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(54) **Control valve for variable displacement compressor**

(57) In a control valve for a variable displacement compressor a solenoid plunger is divided into a first plunger 26 and a second plunger 22 with a diaphragm 29 disposed therebetween for sensing the suction pressure P_s . The second plunger 22 is urged by a spring 24 away from the diaphragm 29 simply in axial contact with an axially guided shaft 17 that transmits changes of the suction pressure P_s as sensed by the diaphragm 29 to a valve element 16. When an attractive force is generated by the solenoid to move the second plunger 22, no couple of forces can act on the shaft 17. The shaft 17 is smoothly sidable to assure an enhanced control performance of the control valve.

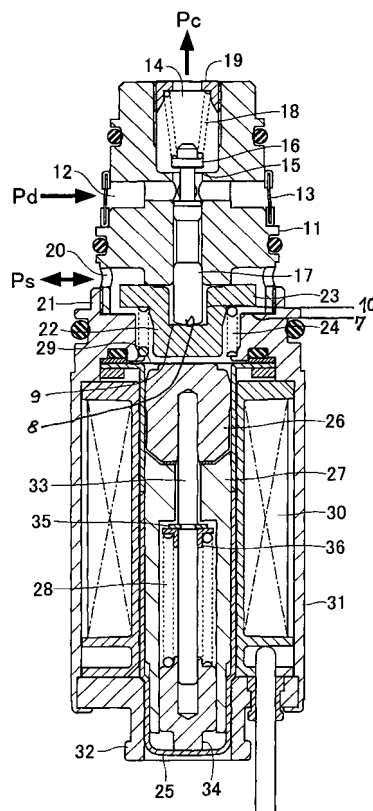


FIG. 1

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Description

[0001] The invention relates to a control valve according to the preamble of claim 1, particularly to a displacement control valve for a variable displacement compressor for an automotive air conditioner.

[0002] Variable displacement compressors are employed in automotive air conditioners so as to obtain an adequate refrigerating capacity without being constrained by speed variations of the engine which drives the compressor.

[0003] In known wobble plate variable displacement compressors, the inclination angle of the wobble plate in a crankcase can be changed by changing the pressure in the crankcase, whereby the stroke of pistons driven by the wobble plate is changed for changing the refrigerant discharge amount. The control valve controls the pressure in the crankcase.

[0004] In general, a displacement control valve operates to introduce part of refrigerant at discharge pressure P_d discharged from the discharge chamber into the crankcase such that pressure P_c in the crankcase is controlled e.g. according to the suction pressure P_s in the suction chamber. That is, the control valve senses the suction pressure P_s and controls the refrigerant flow rate at the discharge pressure P_d from the discharge chamber into the crankcase, so as to maintain the suction pressure P_s at a constant level. The control valve has a P_s pressure-sensing section and a valve section to open and close a passage between the suction chamber and the crankcase. To freely externally set the value of the suction pressure P_s at the start of a variable displacement operation a solenoid is provided in order to carry out the settings of the pressure-sensing section by an external electric current.

[0005] A control valve for a variable displacement compressor of a so-called clutchless type is known from JP-2000-110731 A. The driving engine is directly connected to a shaft without an electromagnetic clutch between the engine and the shaft of the wobble plate.

[0006] The control valve section controls the flow through a passage between the discharge chamber and the crankcase. A solenoid generates, when energized, an electromagnetic force causing the valve section to operate in valve closing direction. The pressure-sensing section causes the valve section to operate in valve opening direction as the suction pressure P_s drops below the atmospheric pressure. When the solenoid is not energized, the valve section is fully open, whereby the pressure P_c in the crankcase is held close to discharge pressure P_d . The wobble plate is adjusted substantially at right angles to the shaft. The compressor operates at the minimum displacement. Thus, the refrigerant displacement can be substantially reduced to approximately zero. Even when the engine is directly connected to the shaft an electromagnetic clutch can be eliminated. The pressure-sensing section and the valve section are arranged with the solenoid interposed therebetween. The suction

pressure P_s is introduced via or through the solenoid to the pressure-sensing section which compares the suction pressure P_s and the atmospheric pressure. This necessitates that the solenoid in its entirety is accommodated within a pressure chamber, and hence, the solenoid components need to be designed pressure resistant.

