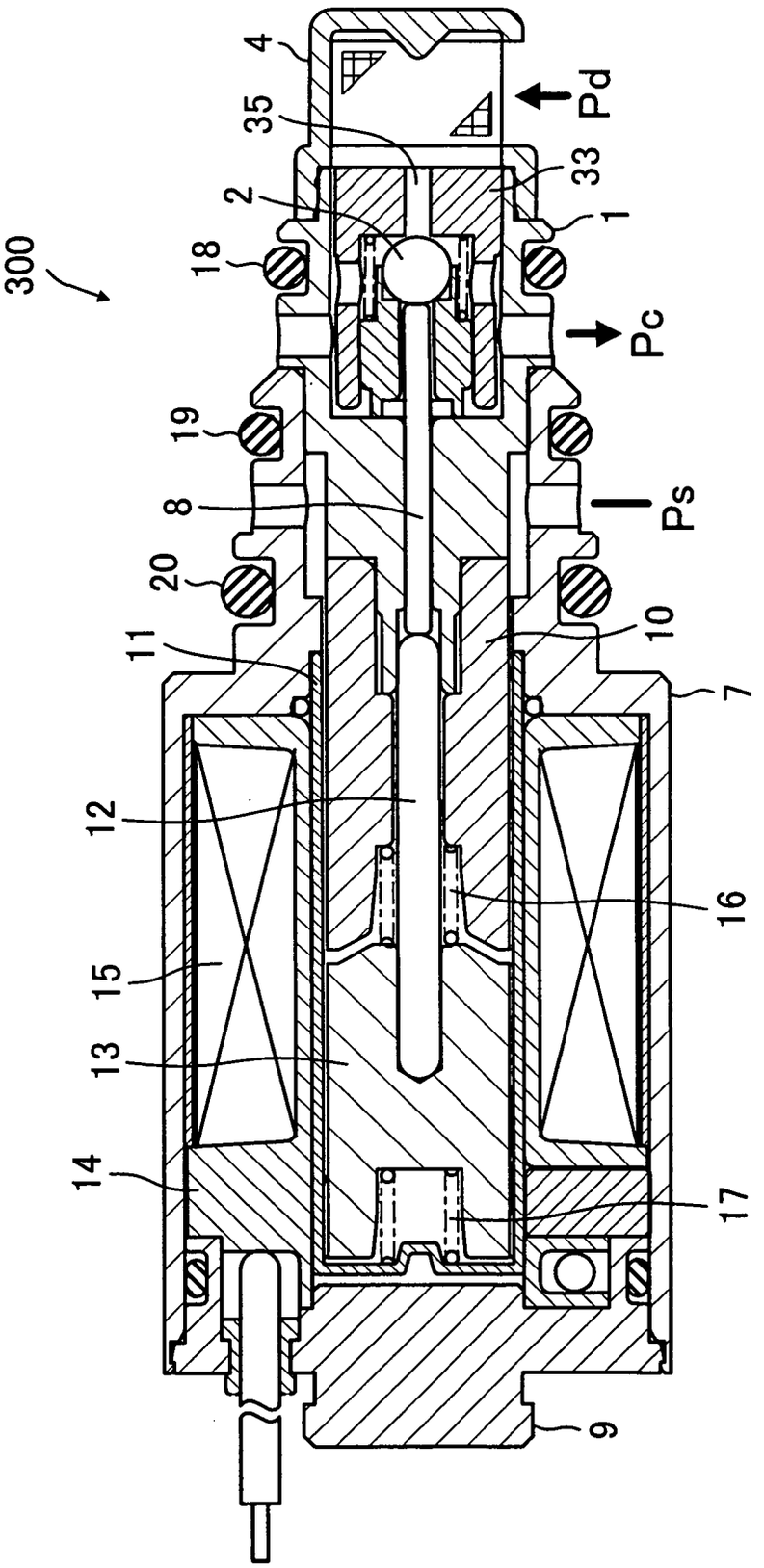

FIG. 5

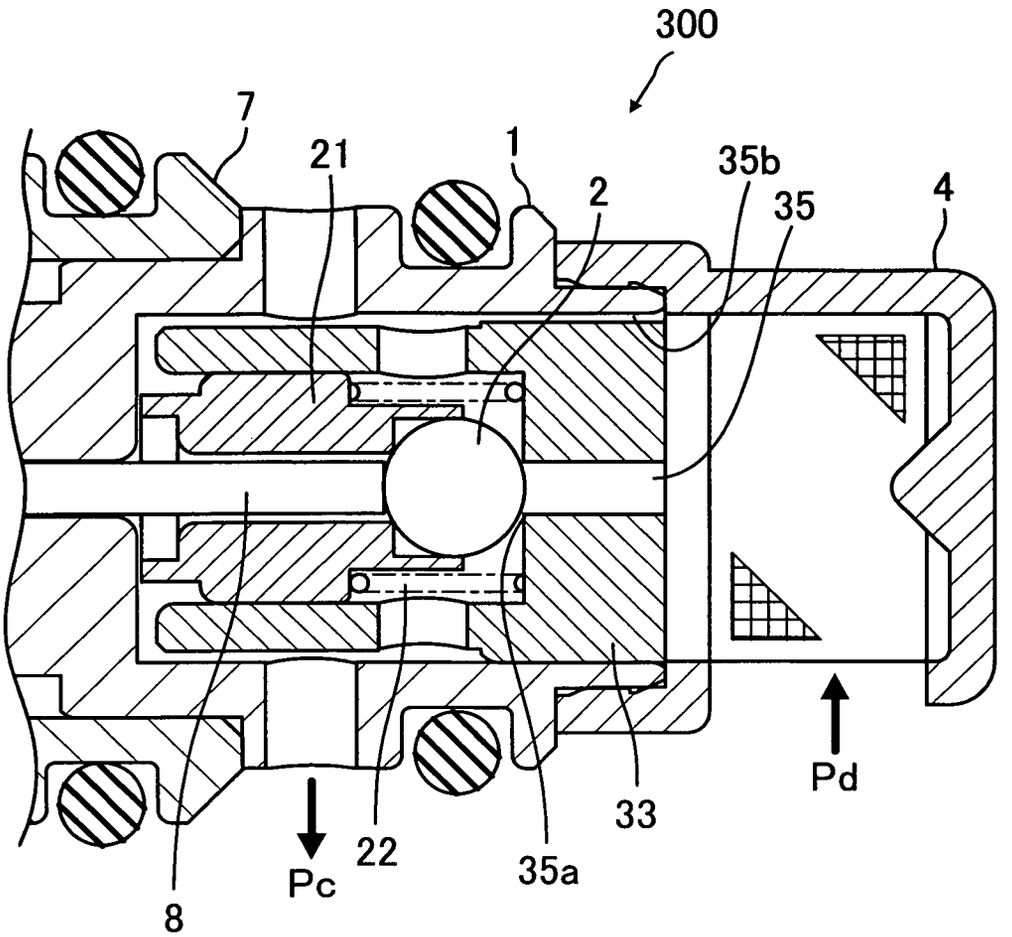

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 03 02 3513

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	19 January 2004	Fistas, N

CATEGORY OF CITED DOCUMENTS

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