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

(57) A valve section 13 of a control valve controls the flow rate between a discharge chamber and a crankcase, based on the differential pressure between discharge pressure Pd and suction pressure Ps. A pressure-sensing section 12 is provided in a high-pressure port 18. When a pressure-sensing piston 19 having a pressure-receiving area larger than a valve element 23 is exposed to a rapid discharge pressure change, the differential pressure generated between the discharge pressure Pd and a pressure in a pressure-adjusting chamber 20 acts on the valve element 23 opposite to the valve-opening/closing direction, to temporarily retard the motion of the valve element 23 which opens or closes by the differential pressure (Pd-Ps). Even a high-sensitivity variable displacement compressor promptly restores without hunting to a predetermined discharge capacity.

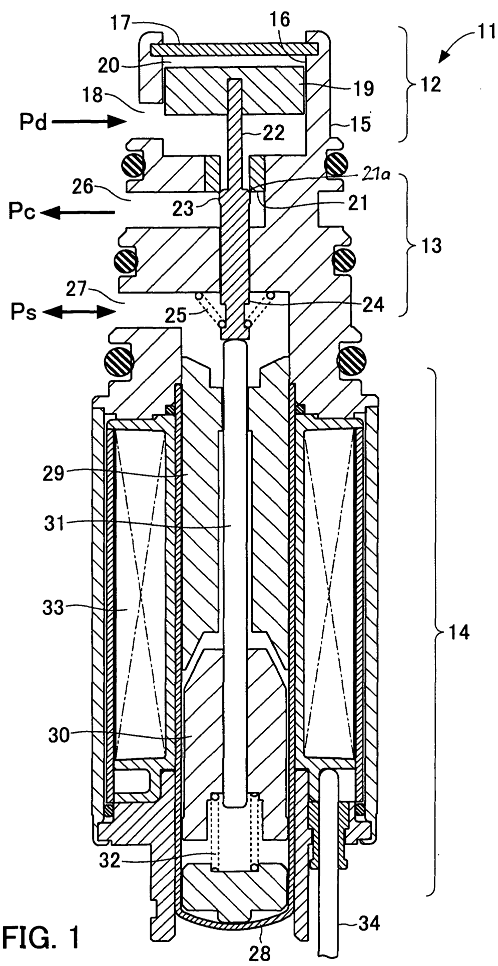

FIG. 1

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Description

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

[0002] Variable displacement compressors capable of varying the refrigerant compression capacity are employed in automotive air conditioners so as to obtain an adequate cooling capacity without being constrained by the rotational speed of the engine driving the compressor. In a known compressor a wobble plate on a shaft driven by the engine drives compression pistons. By varying the wobble plate inclination angle the piston stroke is varied to vary the refrigerant discharge amount. The inclination angle is continuously changed by controlling the pressure in a crankcase, and by changing the balance of pressures acting on opposite ends of each piston.

[0003] A known control valve (JP-2001-132650 A) is disposed either between the discharge chamber and the crankcase, or between the crankcase and the suction chamber of the compressor. The control valve adjusts the pressure in the crankcase by controlling the flow rate between the discharge chamber and the crankcase, or between the crankcase and the suction chamber, respectively. The control valve comprises a valve section in a refrigerant passage between the discharge chamber and the crankcase. A path extends between the discharge chamber and the suction chamber via an orifice between the crankcase and the suction chamber. A valve element in the valve section receives discharge pressure Pd in valve-opening direction. A piston rod integral with the valve element has approximately the same diameter as a valve hole. An end face of the piston rod receives the suction pressure Ps and the load of a solenoid in valve-closing direction for setting the discharge capacity of the compressor by an external signal. Hence, the discharge pressure Pd and the suction pressure Ps act on the opposite ends of the valve element and piston rod on equal effective pressure-receiving areas. The differential pressure (Pd - Ps) causes opening/closing operations of the valve element to control the flow rate between the discharge chamber and the crankcase.

[0004] As the rotational speed of the compressor increases with increasing engine speed the discharge capacity of the compressor is increased" i.e. the discharge pressure Pd increases and the suction pressure Ps decreases to increase the differential pressure (Pd - Ps). The valve lift increases depending on the value of the differential pressure (Pd - Ps). The control valve increases the flow rate into the crankcase to increase the pressure Pc and to decrease the discharge capacity. The value of the of the differential pressure (Pd - Ps) decreases as well. In short, the control valve controls the flow rate to the crankcase such that the differential pressure (Pd - Ps) is held at a predetermined value which can be set by the value of electric current supplied to the solenoid.

[0005] Any changes of the discharge capacity change the value of the differential pressure (Pd - Ps) to change the pressure Pc in the crankcase, whereby the wobble plate inclination angle is changed to vary the discharge capacity between the maximum and minimum capacities. For example, when the differential pressure (Pd - Ps) is zero as at the start of the compressor, the compressor operates with maximum capacity. When the differential pressure (Pd - Ps) reaches a certain value, the capacity starts to be varied. However, each variable displacement compressor has an individual character, and the other differential pressure (Pc - Ps) between the pressure Pc in the crankcase and the suction pressure Ps at the start of varying the discharge capacity has a range of values varying depending on the compressor. This is caused e.g. by individual fluctuations of the mobility of the wobble plate, that is, by differences of sensitivity or response behaviour among a series of compressors. A high-sensitivity compressor has the problem of reacting sensitively to rapid changes in the discharge pressure Pd and the suction pressure Ps caused by a sudden change of the engine speed, resulting in hunting.

[0006] It is an object of the invention to provide a control valve for a variable displacement compressor, which is capable of controlling even a high sensitivity compressor stably without causing hunting, i.e. when a rapid pressure change is caused by a sudden change of the engine speed.

[0007] This object is achieved by the features of claim 1.

[0008] When a pressure change results from a gentle speed change of the compressor, the pressure-sensing section remains insensitive to the pressure change, and performs the same operation as the conventional compressor. However, when a pressure change results from a rapid speed change of the compressor, the pressure-sensing section senses and responds to this pressure change, and makes the motion of the valve section slower (retarding effect) by interfering with action of the valve section in a direction opposite to the valve-opening or valve-closing direction. This motion is retarded by a value, which is proportional to the degree of the occurring pressure change.

[0009] Even a high-sensitivity compressor promptly restores a predetermined discharge capacity without overshooting the carried out pressure change even when a rapid speed change of the compressor occurs.

[0010] This enables the control valve to perform stable displacement control without any hunting even when the high-sensitivity compressor undergoes a rapid speed change.

[0011] Embodiments of the invention will be described with reference to the drawings.

Fig. 1 is a longitudinal section view of a first embodiment of a control valve for a variable displacement compressor,

Fig. 2 is a diagram explaining the operation of the control valve when the rotational compressor speed rapidly increases,

Fig. 3 is a longitudinal section of a second embodiment of the control valve,

Fig. 4 is a longitudinal section of a fourth embodiment of the control valve,

Fig. 6 is a longitudinal section of a fifth embodiment of the control valve,

Fig. 7 is a longitudinal section of a sixth embodiment of the control valve,

Fig. 8 is a longitudinal section of a seventh embodiment of the control valve, and

Fig. 9 is a longitudinal section of an eighth embodiment of the control valve.

[0012] A control valve 11 in Fig. 1 comprises a pressure-sensing section 12 for exclusively sensing rapid changes in a discharge pressure Pd, a valve section 13 for sensing the differential pressure (Pd - Ps) between the discharge pressure Pd and suction pressure Ps to control the refrigerant flow rate between a discharge chamber and a crankcase, and a solenoid 14 for setting a predetermined value to which the differential pressure (Pd - Ps) is to be controlled by the control valve, from outside. These sections are arranged on the same axis.

[0013] A body 15 containing the pressure-sensing section 12 and the valve section 13 has a cylinder in an upper part. An upper end opening is closed by a lid 17. A high-pressure port 18 communicating with the discharge chamber of the variable displacement compressor is provided in the body 15 at a location below the cylinder 16. A pressure-sensing piston 19 is axially movably disposed within the cylinder 16. A space for a pressure-adjusting chamber 20 is defined by an upper portion of the cylinder 16, by the body 15 and by the lid 17. The pressure-adjusting chamber 20 communicates with the high-pressure port 18 via a predetermined clearance between the cylinder 16 and the pressure-sensing piston 19. A hole is formed in the centre of a bottom of the cylinder 16. A hollow cylindrical valve seat-forming member 21 is press-fitted in the hole. The valve seat-forming member 21 has a passage axially extending therethrough, i.e. a valve hole, and a lower end forming a valve seat 21 a of the valve section 13. A shaft 22 extends through the valve hole of the valve seat-forming member 21. One end of the shaft 22 is fixed to the pressure-sensing piston 19.

[0014] A valve element 23 is movably disposed opposed to the valve seat 21 a. The valve element 2 at one side is integrally formed with the shaft 22 and with a piston rod 24 at the other side. The piston rod 24 is movably guided in a hole of the body 15. The outer diameter of the piston rod 24 is equal to the inner diameter of the valve hole of the valve seat-forming member 21. The piston rod 24 is urged by a spring 25 in valve opening direction. A space accommodating the valve element 23 communicates with a medium-pressure port 26 for supplying pressure Pc to the crankcase of the compressor. A space accommodating the spring 25 communicates with a low-pressure port 27 for receiving the suction pressure Ps from a suction chamber.