[0007] To eliminate this inconvenience, a control valve is proposed in JP Patent Application 2003-289581 which is configured such that the solenoid plunger is divided into first and second plungers. The P_s -pressure-sensing member, such as a diaphragm or a bellows, is interposed therebetween, whereby the suction pressure P_s is isolated from the atmospheric pressure and from the solenoid.

[0008] Further, a control valve with separate first and second plungers has been proposed in Japanese Patent Application No. 2004-125532. One of the plungers is provided in a vacuum container. An opening of the vacuum container is sealed by a diaphragm, isolating the suction pressure P_s from the atmospheric pressure and the coil of the solenoid. FIG. 2 shows this control valve. The control valve of FIG. 2 receives the discharge pressure P_d of the compressor to supply the controlled pressure P_c to the crankcase. The valve section comprises a valve seat 101, a downstream side valve element 102 and a spring 103 urging the valve element 102 in valve closing direction. The valve element 102 is integral with an axially moveable shaft 104 having an outer diameter equal to the inner diameter of a valve hole. A solenoid comprises a core 106 and a first plunger 107, both disposed within a bottomed sleeve 105, and a second plunger 108 and a coil 109 both disposed outside the bottomed sleeve 105. A diaphragm 110 is provided between the first and second plungers 107, 108. The diaphragm 110 seals the open end of the bottomed sleeve 105. Within the bottomed sleeve 105, the first plunger 107 is fixed to a shaft 111 that extends through the core 106. The shaft 111 is urged by a spring 112 in a direction of causing the first plunger 107 to be moved away from the core 106 into contact with the diaphragm 110.

[0009] The suction pressure P_s from the suction chamber of the compressor is introduced into a space where the second plunger 108 is disposed. The second plunger 108 is firmly fixed to an end of the shaft 104 remote from the valve element 102. The second plunger 108 is urged by a spring 113 having stronger spring force than the spring 103 away from the diaphragm 110. When the control valve is not in operation, the valve section is fully-open. Even if the compressor is directly driven by the engine, the compressor is operated at the minimum displacement. If control current is supplied to the coil 109 of the solenoid, the first and second plungers 107, 108 become magnetically coupled to each other with the diaphragm 110 therebetween so as to behave like one plunger. At this time, the axial positions of the first and second plungers 107, 108 determine a certain valve lift set according to the value of the control current. The di-

aphragm 110 receives the suction pressure PS, and is axially displaced accordingly. The diaphragm displacement is transmitted to the valve element 102 via the second plunger 108 and the shaft 104. The control valve introduces refrigerant at pressure Pc into the crankcase by controlling the flow of refrigerant at discharge pressure Pd to a flow rate dependent on the value of the control. The compressor operates at a displacement dependent on the control current. In this state, if the suction pressure Ps rises or drops, the diaphragm 110 is displaced downward or upward in FIG. 2 and the valve lift is varied to adjust the pressure Pc in the crankcase. The displacement is controlled such that suction pressure Ps becomes equal to a value set by the solenoid. The shaft is integral with the valve element and also has the function of guiding the second plunger. When the second plunger is axially moved by the solenoid, the second plunger may become tilted depending on the state of the spring axially urging the second plunger. The tilt tendency creates a couple of forces and/or a bending torque which act on the shaft which is axially guided in the body and which has to guide the second plunger. This effect markedly spoils the axial slidability of the shaft in the body so that the valve element cannot move smoothly.

[0010] It is an object of the invention to provide a control valve having enhanced controllability for a variable displacement compressor, i.e. to improve the slidability of a guided shaft provided for transmitting a motion resulting from a change of the suction pressure to a valve element.

[0011] This object is achieved by the features of claim 1.

