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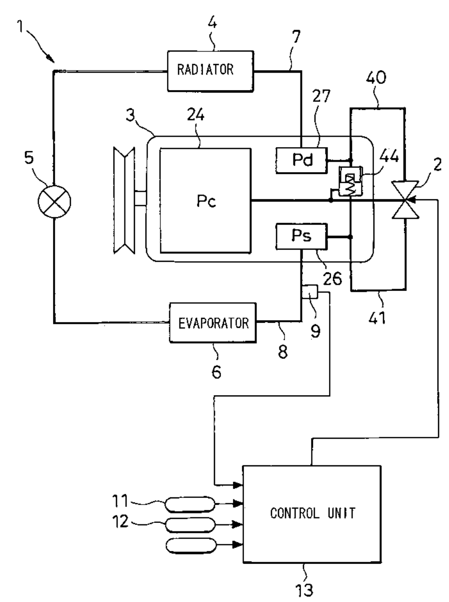
(54) CONTROL DEVICE FOR VARIABLE CAPACITY COMPRESSOR

(57) A control device for a variable-capacity compressor, the discharge capacity of which decreases as the pressure in a crankcase 24 rises and increases as the pressure in the crankcase 24 becomes lower, adopts a structure that includes a supply passage 40 that allows a discharge chamber 27 and the crankcase 24 to communicate with each other and a bleed passage 41 that allows the crankcase 24 and an intake chamber 26 to communicate with each other so as to adjust the pressure in the crankcase 24 via the supply passage 40 and the bleed passage 41. The structure further includes a differential pressure regulating valve 44 that allows the crankcase 24 and the intake chamber 26 to communicate with each other when the difference between the pressure in the discharge chamber 27 and the pressure in another area (the intake chamber 26 or the crankcase 24) becomes equal to or smaller than a predetermined value. The structure, which satisfies the need for power efficiency through higher efficiency achieved in the compressor, can be adopted in a clutchless variable-capacity compressor. The structure also assures a desirable startup response in the compressor.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a control device for a variable-capacity compressor, which varies the discharge capacity by adjusting the pressure in a control pressure chamber via a supply passage that allows a discharge pressure area and the control pressure chamber to communicate with each other and a bleed passage that allows the control pressure chamber and an intake pressure area to communicate with each other.

BACKGROUND ART

[0002] As power efficiency in on vehicle air-conditioning systems becomes more important, externally controlled variable-capacity compressors, the discharge capacity of which can be adjusted freely have become more common. In particular, clutchless type variable-capacity compressors are now routinely used in order to achieve compressor weight reduction and to lower the production cost.

[0003] Variable-capacity control is achieved by adjusting the pressure in the crank-case of the compressor with a control valve, and a standard structure includes an external control valve disposed at a supply passage communicating between a discharge pressure area and the crank-case and a fixed orifice disposed at a bleed passage communicating between the crank-case and an intake pressure area (see Patent Reference 1). In addition, the use of a control valve adopting a three-way valve system in which the supply passage communicating between the discharge pressure area and the crank-case and the bleed passage communicating between the crank-case and the intake pressure area are controlled simultaneously has been proposed (see Patent Reference 2)

(Patent Reference 1) Japanese Unexamined Patent Publication No. 2001-153042 (column 0030 and FIGS. 1 and 3)
(Patent Reference 2) Japanese Unexamined Patent Publication No. 2001-12358 (columns 0024 to 0029, FIG. 3)

[0004] In a clutchless variable-capacity compressor, a very small quantity of coolant is discharged even at the minimum discharge capacity, i.e., even when the air-conditioning system is in an OFF state. In order to disallow the outflow of the coolant into the refrigerating cycle when the discharge capacity is at the minimum level, i.e., when the air-conditioning system is in an OFF state, an internal circulating path having a check valve disposed in the discharge passage of the compressor, through which the coolant in the discharge pressure area is returned to the intake pressure area via the crankcase, needs to be formed.