[0015] A hole is formed in the centre of a lower part of the body 15. The rim of an opening of a bottomed sleeve 28 is tightly connected to the hole. The bottomed sleeve 28 contains a core 29 and a plunger 30 of the solenoid 14. The core 29 is fixed to the hole in the centre of the lower part of the body 15 and the bottomed sleeve 28 by press-fitting. The plunger 30 is axially slidably disposed in the bottomed sleeve 28, and is fixed to one end of a shaft 31 which axially extends through the core 29. The plunger 30 is urged toward the core 29 by a spring 32 such that the other end of the shaft 31 is brought into abutment with a lower end face of the piston rod 24. A coil 33 surrounds the bottomed sleeve 28. A harness 34 leads from the coil 33 to the outside.

[0016] The force of the spring 25 is stronger than the force of the spring 32. When the solenoid 14 is de-energized, the valve element 23 is kept away from the valve seat 21 a, the valve section 13 is fully open. High-pressure refrigerant (discharge pressure Pd) passes from the high-pressure port 18 through the open valve section 13 and flows from the medium-pressure port 26 into the crankcase. The pressure Pc in the crankcase is close to the discharge pressure Pd. The compressor operates with minimum discharge capacity.

[0017] When the automotive air conditioner is started or when the cooling load is maximum, the value of electric control current supplied to the solenoid 14 is maximum. The plunger 30 is attracted with the maximum attractive force by the core 29. The piston rod 24 is pushed by the shaft 31 fixed to the plunger 30, in valve-closing direction against the force of the spring 25. The valve element 23 is seated on the valve seat 21a. The valve section 13 is fully closed. The high-pressure refrigerant (discharge pressure Pd) is blocked by the valve section 13. The pressure Pc in the crankcase is close to the suction pressure Ps. The compressor operates with maximum discharge capacity.

[0018] When the value of the electric current supplied to the solenoid 14 is set to a predetermined value, the valve element 23 will stop at a valve lift position where the load of the spring 25, the load of the solenoid 14, the force of the discharge pressure Pd, and the force of the suction pressure Ps are balanced.

[0019] In the above balanced state, when the compressor speed is increased e.g. by an increase of the engine speed, in order to increase the discharge capacity of the compressor, the discharge pressure Pd increases and the suction pressure Ps decreases so that the differential pressure (Pd - Ps) increases. This action causes a force in valve-opening direction on the valve element 23 and the piston rod 24. The valve element 23 is lifted further from the balanced position. Refrigerant flows from the discharge chamber into the crankcase at an increased flow rate. The pressure Pc in the crankcase is increased to adjust the compressor to operate in a direction reducing the discharge capacity, and such that the differential pressure (Pd - Ps) is controlled to the predetermined value set by the solenoid 14.

[0020] When, however, the engine speed has decreased, the control valve operates inversely and the compressor is controlled such that the differential pressure (Pd - Ps) again becomes equal to the predetermined value set by the solenoid 14.

[0021] When the compressor speed changes only gently as in the case where the automotive vehicle is cruising at an approximately constant speed, the pressure-sensing section 12 will remain insensitive, and will perform like the conventional control valve. This is due to the fact that then a piston driving differential pressure does not occur, because the gentle pressure change is also directly transmitted into the pressure-adjusting chamber 23.

[0022] Next, the operation will be described when the compressor speed rapidly changes when the automotive vehicle i.e. the engine suddenly accelerates or decelerates.

[0023] When the compressor in Fig. 2 first has been stably operating e.g. at a speed of 800 rpm, and then the speed has increased suddenly up to a rotational speed of 2000 rpm, the valve lift is increased due to the rising discharge pressure Pd and the dropping suction pressure Ps. The control valve 11 increases the pressure Pc in the crankcase. At this time, in the compressor with higher sensitivity, as indicated by broken lines in Fig. 2, overshooting of the valve lift, of the discharge pressure Pd, of the pressure Pc in the crankcase, and of the suction pressure Ps tend to occur, causing a hunting phenomenon.

[0024] When the overshooting tendency occurs, the pressure-sensing section 12 receives the rapidly increased discharge pressure Pd at the pressure-sensing piston 19 in a sufficiently larger pressure-receiving area than that of the valve element 23. In contrast, in the pressure-adjusting chamber 20, pressure Pd(av), which is an average pressure remaining from the discharge pressure Pd before it has rapidly increased, is maintained. The differential pressure (Pd - Pd(av)) now generates a force on the pressure-sensing piston 19 in valve opening direction. This force is transmitted via the shaft 22 to the valve element 23, namely a force obtained by subtracting the differential pressure (Pd - Pd(av)) acting on the pressure-sensing section 12 from the rapidly increased discharge pressure Pd. As a result, as indicated by solid lines in FIG. 2, the valve lift is increased more slowly or the valve element movement is retarded, respectively, so that the control valve 11 increases the pressure Pc in the crankcase more slowly. After that, in the pressure-sensing section 12, the rapidly increased discharge pressure Pd promptly also reaches the pressure-adjusting chamber 20 via the clearance between the cylinder 16 and the pressure-sensing piston 19. Now the differential pressure (Pd - Pd(av)) becomes equal to zero. At this time, the retarding servo-function of the pressure-sensing section 12 has been lost, meaning that the pressure-sensing section 12 has the function of sensing and responding to a rapid increase in the discharge pressure Pd only, to temporarily make the motion of the valve section 13 in valve-opening direction slower by a value proportional to the degree of the rapid pressure change. The control valve 11 promptly restores the compressor to the predetermined discharge capacity without causing any hunting.

[0025] The control valve 11 operates similarly but in quite an opposite way when the compressor speed is rapidly decreased. Then, the differential pressure (Pd (av) - Pd) acting on the pressure-sensing section 12 serves as a force for moving the pressure-sensing piston 19 toward the valve section 13 and for temporarily urging the valve element 23, which is about to move in valve-closing direction, in the valve-opening direction, i.e. retarding the valve element movement.

[0026] The pressure-sensing piston 19 optionally may be provided with flow rate-adjusting means, such as a piston ring, which has a circumferentially cut out portion of a predetermined length, to adjust the size of a passage via which refrigerant flows into or out of the pressure-adjusting chamber 20 to thereby control the response characteristics of the pressure-sensing section 12.

[0027] Distinct from the control valve 11 in Fig. 1, the control valve 11a in Fig. 3 (second embodiment) is configured to sense and respond to a rapid change of the pressure Pc instead as supplied to the crankcase when controlling the valve lift of the valve section 13.

[0028] The pressure-sensing section 12 is disposed in a space communicating with the medium-pressure port 26, and the pressure-sensing piston 19 receiving the pressure Pc is fixed to the piston rod 24 which is integrally formed with the valve element 23. The valve seat-forming member 21 has a flange portion that is fitted in an opening formed in an upper end of the body 15. The pressure-sensing piston 19 is loosely, i.e. axially movably, fitted in the body 15 at a location below the valve seat-forming member 21. An annular space of the pressure-adjusting chamber 20 is defined by the body 15 and the flange portion of the valve seat-forming member 21. The pressure-sensing piston 19 has an upper central recess 19a. The recess 19a is formed with a communication hole 19b through the bottom of the piston 19 such that the recess 19a communicates with the space communicating with the medium-pressure port 26 via the communication hole 19b.

[0029] When the control valve 11 a controls the compressor at a predetermined valve lift, if the discharge pressure Pd rapidly increases, and the suction pressure Ps rapidly decreases, the differential pressure (Pd - Ps) between the opposite ends of the valve element 23 and the piston rod 24 increases, whereby the valve lift is about to increase. This causes the pressure Pc on the downstream side of the valve section 13 as well to rapidly increase. Since the pressure-sensing piston 19 has a sufficiently larger pressure-receiving area than the valve element 23, an upwardly acting force is generated on the pressure-sensing piston 19. The force causes the piston rod 24 fixed to the pressure-sensing piston 19 to act in valve-closing direction also on the valve element 23, which was about to move in valve-opening direction by the increased differential pressure (Pd - Ps), and hence the valve lift increases more slowly or in retarded fashion. The discharge pressure Pd and the pressure Pc in the crankcase also increase slowly in accordance with the slowed down increase in the valve lift. After a short time, when the pressure in the pressure-adjusting chamber 20 becomes equal to the pressure Pc in the crankcase, the discharge pressure Pd, the pressure Pc in the crankcase, the suction pressure Ps, and the valve lift promptly return to their original states, however, without showing any overshooting tendency. Of course, similarly, also when the compressor speed rapidly decreases, the control valve 11 a operates with retardation to promptly restore the compressor to the predetermined discharge capacity.

[0030] The control valve 11 b in Fig. 4 (third embodiment) is configured to sense and to respond to a rapid change of the suction pressure Ps instead when controlling the valve lift of the valve section 13.

[0031] The pressure-sensing piston 19 separates a space accommodating the spring 25 and communicating with the low-pressure port 27 from a space communicating with the solenoid 14. The pressure-sensing piston 19 is fixed to the piston rod 24 which is integral with the valve element 23. In the control valve 11 b, a space defined by the body 15, by the pressure-sensing piston 19, by the piston rod 24, by the core 29, and by the shaft 31 forms the pressure-adjusting chamber 20.