[0012] In the control valve the guided shaft provided for transmitting a change in suction pressure to the valve element is set-free from the function of guiding the second plunger. Even if the second plunger is tilted when the second plunger is axially moved by an attractive force generated by the solenoid, the sliding movement of the shaft will no longer be detrimentally influenced by the operational behavior of the second plunger but has the sole function to transmit the axial force and the axial component of the movement of the second plunger to the valve element. This enhances the controllability of the control valve and assures a smooth movement of the valve element in relation to the valve seat without any parasitary lateral shaft braking forces between the shaft and the shaft guidance in the body.

[0013] In the drawings are

FIG. 1 a longitudinal section of a control valve for a variable displacement compressor of the present invention, and

FIG. 2 a section of a conventional control valve.

[0014] The control valve in FIG. 1 has a valve section including a body 11 with a side port 12 communicating with a discharge chamber of the variable displacement compressor for receiving the discharge pressure Pd. A

strainer 13 is fixed at the side port 12. The port 12 communicates via an inner refrigerant passage with a top port 14 of the body 11. The top port 14 communicates with the crankcase to deliver the controlled pressure Pc.

[0015] A valve seat 15 is integral with the body 11. On a pressure Pc side of the valve seat 15, an axially movable valve element 16 is disposed. The valve element 16 is integral with a shaft 17. The shaft 17 extends through a valve hole of the valve seat 15 and is axially movably guided in a bore of the body 11. The discharge pressure Pd is introduced to a small-diameter portion of the shaft 17 between the valve element 16 and a lower part of the shaft 17. The outer diameter of the lower part of the shaft 17 is equal to the inner diameter of the valve hole of the valve seat 15 such that the pressure-receiving area of the valve element 16 is equal to that of the lower part of the shaft 17. An upward force generated by the discharge pressure Pd on the valve element 16 is cancelled by a downward force on the lower part of the shaft 17. This prevents the control behavior of the valve section being adversely affected by the value of the discharge pressure Pd which can be relatively high.

[0016] The valve element 16 is urged by a spring 18 in valve closing direction. The force of the spring 18 is adjusted by an adjustment screw 19 screwed into the top port 14. Another side port 20 communicating with a suction chamber (suction pressure Ps) is formed in a lower portion of the body 11 as viewed in FIG. 1.

[0017] The lower end of the body 11 is rigidly press-fitted in a body 21 of a magnetic material forming a part of the solenoid. The body 21 contains a second plunger 22 as one of two divided plungers of the solenoid. The second plunger 22 has a central blind hole 10 in an upper end face. The blind hole 10 has an inner diameter larger than the outer diameter of the lower part of the shaft 17. The lower part of the shaft 17, which is axially slidably guided by the body 11 without almost any clearance, has a lower end face 8 which is brought into contact with a bottom 9 of the blind hole 10. The lower end face 8 is formed to be arcuate in cross-section, i.e. is convexly rounded versus the e.g. planar bottom 9 of the blind hole 10. Alternatively, the end face 8 could be planar while the bottom 9 is convexly rounded in a central region. Even both the end face 8 and the bottom 9 could be convexly rounded in relation to each other.

[0018] This design creates a hinge in the force transmission path between the second plunger 22 and the axially guided shaft 17 and prevents a couple of forces from being generated on the shaft 17 by vertical motions of the second plunger 22 even when the shaft 17 does not contact the bottom 9 precisely at right angles. The second plunger 22 has a T-shaped cross-section with a lower surface of a flange 23 situated opposed to an upper surface 7 of the body 21. This causes an axial attractive force to be generated between the opposed surfaces of the flange 23 and the body 21 thereby assisting the valve element 16 to promptly move in valve closing direction. The second plunger 22 is urged upward by a spring 24

seated on a stepped shoulder inside the body 21. The spring 24 has a larger spring force than the spring 18 urging the valve element 16 in valve closing direction.