[0005] While the first structure, in which the bleed passage (between Pc and Ps) remains in an open state at all times, as shown in FIG. 16, has an advantage in that the circulation of the coolant inside the compressor can be assured at the minimum discharge capacity, a great quantity of compressed gas needs to be supplied at an intermediate discharge capacity so as to sustain the pressure inside the crankcase at a predetermined level, which leads to poor compressor efficiency and difficulty in achieving power efficiency.

[0006] For this reason, it is desirable to set the diameter of the orifice constituting a release passage to a value as small as possible in the first structure. However, if the diameter of the release passage is too small, the gas having entered the crankcase as blow-by cannot be released promptly. As a result, the pressure in the crankcase does not become sufficiently lowered even as the supply passage is cut off with the control valve to result in a problem in that control that allows the pistons to achieve the maximum stroke cannot be implemented. Thus, it is necessary to set the diameter of the release passage to a smallest possible value within the range over which the control valve is enabled to control piston strokes up to the maximum stroke with the control valve.

[0007] However, at a startup of the compressor having the release passage adjusted as described above, a very small quantity of blow-by gas will have been generated although the piston stroke is at the minimum level and the pressure applied to the piston has not risen to a sufficiently high level. As a result, sufficient moment for increasing the tilt angle (rocking angle) of the swash plate may not be generated and, in such a case, it may not be possible to start up the compressor.

[0008] In addition, if the compressor remains in an OFF state over an extended period of time, liquid coolant will be collected in the crankcase. In this condition, the crankcase pressure will not be lowered until all the liquid coolant is a gasified and released via the bleed passage and thus, the compressor cannot be started up immediately.

[0009] In contrast, the second structure, in which the supply passage is made to open to a greater degree and the opening of the bleed passage is narrowed as the discharge capacity of the compressor becomes smaller, as shown in FIG. 17, does not require a great quantity of compressed gas in order to sustain the crankcase pressure at a predetermined level, thereby achieving superior compressor efficiency and satisfying the need for power efficiency. However, at the minimum discharge capacity, the bleed passage is completely closed, which cuts off the coolant circulation inside the compressor. For this reason, the second structure cannot be adopted in an ideal manner in a clutchless variable-capacity compressor. There is another problem in that when the bleed passage is completely cut off, the pressure in the crankcase rises to an excessively high level, which is bound to increase the extent of machine loss.

[0010] Accordingly, an object of the present invention is to provide a control device for a variable-capacity compressor that addresses the problems that occur in the various types of variable-capacity compressors as discussed above, satisfies the need for power efficiency by achieving higher efficiency in the compressor and can be adopted in conjunction with a clutchless compressor. Another object of the present invention is to assure highly responsive startup characteristics in the compressor.

DISCLOSURE OF THE INVENTION

[0011] In order to achieve the objects described above, a control device according to the present invention for a variable-capacity compressor a discharge capacity of which decreases as the pressure in a control pressure chamber (crankcase) rises and increases as the pressure in the control pressure chamber becomes lower, adopting a structure having a supply passage that allows a discharge pressure area and the control pressure chamber to communicate with each other and a bleed passage that allows the control pressure chamber and an intake pressure area to communicate with each other so as to adjust the pressure in the control pressure chamber via the supply passage and the bleed passage, is characterized in that a differential pressure regulating valve which communicates between the control pressure chamber and the intake pressure area when the difference between the pressure in the discharge pressure area and the pressure in another area such as the intake pressure area or the control pressure chamber becomes equal to or smaller than a predetermined value is included.

[0012] As the discharge capacity decreases, the difference between the pressure in the discharge pressure area and the pressure in the intake pressure area or the control pressure chamber, too, becomes smaller, and once the pressure difference between the discharge pressure area and the intake pressure area or the control pressure chamber becomes equal to or smaller than the predetermined value, the differential pressure regulating valve is engaged in operation to communicate between the control pressure chamber and the intake pressure area. As a result, even when the communication achieved with the bleed passage is cut off, the state of communication between the control pressure chamber and the intake pressure area is sustained. This, in turn, makes it possible to assure the coolant circulation inside the compressor even at the minimum discharge capacity. In addition, at startup, the differential pressure regulating valve is open, assuring the state of communication between the control pressure chamber and the intake pressure area due to a small difference between the pressure in the discharge pressure area and the pressure in the intake pressure area or the control pressure chamber. Thus, the crankcase pressure can be quickly released into the intake pressure area.