[0032] When the control valve 11b controls the compressor at a predetermined valve lift, if the discharge pressure Pd rapidly increases, and the suction pressure Ps rapidly decreases, the differential pressure (Pd - Ps) between the opposite ends of the valve element 23 and the piston rod 24 increases, whereby the valve lift increases. This causes the suction pressure Ps to rapidly decrease. At this time, since the pressure-sensing piston 19 of the pressure-sensing section 12 has a sufficiently larger pressure-receiving area than the valve element 23, an upwardly acting force is generated on the pressure-sensing piston 19. The force causes the piston rod 24 fixed to the pressure-sensing piston 19 to act in valve-closing direction on the valve element 23, i.e. opposite to the direction of the lift of the valve element 23. The valve lift then only slowly increases, to cause the discharge pressure Pd and the pressure Pc in the crankcase to also only slowly increase. In a short time, however, after the pressure in the pressure-adjusting chamber 20 has become equal to the suction pressure Ps, the discharge pressure Pd, the pressure Pc in the crankcase, the suction pressure Ps, and the valve lift promptly return to their original states without causing overshooting tendencies. Of course, similarly, also when the compressor speed rapidly decreases, the control valve 11 b will operate slowly to restore the compressor to the predetermined discharge capacity.

[0033] The control valve 11c in Fig. 5 (fourth embodiment) has a pressure-sensing section 12 which does not sense or respond to a rapid change in the discharge pressure Pd in increasing direction but sensitively senses and responds to a rapid change in the discharge pressure Pd in decreasing direction only for controlling of the valve lift of the valve section 13.

[0034] The pressure-sensing piston 19 as a component of the pressure-sensing section 12 is equipped with a check valve mechanism (sensitivity-switching means) for switching the response sensitivity between when a rapid change occurs in the discharge pressure Pd in increasing direction and when a rapid change occurs in decreasing direction. The check valve mechanism comprises a passage 19c with a stepped portion in the pressure-sensing piston 19 for communication between the high-pressure port 18 and the pressure-adjusting chamber 20, further a ball-shaped valve element 41 in a large-diameter passage part 19b facing the pressure-adjusting chamber 20, and a leaf spring 42 in an open end of the passage 19b facing the pressure-adjusting chamber 20 to prevent the valve element 41 from falling out.

[0035] When the control valve 11 c controls the compressor at a predetermined valve lift, if the discharge pressure Pd rapidly increases, the check valve mechanism immediately opens by the differential pressure between the discharge pressure Pd and the pressure in the pressure-adjusting chamber 20, to thereby reduce the differential pressure to zero. As a result, the pressure-sensing section 12 is placed in an insensitive state. The valve section 13 acts rapidly in the valve-opening direction in a manner sensitively responsive to the rapid increase in the discharge pressure Pd, thereby causing the pressure Pc in the crankcase to rise more promptly such that the discharge capacity of the compressor is promptly controlled in the decreasing direction.

[0036] Inversely, if the discharge pressure Pd has rapidly decreased, the check valve mechanism closes by the differential pressure between the rapidly-lowered discharge pressure Pd and the pressure Pd(av) in the pressure-adjusting chamber 20, which is an average pressure remaining from the discharge pressure Pd before it has rapidly decreased. The pressure-sensing piston 19 having a larger pressure-receiving area than the valve element 23 sensitively detects and responds to the change in the rapidly-lowered discharge pressure Pd. Although the valve element 23 attempts to act in valve-closing direction in response to the rapid decrease in the discharge pressure Pd, since the pressure-sensing piston 19 instantaneously responds in valve-opening direction due to the rapid change in the discharge pressure Pd, the valve element 23 is made slower in its action in valve-closing direction. The control valve 11 c then has asymmetric valve-opening characteristics, i.e. operates with high sensitivity in case of a rapid change in the discharge pressure Pd in increasing direction, but operates with low sensitivity in case of a rapid change in the discharge pressure Pd in decreasing direction. Therefore, e.g. even if the compressor excessively tends to respond to a rapid change in the discharge pressure Pd in increasing direction to cause the discharge pressure Pd to rapidly change in decreasing direction, the compressor is hindered from excessively responding to a rapid change in the discharge pressure Pd in decreasing direction. This prevents the occurrence of a hunting phenomenon.

[0037] In the control valve I1d in Fig. 6 (fifth embodiment), the check valve mechanism of the pressure-sensing section 12 is provided in the lid 17. The valve element 41 of the check valve is a poppet valve body.

[0038] The check valve mechanism comprises a passage 17a with a stepped portion in the lid 17 communicating between a space receiving the discharge pressure Pd and the pressure-adjusting chamber 20, the valve element 41 in the form of a mushroom or a poppet valve body in a large-diameter passage part facing toward the pressure-adjusting chamber 20, and a fixed leaf spring 42 in the open end of the passage 17a facing the pressure-adjusting chamber 20 to prevent the valve element 41 falling into the pressure-adjusting chamber 20. A weak spring 43 between the lid 17 and the pressure sensing piston 19 urges the pressure-sensing piston 19 away from the lid 17.

[0039] The operation of the control valve 11d is the same as the operation of the control valve 11 c in Fig. 5.

[0040] In a further not shown alternative of the control valve the check valve mechanism instead may be provided in the body 15 for isolating the pressure-adjusting chamber 20 from a side exposed to the discharge pressure Pd.

[0041] The control valve 11e in Fig. 7 (sixth embodiment) includes a sensitivity-switching mechanism for switching the response sensitivity between when the discharge pressure Pd rapidly increases and when the same rapidly decreases.

[0042] The sensitivity-switching mechanism in the pressure-sensing section 12 in Fig. 7 switches the ease of flow into or out of the pressure-adjusting chamber 20. The peripheral shape of the pressure-sensing piston 19 is tapered, such that the outer diameter of the pressure-sensing piston progressively increases from the side of the high-pressure port 18 to the pressure-adjusting chamber 20. A gap 19c formed between the periphery of the pressure-sensing piston 19 and the cylindrical wall of the body 15 has a narrowest restriction at an upper end in the pressure-adjusting chamber 20. The gap 19c progressively increases in passage cross-sectional area from the restriction to a lower space communicating with the high-pressure port 18. Assuming that the cross-sectional area of the refrigerant passage is hugely expanded on the high-pressure port side of the restriction in the gap 19c, and refrigerant flows through the restriction into the hugely-expanded portion, a contracted flow will be produced there. Insofar as the differential pressure between pressure in the high-pressure port 18 and the pressure in the pressure-adjusting chamber 20 is the same, the pressure-sensing section 12 has a characteristic that the flow rate is smaller when refrigerant flows from the pressure-adjusting chamber 20 to the high-pressure port 18 after being abruptly restricted in flow by the restriction than when refrigerant flows from the high-pressure port 18 flows into the pressure-adjusting chamber 20 through the restriction after being progressively restricted in flow.

[0043] When the compressor speed is rapidly increased to thereby rapidly increase the discharge pressure Pd, refrigerant is about to flow from the high-pressure port 18 into the pressure-adjusting chamber 20 through the gap 19c, i.e. by the difference in pressure between the increased pressure in the high-pressure port 18 and the still lower pressure in the pressure-adjusting chamber 20. Inversely, when the compressor speed is rapidly decreased to rapidly lower the discharge pressure Pd, refrigerant is about to flow through the gap 19c from the pressure-adjusting chamber 20 toward the high-pressure port 18. In this regard, there is a difference in the flow rate through the gap 19c between when the discharge pressure Pd has rapidly increased and when the same has rapidly decreased. When the discharge pressure Pd has rapidly increased, it takes a short time until the pressure in the pressure-adjusting chamber 20 becomes equal to the rapidly increased discharge pressure Pd. When the discharge pressure Pd has rapidly decreased, it takes a longer time until the pressure in the pressure-adjusting chamber 20 becomes equal to the rapidly decreased discharge pressure Pd. The force exerted by the pressure-sensing piston 19 on the valve element 23 in valve-closing direction when the discharge pressure Pd has rapidly increased is smaller than the force exerted by the pressure-sensing piston 19 on the valve element 23 in valve-opening direction when the discharge pressure Pd has rapidly decreased. That is, when the discharge pressure Pd has rapidly increased, the pressure-sensing section 12 becomes less sensitive, whereby the sensitivity of the valve section 13 is not much lowered. On the other hand, during a transition period over which the discharge pressure Pd rapidly decreases, the pressure-sensing piston 19 easily moves in valve-opening direction, and hence the pressure-sensing section 12 becomes more sensitive. Since the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes smaller, a force trying to operate the valve section 13 in valve-closing direction is instantaneously cancelled by a force trying to operate the pressure-sensing section 12 in valve-opening direction. As a result, the movement of the valve element 23 of the valve section 13 in valve-closing direction is suppressed or retarded, and the valve section 13 is inhibited from performing an excessive response in the direction in which the discharge pressure Pd is rapidly decreased. This prevents a high-sensitivity compressor from causing a hunting phenomenon due to a rapid change in the discharge pressure Pd.

[0044] In the control valve 11f in Fig. 8 (seventh embodiment), the pressure-sensing section 12 does not sense or respond to a rapid change in the pressure Pc supplied to the crankcase in increasing direction but sensitively detects and responds to only a rapid change in the pressure Pc in decreasing direction for controlling or retarding the valve lift of the valve section 13.