[0019] When the solenoid is de-energized, the second plunger 22 can push the shaft 17 upward until the shaft 17 is brought into contact with the ceiling of a chamber communicating with the port 20 to hold the valve element 16 in the fully open position. The spring 24 also centers a part of the second plunger 22 below the flange 23 such that the spring 24 tends to guide the second plunger 22 axially.

[0020] The pressure-sensing section and the remaining component parts of the solenoid are arranged below the second plunger 22. Below the second plunger 22 in FIG. 1, is disposed an assembly formed by accommodating a first plunger 26 as the other of divided plungers of the solenoid, a core 27, and a spring 28, in a bottomed sleeve 25 forming a vacuum container. The opening of the bottomed sleeve 25 is sealed by a metal diaphragm 29. Outside the bottomed sleeve 25, there are arranged a coil 30, and a case 31 formed integrally with the body 21, and a handle 32 which constitute a yoke for forming a magnetic circuit.

[0021] The core 27 is rigidly press-fitted into the bottomed sleeve 25. The first plunger 26 is axially movably disposed on the upper side of the core 27. The first plunger 26 is rigidly press-fitted on one end of a shaft 33 which axially movably extends through the center of the core 27. The other lower end of the shaft 33 is slidably supported and guided by a bearing 34 which is slidably disposed in the core 27. A stop ring 35 on an intermediate portion of the shaft 33 limits the upward movement of a spring-receiving member 36. The spring 28 is interposed between the spring-receiving member 36 and the bearing 34. The first plunger 26 is urged by the spring 28 via the shaft 33 in a direction away from the core 27. It should be noted that the bottom of the bottomed sleeve 25 is pushed or stamped to be deformed inward, whereby the axial position of the bearing 34 is adjusted and fixed to accordingly adjust the force of the spring 28 and to adjust the set point of the control valve, e.g. when assembling the control valve.

[0022] The bottomed sleeve 25 is sealed by welding the diaphragm 29 to a flange portion formed on the open end of the bottomed sleeve 25. The inside of the gastight assembly is maintained under vacuum.

[0023] The body 21, the case 31, and the handle 32 are made of magnetic substances to serve as the yoke of the magnetic circuit of the solenoid. Magnetic lines of force generated by the coil 30 pass through the magnetic circuit formed by the case 31, the body 21, the second plunger 22, the first plunger 26, the core 27, and the handle 32.

[0024] In FIG. 1 the solenoid is de-energized. The suction pressure P_s is relatively high, i.e. like in the state in which the air conditioner is not operating. Since the suction pressure P_s is high, the diaphragm 29 is displaced downward against the load of the spring 28. The first

plunger 26 is in contact with the core 27. On the other hand, the second plunger 22 is urged upward by the spring 24 such that it is moved away from the diaphragm 29 to urge the valve element 16 via the shaft 17 toward the fully open position. Even when the variable displacement compressor is directly driven by the engine in the above state, the compressor is operated at the minimum displacement.

[0025] When maximum control current is supplied to the coil 30, as in the case of the start of the automotive air conditioner, the first plunger 26 remains pressed downward as in FIG. 1 by the high suction pressure P_s into contact with the core 27. Even if the first plunger 26 is attracted by the core 27, it remains in this position. Therefore, in this case, the first plunger 26 and the core 27 behave as if they were a fixed core, so that the first plunger 26 attracts the second plunger 22 via the diaphragm 29 against the urging force of the spring 24 into contact with the diaphragm 29. The spring 18 pushes the valve element 16 downward to be seated on the valve seat 15 and to fully close the valve section. This blocks the passage between the discharge chamber and the crankcase, so that the compressor is promptly shifted into the operation at the maximum displacement.

[0026] At this time, the second plunger 22 is only axially in contact with the end face 8 of the shaft 17 but is not constrained thereby, so that even when the second plunger 22 is about to be moved in a tilted state depending on the condition of the spring 24 guiding the second plunger 22, no couple of forces can act on the shaft 17 and, hence, the axial slidability of the shaft 17 is not spoiled.