[0013] The control device according to the present invention may be adopted in conjunction with an intake/outlet control-type compressor having a control valve used to individually adjust the state of communication achieved with the supply passage for communicating between the discharge pressure area and the crankcase and the state of communication achieved with the bleed passage for communicating between the crankcase and the intake pressure area, with the control valve controlled by using a control signal provided from the outside so as to adjust the pressure in the control pressure chamber or in conjunction with an intake control type compressor having a control valve used to adjust the state of communication at the supply passage and a bleed passage which includes a constriction, with the control valve controlled by using a control signal provided from the outside so as to adjust the pressure in the control pressure chamber. The differential pressure regulating valve may be disposed at the housing of the variable-capacity compressor as a component independent of the control valve, or it may constitute an integrated part of the control valve.

[0014] Alternatively, a control device according to the present invention for a variable-capacity compressor a discharge capacity of which decreases as the pressure in a control pressure chamber rises and increases as the pressure in the control pressure chamber becomes lower, adopting a structure having a supply passage that allows a discharge pressure area and the control pressure chamber to communicate with each other, a bleed passage that allows the control pressure chamber and an intake pressure area to communicate with each other and a control valve that adjusts the state of communication achieved with the supply passage and the state of communication achieved with the bleed passage, with the control valve controlled by using a control signal provided from the outside so as to adjust the pressure in the control pressure chamber, is characterized in that the control valve achieves opening characteristics whereby the degree of openness of the supply passage is increased and the degree of openness of the bleed passage is decreased as the discharge capacity decreases and the communication between the control pressure chamber and the intake pressure area is assured at a minimum discharge capacity.

[0015] This structure, in which the degree of openness of the supply passage increases and the degree of openness of the bleed passage decreases as the discharge capacity of the compressor becomes smaller, does not require a great quantity of compressed gas in order to sustain the pressure in the control pressure chamber at a specific level. In addition, since the state of communication achieved with the supply passage is sustained, the coolant circulation inside the compressor is assured even at the minimum discharge capacity.

[0016] It is desirable to adopt the control device described above in conjunction with, for instance, a swash plate type variable-capacity compressor comprising a drive shaft disposed inside a cylinder block, a drive swash plate allowed to rotate together with the drive shaft, an angle of inclination of which relative to the drive shaft can be varied freely, a cylinder disposed inside the cylinder block and having an axis extending parallel to the drive shaft, a piston slidably disposed in the cylinder to make a reciprocal movement inside the cylinder as the drive swash plate rotates, a compression space defined by the cylinder and the piston, a crankcase constituting a control pressure chamber formed at the piston on a side opposite the compression space side, an intake chamber constituting an intake pressure area that comes into communication with the compression space during an intake stroke of the piston and a discharge chamber constituting a discharge pressure area that comes into communication with the compression space during a compression stroke of the piston.

[0017] As described above, the control device according to the present invention for a variable-capacity compressor the discharge capacity of which decreases as the pressure in the control pressure chamber rises and increases as the pressure in the control pressure chamber decreases, adopting a structure having a supply passage that allows a discharge pressure area and the control pressure chamber to communicate with each other and a bleed passage that allows the control pressure chamber and an intake pressure area to communicate with each other so as to adjust the pressure in the control pressure chamber via the supply passage and the bleed passage, further includes a differential pressure regulating valve that causes the control pressure chamber and the intake pressure area to come into communication with each other when the difference between the pressure in the discharge pressure area and the pressure in another area becomes equal to or smaller than a predetermined value. As a result, even if the communication enabled by the control valve at the bleed passage becomes cut off at the minimum discharge capacity, the state of communication between the control pressure chamber and the intake pressure area can be maintained so as to ensure that the coolant is allowed to circulate inside the compressor. Consequently, higher efficiency is achieved in the compressor to better meet the need for power efficiency and the control device can be adopted with a high level of effectiveness in conjunction with a clutchless variable-capacity compressor.