[0045] The pressure-sensing piston 19 contains a check valve mechanism for switching the response sensitivity between when a rapid change occurs in the pressure Pc supplied to the crankcase in increasing direction and when a rapid change occurs in decreasing direction. The check valve mechanism comprises a passage 19b with a stepped portion in the pressure-sensing piston 19 for communication between the medium-pressure port 26 and the pressure-adjusting chamber 20 the ball-shaped valve element 41 in a large-diameter passage part facing the pressure-adjusting chamber 20, and a valve element stopper 44 fitted into an open end of the passage toward the pressure-adjusting chamber 20.

[0046] When the control valve 11f in Fig. 8 controls the compressor at a predetermined valve lift, if a rapid increase in the discharge pressure Pd causes the valve section 13 to operate in valve-opening direction to thereby rapidly increase the pressure Pc supplied to the crankcase, the check valve mechanism immediately opens by the differential pressure between the pressure Pc in the crankcase and the pressure in the pressure-adjusting chamber 20. The pressure-sensing section 12 does not adversely affect the operation of the valve section 13, such that the valve section 13 promptly operates in valve-opening direction in response to the rapid increase in the pressure Pc to increase the pressure Pc in the crankcase more promptly, thereby promptly controlling the discharge capacity of the compressor in the decreasing direction.

[0047] Inversely, if the pressure Pc supplied to the crankcase has rapidly decreased, the pressure Pc in the medium-pressure port 26 becomes lower than a pressure Pc(av) in the pressure-adjusting chamber 20, which is an average pressure remaining from the pressure Pc before it has rapidly decreased. Then the check valve mechanism is closed. As a result, the pressure-sensing piston 19 having a larger pressure-receiving area than the valve element 23 sensitively detects the rapid decrease in the pressure Pc, and the differential pressure between the discharge pressure Pd and the suction pressure Ps becomes smaller, so that the operation of the valve section 13 in valve-closing direction is instantaneously suppressed or retarded by the pressure-sensing section 12 sensitively acting in valve-opening direction.

[0048] The control valve 11f in Fig. 8 has asymmetric valve-opening characteristics, namely a high sensitivity to a rapid change in the pressure Pc supplied to the crankcase in increasing direction, but a low sensitivity to a rapid change in the pressure Pc in decreasing direction. This prevents occurrence of control hunting even if the pressure Pc is rapidly changed due to the rapid change in the discharge pressure Pd.

[0049] In the control valve 11 g in Fig. 9 (eighth embodiment), the pressure-sensing section 12 does not sense a rapid change in the suction pressure Ps in decreasing direction but sensitively detects only a rapid change in the suction pressure Ps in increasing direction for controlling the valve lift of the valve section 13.

[0050] The pressure-sensing piston 19 contains a check valve mechanism for switching the response sensitivity between when a rapid change occurs in the suction pressure Ps in increasing direction and when a rapid change occurs in decreasing direction. The check valve mechanism comprises a passage 19b with a stepped portion in the pressure-sensing piston 19 for communication between the low-pressure port 27 and the pressure-adjusting chamber 20, the ball-shaped valve element 41 in a large-diameter passage part facing the low-pressure port 27, and the valve element stopper 44 in an open end of the passage 19b facing the low-pressure port 27.

[0051] When the control valve 11 g controls the compressor at a predetermined valve lift, if a rapid increase in the discharge pressure Pd causes a rapid decrease in the suction pressure Ps, the check valve mechanism opens by the differential pressure between the suction pressure Ps and the pressure in the pressure-adjusting chamber 20. The pressure-sensing section 12 then does not adversely affect the operation of the valve section 13, so that the valve section 13 promptly opens in response to the rapid increase in the discharge pressure Pd to increase the pressure Pc in the crankcase more promptly, and promptly adjusts the compressor to decrease the discharge capacity.

[0052] Inversely, if a rapid decrease in the discharge pressure Pd causes a rapid increase in the suction pressure Ps, the suction pressure Ps in the low-pressure port 27 becomes higher than the pressure Ps(av) in the pressure-adjusting chamber 20, which is an average pressure remaining from the suction pressure Ps before it has rapidly increased. The check valve mechanism closes. As a result, the pressure-sensing piston 19 sensitively detects the rapid increase in the suction pressure Ps, and the operation of the valve section 13 in the valve-closing direction is instantaneously suppressed or retarded by the pressure-sensing section 12 which sensitively acts in the valve-opening direction.

[0053] The control valve 11 g in Fig. 9 has asymmetric valve-opening characteristics, namely high sensitivity for a rapid change in the suction pressure Ps in decreasing direction, and low sensitivity for a rapid change in the pressure Pc in increasing direction. This prevents occurrence of hunting.

Claims

1. A control valve for a variable displacement compressor, the control valve (11, 11a, 11b, 11c, 11d, 11e, 11f, 11g) sensing the differential pressure (Pd-Ps) between the discharge pressure (Pd) in a compressor discharge chamber and the suction pressure (Ps) in a compressor suction chamber, and controlling the refrigerant flow rate between the discharge chamber and a crankcase to thereby change the refrigerant discharge capacity, **characterised by**:

   a pressure-sensing section (13) in the control valve for sensing pressure changes caused by a rapid change of the rotational compressor speed and for retarding a valve section motion in valve-opening/closing direction by a value which is proportional to a degree of the respective pressure change.

2. The control valve according to claim 1, **characterised in that** the pressure-sensing section (13) comprises a pressure-sensing piston (19) in a high-pressure port (18), for receiving the discharge pressure (Pd) at a larger pressure-receiving area than the pressure receiving area of a valve element (23), that a shaft (22) transmits an axial motion or force of the pressure sensing piston (19) generated by the differential pressure (Pd-Pd(av)) between the discharge pressure (Pd) and a pressure (Pd(av)) in a pressure-adjusting chamber (20) which is bounded by the pressure-sensing piston (19) to the valve element (23).

3. The control valve according to claim 2, **characterised in that** the shaft (22) is integral with the valve element (23), that the valve element (23) receives the discharge pressure (Pd) at one end face, that a piston rod (24) is integral with the valve element (23), and that the piston rod (24) receives the suction pressure (Ps) at an end face opposite to the other end face.

4. The control valve according to claim 2, **characterised in that** the pressure-sensing section (12) further comprises sensitivity-switching means for making the force of the pressure-sensing piston (19) on the valve element (23) smaller when the discharge pressure (Pd) is rapidly increased than when the discharge pressure (Pd) is rapidly decreased.

5. The control valve according to claim 4, **characterised in that** the sensitivity-switching means is a check valve disposed in a passage (19b) in the pressure-sensing piston (19) between a high-pressure port side and the pressure-adjusting chamber (20), for allowing flow from the high-pressure port side into the pressure-adjusting chamber (20), and blocking flow from the pressure-adjusting chamber (20) to the high-pressure port side.

6. The control valve according to claim 4, **characterised in that** the sensitivity-switching means is a check valve provided in a passage (17a) in a member (17) jointly defining the pressure-adjusting chamber (20) together with the pressure-sensing piston (19), the passage (17a) communicating between a discharge pressure side and the pressure-adjusting chamber (20), for blocking flow from the discharge pressure side to the pressure-adjusting chamber (20), and allowing flow from the pressure-adjusting chamber (20) to the discharge pressure side.

7. The control valve according to claim 4, **characterised in that** the sensitivity-switching means is formed by a tapered periphery of the pressure-sensing piston (19) such that a gap (19c) formed with the wall of a cylinder accommodating the pressure sensing piston (19), and that the gap (19c) progressively decreases in cross-sectional area from the high-pressure port side to the pressure-adjusting chamber (20).

8. The control valve according to claim 1, **characterised in that** the pressure-sensing section (12) has a pressure-sensing piston (19) disposed in communication with a medium-pressure port (26) through which control pressure (Pc) controlled by the valve section (13) is delivered to the crankcase, that the pressure sensing piston (19) receives the control pressure at a pressure-receiving area larger than that of a valve element (23), and that the pressure-sensing piston (19) is configured to transmit an axial motion or force generated by the differential pressure (Pc-Pc(av)) between the control pressure (Pc) and a pressure (Pc(av)) in a pressure-adjusting chamber (20) which is bounded by the pressure-sensing piston (19) to the valve element (23).

9. The control valve according to claim 8, **characterised in that** the pressure-sensing section (12) further comprises sensitivity-switching means for making the force transmitted by the pressure-sensing piston (19) on the valve element (23) smaller when the control pressure (Pc) rapidly increases than when the control pressure (Pc) rapidly decreases.

10. The control valve according to claim 9, **characterised in that** the sensitivity-switching means is a check valve provided in a passage (19c) through the pressure-sensing piston (19) between a first a side communicating with the medium-pressure port (26) and the pressure-adjusting chamber (20), for allowing flow from the first side to the pressure-adjusting chamber (20), and blocking flow from the pressure-adjusting chamber (20) to the first side.

11. The control valve according to claim 1, **characterised in that** the pressure-sensing section (12) has a pressure-sensing piston (19) disposed adjacent to a low-pressure port (27) through which the suction pressure (Ps) is introduced, that the pressure sensing piston (19) receives the suction pressure at a pressure-receiving area larger than that of a valve element (23), and that the pressure-sensing piston (19) is configured to transmit an axial motion or force generated by the differential pressure (Ps-Ps(av)) between the suction pressure (Ps) and the pressure (Ps(av)) in a pressure-adjusting chamber (20) which is bounded by the pressure-sensing piston (19) to the valve element (23).