[0027] When the compressor continues to operate at the maximum displacement to make the suction pressure P_s low enough, the diaphragm 29 attempts to move upward, in FIG. 1. At this time, if the control current supplied to the coil 30 is decreased according to the set temperature of the air conditioner, the second and first plungers 22, 26 in an attracted state move upward in unison to respective positions where the suction pressure P_s , the forces of the springs 18, 24, and 28, and the attractive force of the solenoid are balanced. The valve element 16 is pushed upward by the second plunger 22 and moves away from the valve seat 15, thereby being set to a predetermined valve lift. Refrigerant at the discharge pressure P_d is introduced into the crankcase at a flow rate controlled to a value dependent on the valve lift, whereby the variable displacement compressor is shifted to an operation with the displacement corresponding to the control current.

[0028] When the control current supplied to the coil 30 of the solenoid remains constant, the diaphragm 29 senses the suction pressure P_s as an absolute pressure to thereby control the valve lift of the valve section. For example, when the refrigeration load increases, the suction pressure P_s becomes high and the first plunger 26 is displaced downward. The valve element 16 moves downward to decrease the valve lift causing the compressor

to operate in a direction of increasing the displacement. When the refrigeration load decreases and the suction pressure P_s becomes low, the first plunger 26 is displaced upward to increase the valve lift causing the compressor to operate in a direction of decreasing the displacement. Thus, the control valve controls the displacement of the compressor such that the suction pressure P_s becomes equal to a value set by the control current for the solenoid.

[0029] The invention is not limited to the described embodiment. For example, a section accommodating the first plunger 26 could be open to the atmospheric pressure to thereby compare the suction pressure P_s and the atmospheric pressure. Furthermore, instead of the a diaphragm 29, a bellows could be provided.

Claims

1. A control valve for a variable displacement compressor, the control valve comprising a divided solenoid plunger consisting of a first plunger (26) and a second plunger (22), and a pressure-sensing member (29) disposed between the first and second plungers (26, 22), for sensing a suction pressure (P_s), the second plunger (22) transmitting via a shaft (17), a suction pressure change sensed by the pressure-sensing member (29) to a valve element (16),
characterized in that
the second plunger (22) is biased by a spring (24) in a direction away from the pressure-sensing member (29), into contact with the shaft (17).
2. The control valve according to claim 1, **characterized in that** the second plunger (22) has a central blind hole (10) in a surface opposed to the shaft (17), the blind hole having an inner diameter larger than an outer diameter of the shaft (17), and that an end face (8) of the shaft (17) is in contact with a bottom (9) of the blind hole(10).
3. The control valve according to claim 2, **characterized in that** the end face (8) of the shaft (17) is arcuate in cross section.
4. A control valve according to claim 2, **characterized in that** at least one of the bottom (9) and the end face is convexly rounded opposite to the other.