[0018] In addition, since the control valve that adjusts the state of communication achieved with the supply passage for communicating between the discharge pressure area and the control pressure chamber and the state of communication achieved with the bleed passage for communicating between the control pressure chamber and the intake pressure area achieves opening characteristics whereby the degree of openness of the supply passage increases and the degree of openness of the bleed passage decreases as the discharge capacity becomes lower and the state of communication between the control pressure chamber and the intake pressure area is assured at the minimum discharge capacity. As a result, it meets the need for power efficiency by assuring a higher level of efficiency in the compressor, and since the state of communication achieved with the supply passage is sustained at the minimum discharge capacity, the coolant is allowed to circulate inside the compressor even when the discharge capacity is at the minimum level, which allows the control device to be adopted with a high level of effectiveness in conjunction with a clutchless variable-capacity compressor.

[0019] Moreover, when starting up the compressor after it has been left in an OFF state in which the difference between the pressure in the discharge pressure area and the pressure in the intake pressure area or the control pressure chamber remains equal to or smaller than the predetermined value over an extended period of time, the pressure in the crankcase can be lowered promptly by communicating between the control pressure chamber and the intake pressure area via the differential pressure regulating valve so as to improve the startup characteristics of the compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

FIG. 1 schematically shows the refrigerating cycle and the control device for a variable-capacity compressor, achieved in an embodiment of the present invention;

FIG. 2 is a sectional view of a structural example that may be adopted in a clutchless variable-capacity compressor in the embodiment of the present invention;

FIG. 3 is a sectional view of a structural example that may be adopted in the differential pressure regulating valve used in the compressor shown in FIG. 2;

FIG. 4 is a diagram showing the characteristics of the differential pressure regulating valve;

FIG. 5 is a diagram showing the characteristics of the effective passage area of the passage that communicates between the discharge chamber and the crankcase and the effective passage area of the passage that communicates between the crankcase and the intake chamber;

FIG. 6 is a sectional view of a structural example that may be adopted in a clutch type variable-capacity compressor achieved in another embodiment of the present invention;

FIG. 7 is a sectional view of an example of the structure that may be adopted in the differential pressure regulating valve used in the compressor shown in FIG. 6;

FIG. 8 is a sectional view of a structural example that may be adopted in a clutchless variable-capacity compressor in another embodiment of the present invention;

FIG. 9 is a sectional view of a structural example that may be be adopted in the differential pressure regulating valve used in the compressor shown in FIG. 8;

FIG. 10 is a diagram showing the characteristics of the effective passage area of the passage that communicates between the discharge chamber and the crankcase and the effective passage area of the passage that communicates between the crankcase and the intake chamber;

FIG. 11 is a sectional view of a structural example that may be adopted in a clutch type variable-capacity compressor achieved in another embodiment of the present invention;

FIG. 12 is a sectional view of a structural example that may be adopted in the pressure control valve;

FIG. 13 is a diagram of the opening characteristics of a pressure control valve;

FIG. 14 is a structural example that may be adopted in the pressure control valve having the opening characteristics shown in FIG. 13;

FIG. 15 shows another structural example that may be adopted in the pressure control valve having the opening characteristics shown in FIG. 13;

FIG. 16 is a diagram showing the opening characteristics of a compressor in the related art having a fixed orifice disposed in the bleed passage; and

FIG. 17 is a diagram showing the opening characteristics of a duty control valve adopting a three-way valve system in the related art.

BEST MODE FOR CARRYING OUT THE INVENTION

[0021] The following is an explanation of the preferred embodiments of the present invention, given in reference to the attached drawings.