12. The control valve according to claim 11, **characterised in that** the pressure-sensing section (12) further comprises sensitivity-switching means for making the force transmitted by the pressure-sensing piston (19) on the valve element (23 larger when the suction pressure (Ps) rapidly increases than when the suction pressure (Ps) rapidly decreases.

13. The control valve according to claim 12, **characterised in that** the sensitivity-switching means is a check valve disposed in a passage through the pressure-sensing piston (19) between a side toward the low-pressure port (27) and the pressure-adjusting chamber (20), for allowing flow from the side toward the low-pressure port (27) into the pressure-adjusting chamber (20), and blocking flow from the pressure-adjusting chamber (20) to the side toward the low-pressure port (27).

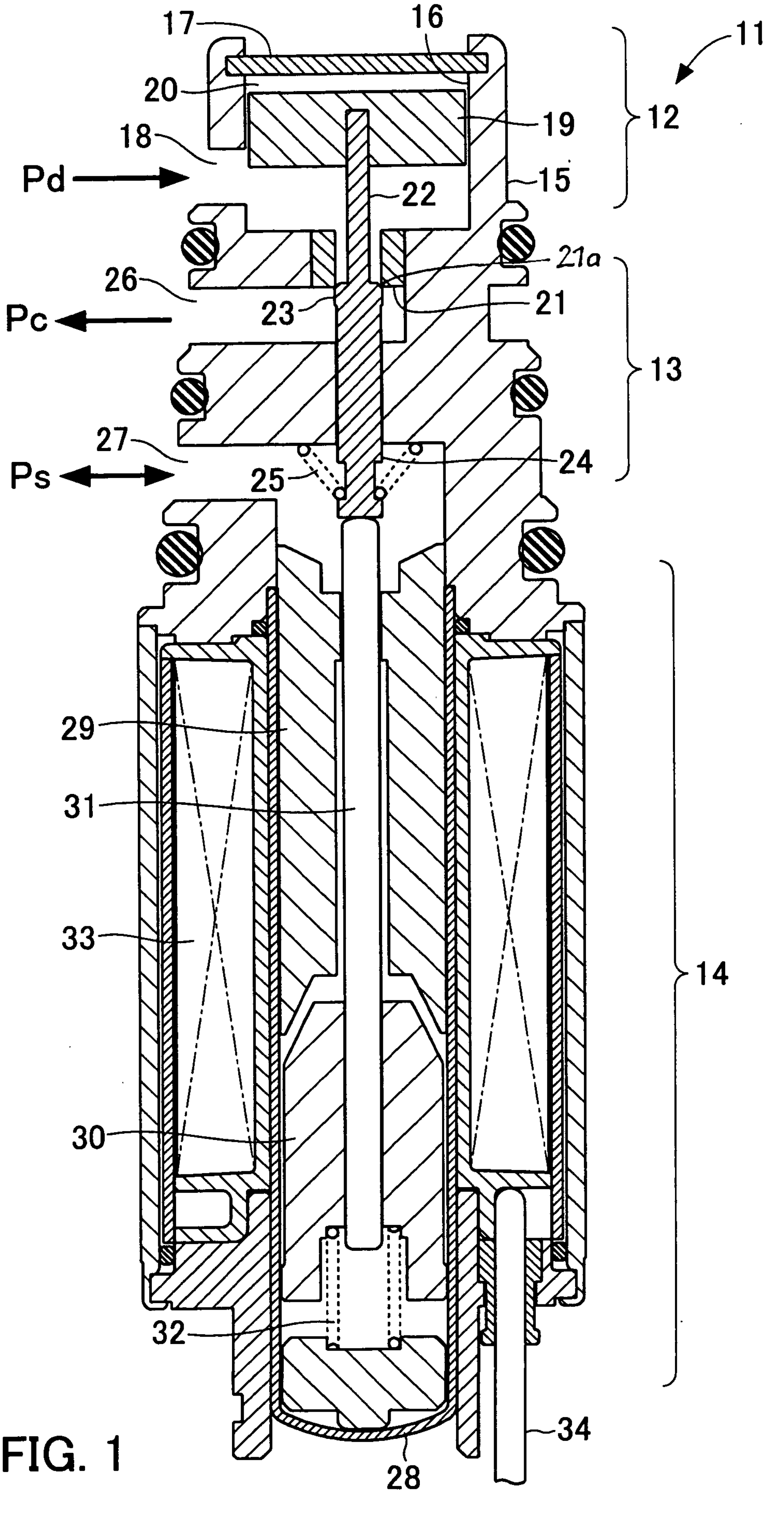

17
16
11
20
19
12
18
Pd
22
15
21a
26
21
23
Pc
13
27
24
Ps
25
29
31
33
14
30
32
34
28

FIG. 1

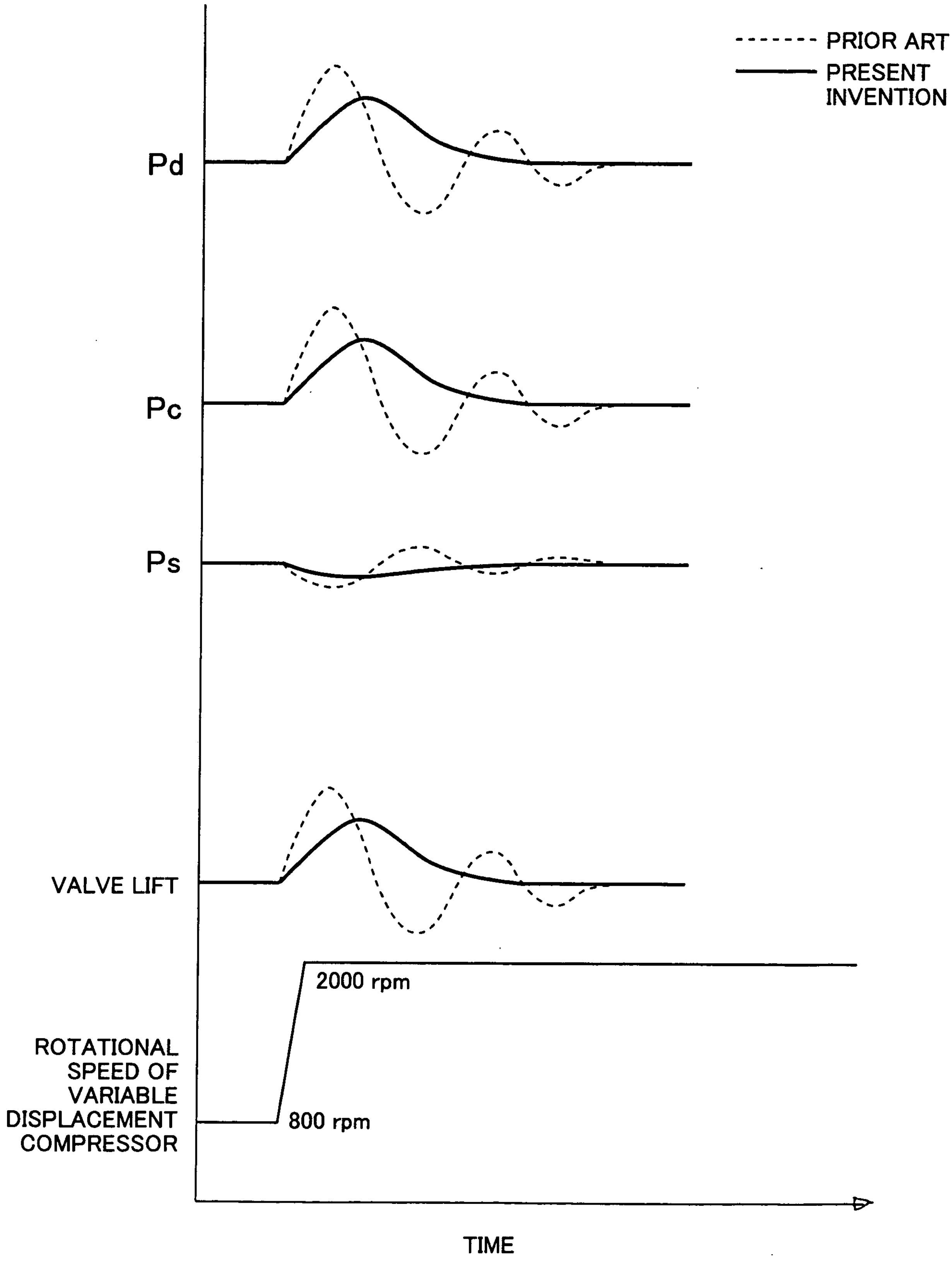

PRIOR ART
PRESENT INVENTION
Pd
Pc
Ps
VALVE LIFT
2000 rpm
ROTATIONAL SPEED OF VARIABLE DISPLACEMENT COMPRESSOR
800 rpm
TIME