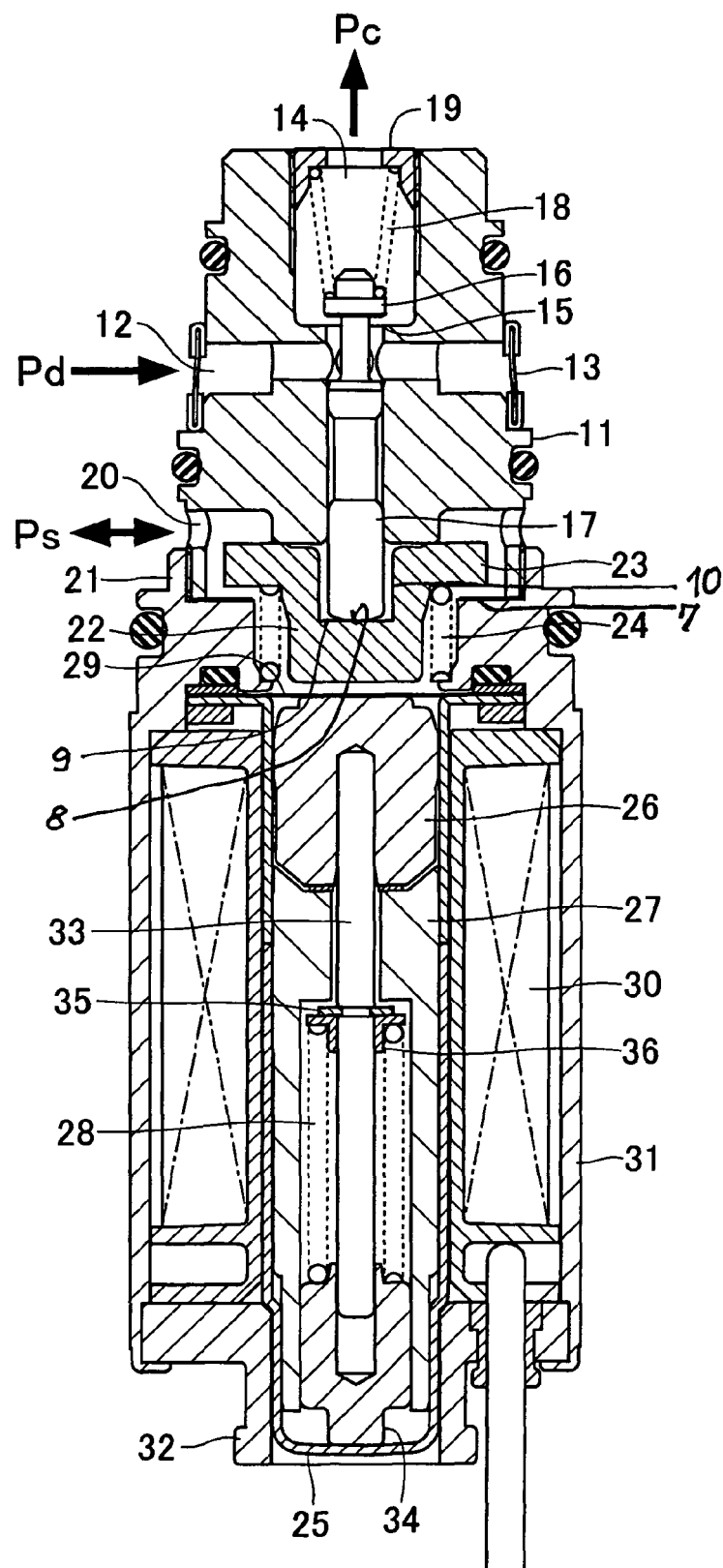


FIG. 1

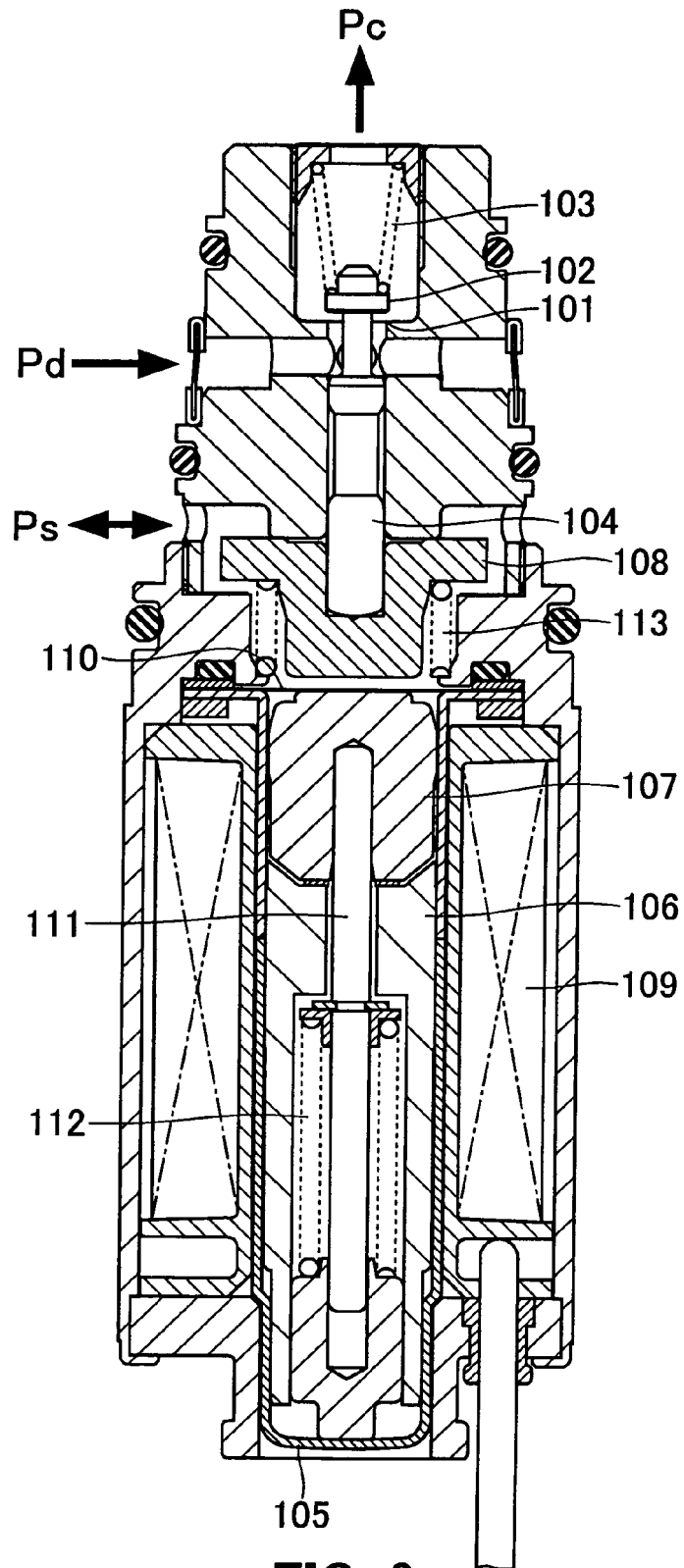


FIG. 2
PRIOR ART



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EUROPEAN SEARCH REPORT

Application Number
EP 05 02 2396

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
P,X	EP 1 574 711 A (TGK COMPANY, LTD) 14 September 2005 (2005-09-14) * abstract; figures 1,2 * -----	1-4	F04B27/18 F04B49/08 F04B49/00
X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 01, 14 January 2003 (2003-01-14) & JP 2002 250456 A (SAGINOMIYA SEISAKUSHO INC), 6 September 2002 (2002-09-06) * abstract; figure 1 * -----	1-4	
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 10, 17 November 2000 (2000-11-17) & JP 2000 205549 A (NIPPON CONTROL KOGYO CO LTD), 25 July 2000 (2000-07-25) * abstract; figure 1 * -----	1-4	
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 07, 29 September 2000 (2000-09-29) & JP 2000 110731 A (TGK CO LTD), 18 April 2000 (2000-04-18) * abstract; figure 1 * -----	1-4	TECHNICAL FIELDS SEARCHED (IPC) F04B
A	EP 1 046 818 A (TGK CO., LTD) 25 October 2000 (2000-10-25) * the whole document * -----	1-4	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 30 November 2005	Examiner Avramidis, P
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 05 02 2396

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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30-11-2005

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1574711	A	14-09-2005	CN 1667271 A	14-09-2005
			JP 2005291190 A	20-10-2005
			US 2005201867 A1	15-09-2005

JP 2002250456	A	06-09-2002	NONE	

JP 2000205549	A	25-07-2000	JP 3291622 B2	10-06-2002

JP 2000110731	A	18-04-2000	NONE	

EP 1046818	A	25-10-2000	DE 60011956 D1	12-08-2004
			DE 60011956 T2	11-11-2004
			ES 2222866 T3	16-02-2005
			JP 3581598 B2	27-10-2004
			JP 2000303981 A	31-10-2000