[0022] In the structural example of the refrigerating cycle installed in a vehicle shown in FIG. 1, the refrigerating cycle 1 comprises a variable-capacity compressor (hereafter referred to as a compressor) 3 having a pressure control valve 2 used to vary the discharge capacity thereof, a radiator 4 that cools a coolant, an expansion device 5 that reduces the pressure of the coolant and an evaporator 6 that gasifies the coolant through evaporation. In the refrigerating cycle 1, the discharge side of the compressor 3 is connected to the expansion device 5 via the radiator 4 and a high pressure line 7 is constituted with a path extending from the discharge side of the compressor 3 to the inflow side of the expansion device 5. In addition, the outflow side of the expansion device 5 is connected to the evaporator 6, the outflow side of the evaporator 6 is connected to the intake side of the compressor 3, and a low pressure line 8 is constituted with the path extending from the outflow side of the expansion device 5 to the intake side of the compressor 3.

[0023] Accordingly, the coolant having been compressed at the compressor 3 enters the radiator 4 as a high-temperature, high pressure coolant, and the coolant cooled at the radiator 4 is then supplied to the expansion device 5. The pressure of the coolant is lowered at the expansion device 5 and the coolant thus becomes low-temperature, low pressure wet steam. At the evaporator 6, the coolant exchanges heat with the air passing through the evaporator 6 and thus becomes gasified, before it is returned to the compressor3.

[0024] Reference numeral 9 indicates a pressure sensor that detects and intake pressure Ps at the compressor disposed in the low pressure line 8, and a signal generated at the pressure sensor 9 is then input to a control unit 13 together with various sensor signals provided by an outlet air temperature sensor 11 that detects the temperature of the air having passed through the evaporator 6 and the like and signals originating from an operation panel 12 at which the target temperature for the air inside the cabin and the like are set.

[0025] The control unit 13 is constituted with an input circuit to which the various signals mentioned above are input as data, a memory unit which includes a read only memory (ROM) and a random access memory (RAM), a central processing unit (CPU) that processes the data and generates control data through arithmetic operations by calling up a program stored in the memory unit, a control signal output circuit that outputs a control signal to be provided to the pressure control valve 2 and the like.

(When the compressor is a clutchless intake/outlet control type compressor)

[0026] The compressor 3 may be, for instance, a clutchless swash plate type variable-capacity compressor such as that shown in FIG. 2. A housing 20 of the compressor 3 includes a front head 21 that defines a crankcase 24, a cylinder block 22 in which a plurality of cylinders 25 are defined and a rear head 23 attached to the cylinder block 22 via a valve plate 19, which defines intake chambers 26 and an outlet chamber 27.

[0027] A drive shaft 28 passing through the housing 20 is rotatably held at the front head 21 and the cylinder block 22 respectively via bearings 29a and 29b. The drive shaft 28 is connected with a traveling engine (not shown) via a belt and a pulley so that as the motive power of the engine is transmitted, the drive shaft 28 is caused to rotate. In addition, a swash plate 30, which rotates together with the drive shaft 28 as the drive shaft 28 rotates and is allowed to tilt freely relative to the drive shaft 28, is disposed at the drive shaft 28.

[0028] The plurality of cylinders 25 are formed over predetermined intervals around the drive shaft 28 inside the cylinder block 22. The cylinders are each formed in a cylindrical shape with a central axis thereof extending parallel to the axis of the drive shaft 28. A piston 31 held at the swash plate 30 via a rod is slidably inserted within each cylinder 25.

[0029] As the drive shaft 28 rotates, the swash plate 30, too, rotates with a specific tilt and, as a result, the edge of the swash plate 30 is caused to rock over a specific width along the axis of the drive shaft 28 in the structure described above. This causes each piston 31 held at the edge of the swash plate 30 to move reciprocally along the axis of the drive shaft 28 to alter the volumetric capacity of a compression space 32 formed inside the cylinder 25. As a result, the coolant is taken in from the intake chamber 26 via an intake port 34 which is opened/closed with an intake valve 33 and is formed at the valve plate 19 and the compressed coolant is discharged into the discharge chamber 27 via a discharge port 36 which is opened/closed with a discharge valve 35 and is formed at the valve plate 19.