FIG. 2

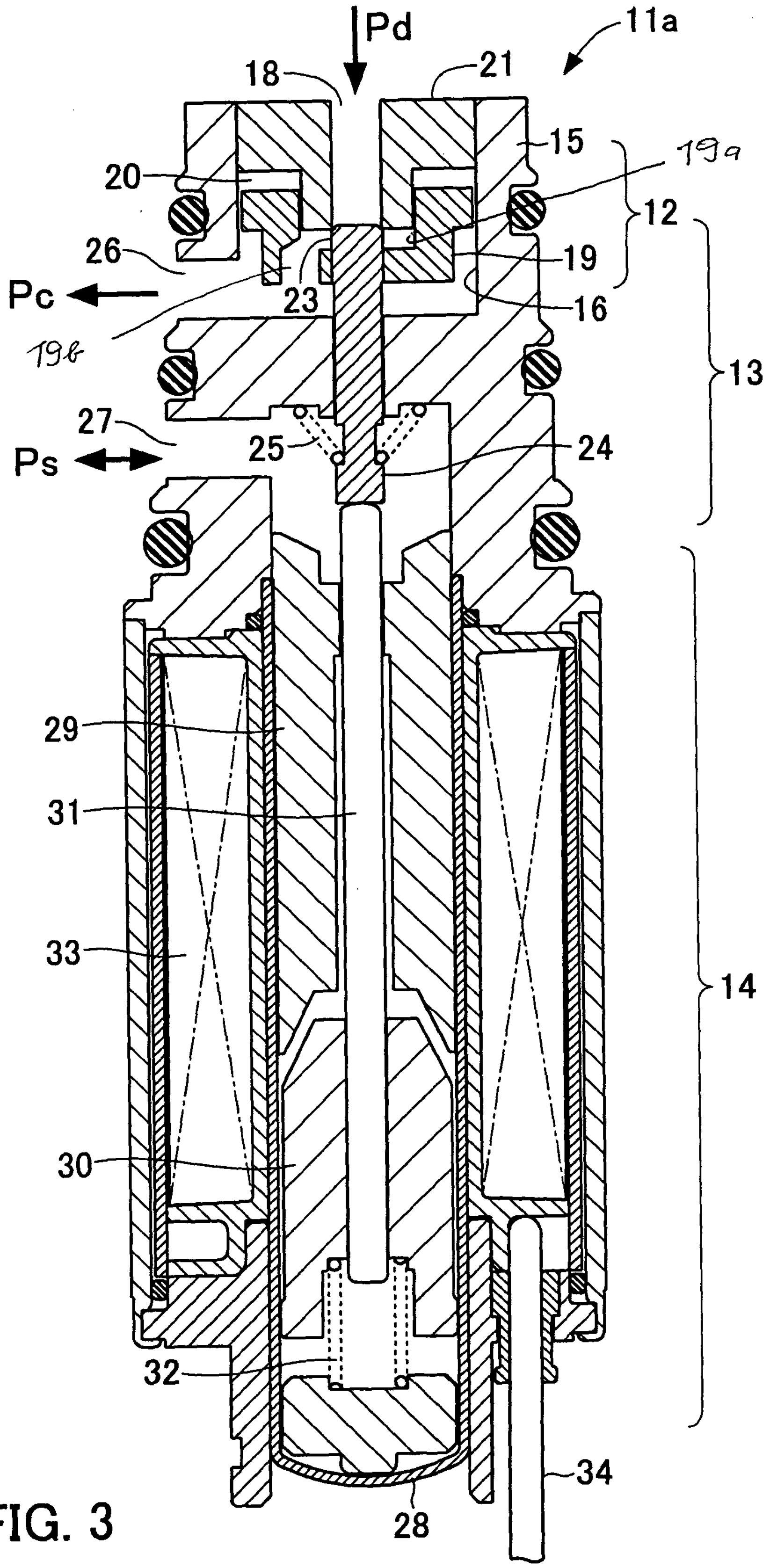

Pd
11a
18
21
15
19a
20
12
19
26
Pc
23
16
19b
13
27
25
24
Ps
29
31
33
14
30
32
34
28

FIG. 3

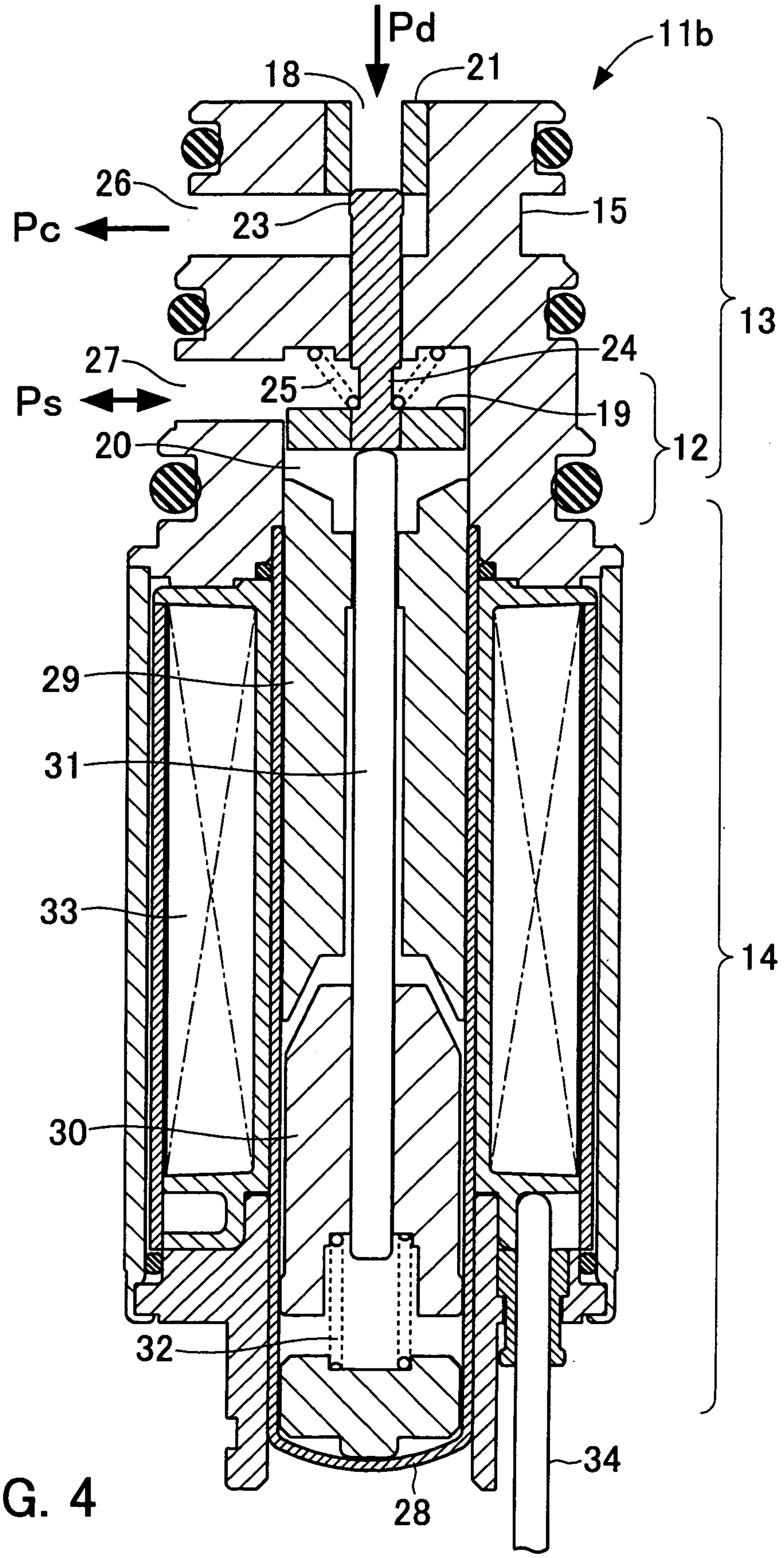


FIG. 4

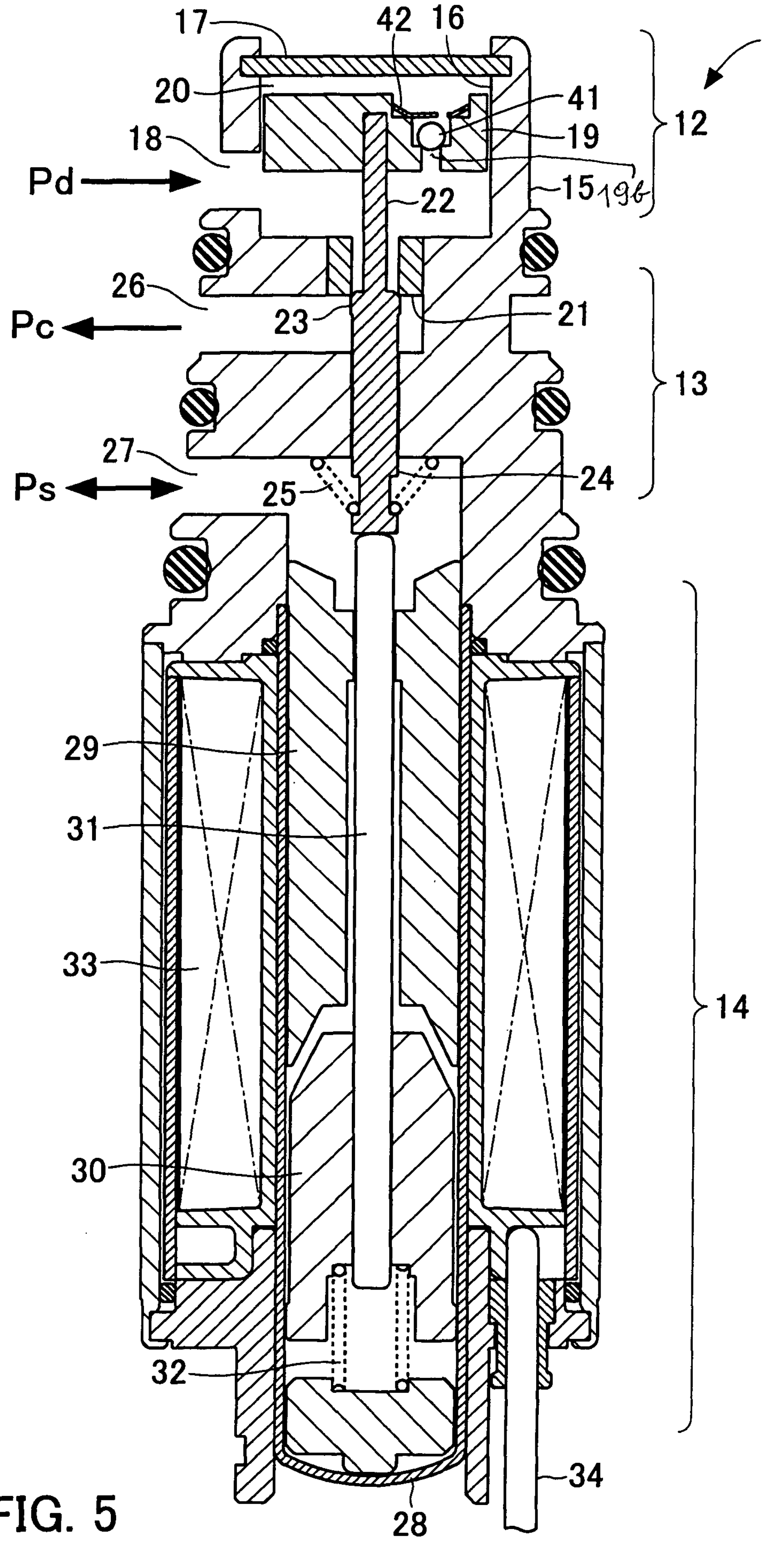
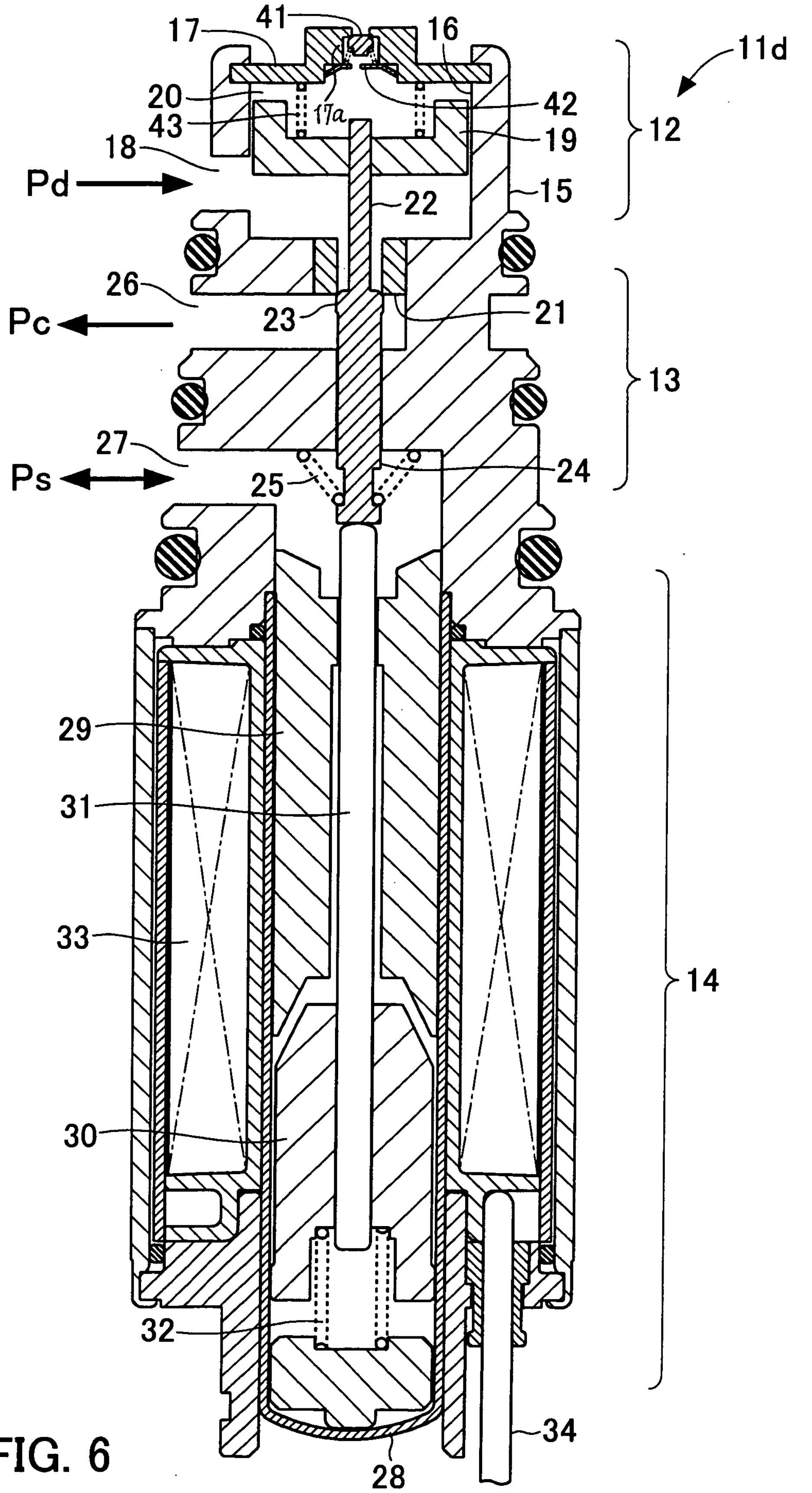

11c
17
42
16
20
41
12
18
19
Pd
15
19b
22
26
21
Pc
23
13
27
24
Ps
25
29
31
33
14
30
32
34
28

FIG. 5


41
17
16
11d
20
42
43
17a
12
18
19
Pd
15
22
26
21
23
Pc
13
27
24
Ps
25
29
31
33
14
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32
34
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FIG. 6

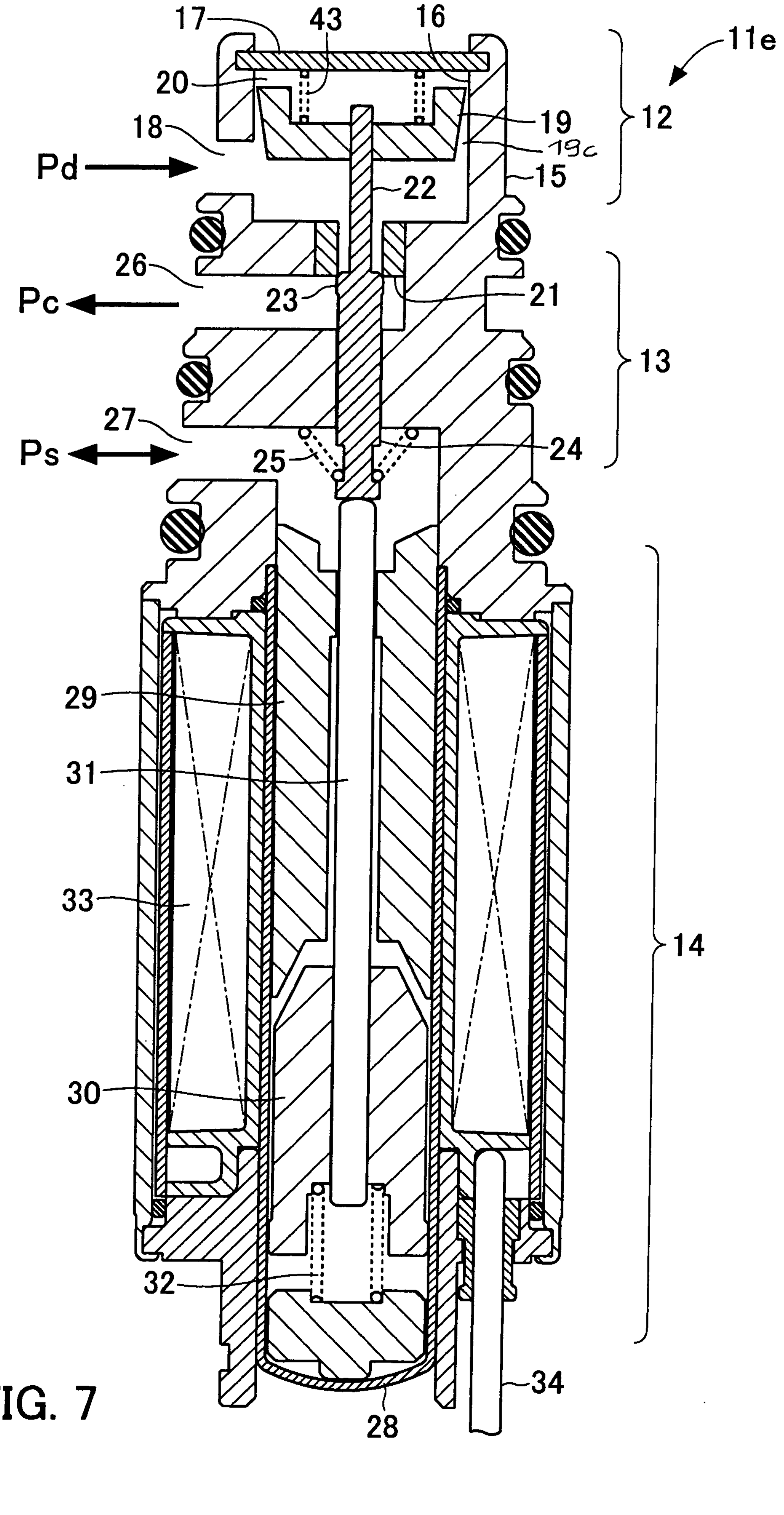
11e
17
43
16
20
19
19c
18
12
Pd
15
22
26
Pc
23
21
13
27
Ps
25
24
29
31
33
14
30
32
34
28

FIG. 7

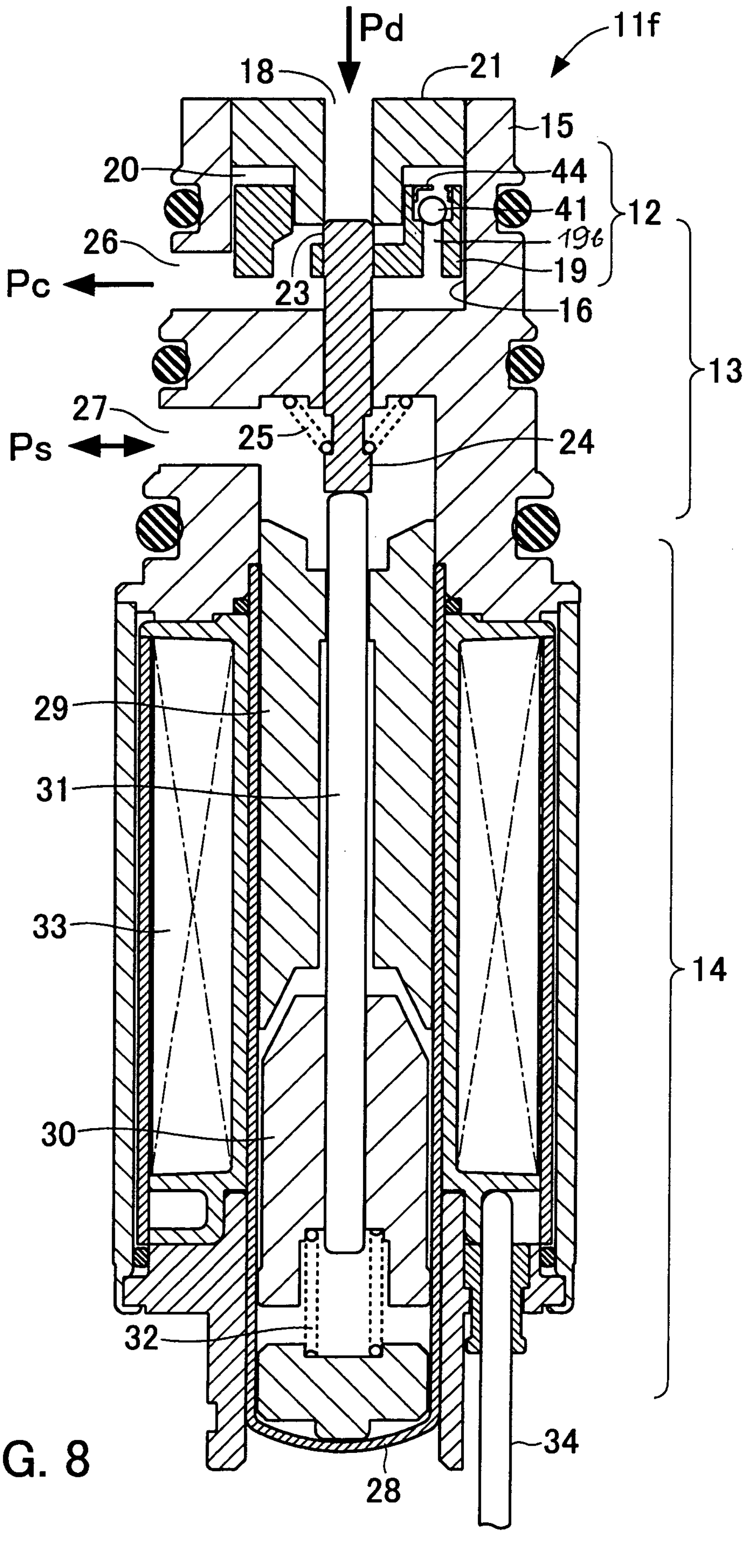
Pd
11f
18
21
15
20
44
41
12
26
196
19
Pc
23
16
13
27
25
24
Ps
29
31
33
14
30
32
34
28

FIG. 8

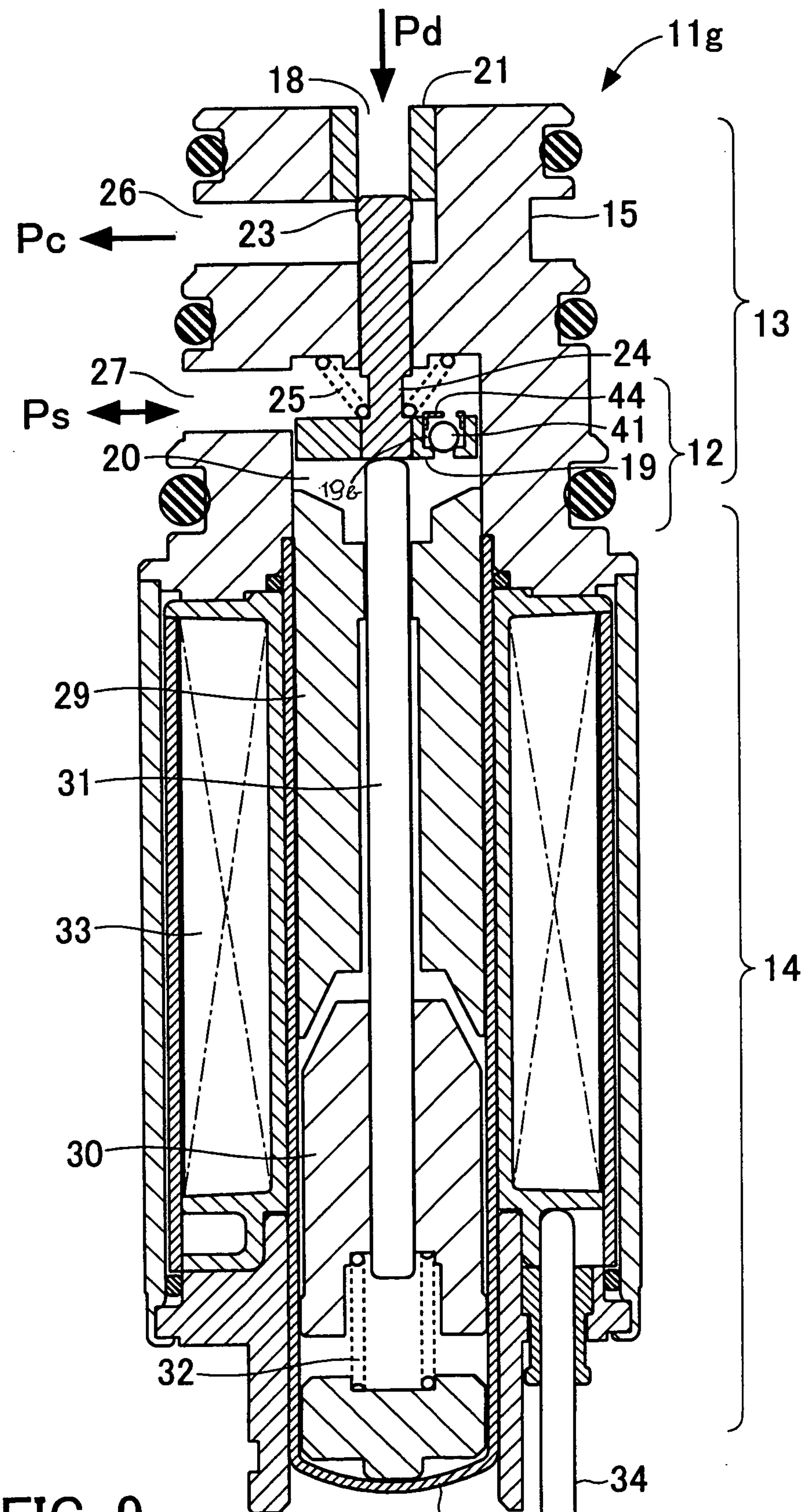
Pd
11g
18
21
26
15
Pc
23
13
27
24
25
44
Ps
41
20
19
12
19b
29
31
33
14
30
32
34
28

FIG. 9