[0030] The discharge capacity of the compressor 3 is determined in conformance to the stroke of the piston 31, and the piston stroke is determined based upon the difference between the pressure applied to the front surface of the piston 31, i.e., the pressure in the compression space 32, and the pressure applied to the rear surface of the piston, i.e., the pressure inside the crankcase 24 (crankcase pressure Pc). More specifically, as the pressure inside the crankcase 24 is raised, the pressure difference between the compression space 32 and the crankcase 24 becomes smaller and the angle of inclination (rocking angle) of the swash plate 30 becomes smaller to result in a smaller piston stroke and a lowered discharge capacity. If, on the other hand, the pressure in the crankcase 24 is reduced, the pressure difference between the compression space 32 and the crankcase 24 increases and the angle of inclination (rocking angle) of the swash plate 30, too, increases to result in a greater piston stroke and a higher discharge capacity.

[0031] The pressure Pc in the crankcase 24 is varied by controlling the quantity of coolant flowing into the crankcase 24 from the discharge chamber 27 and the quantity of coolant flowing out of the crankcase 24 into the intake chamber 26 with the pressure control valve 2 disposed at the rear head 23. The pressure control valve 2 used in the embodiment is constituted with a duty control valve adopting a three-way valve system capable of simultaneously adjusting the state of communication achieved with a supply passage 40 which communicates between the discharge chamber 27 (discharge pressure area) and the crankcase 24 (control pressure chamber) and the state of communication achieved with a bleed passage 41 which communicates between the crankcase (control pressure chamber) and the intake chamber (intake pressure area). The average degree of openness per unit time at each passage is determined based upon the ratio of the length of time over which the supply passage is to remain open and the length of time over which the bleed passage is to remain open, which is determined based upon an external duty signal. The control achieved with such a duty control valve in itself is of the known art as disclosed in, for instance, Japanese Unexamined Patent Publication No. 2001-12358. The pressure control valve 2, which is controlled with a control signal provided by the control unit 13, controls the discharge capacity by adjusting the crankcase pressure Pc so as to achieve a target intake pressure.

[0032] In addition, the pressure control valve 2 has the valve opening characteristics shown in FIG. 17, whereby the degree of openness of the supply passage 40 (the rate at which the supply passage 40 is set in an open state through the duty control achieved with the pressure control valve 2) is increased and the degree of openness of the bleed passage 41 (the rate at which the bleed passage 41 is set in an open state through the duty control implemented with the control valve) is reduced when the discharge capacity needs to be decreased to a greater extent and the supply passage 40 and the bleed passage 41 are respectively set in a fully open state and a fully closed state at the minimum discharge capacity.

[0033] In the compressor 3 structured as described above, a pressure differential regulating valve 44 that allows the crankcase 24 and the intake chamber 26 to communicate with each other when the difference between the pressure Pd in the discharge chamber 27 and the pressure Ps in the intake chamber 26 is equal to or smaller than a predetermined value is disposed at the rear head 23.

[0034] As shown in FIG. 3, the differential pressure regulating valve 44 may be constituted with, for instance, a sleeve 46 slidably housed inside a housing space 45, a high pressure port 47 which is formed so as to face one end of the sleeve 46 and communicates with the discharge chamber 27, a low pressure port 48 which is formed so as to face another end of the sleeve 46 and communicates with the intake chamber 26, a control pressure port 49 which is formed so as to be allowed to communicate with the low pressure port 48 and also communicates with the crankcase 24 with the degree of its openness adjusted in correspondence to the displacement of the sleeve 46, and a spring 50 that applies a force to the sleeve 46 toward the high pressure port. As long as the pressure Pd at the discharge chamber 27 is greater than the pressure Ps at the intake chamber 26 by a sufficient degree, the sleeve 46 is displaced toward the low pressure port against the force applied by the spring 50 and the control pressure port 49 is closed to cut off the communication between the control pressure port 49 and the low pressure port 48, as shown in FIG. 3(a). As the difference between the pressure Pd at the discharge chamber 27 and the pressure Ps at the intake chamber 26 becomes smaller than the force P1 applied by the spring 50, the sleeve 46 is displaced toward the high pressure port, thereby setting the control pressure port 49 and the low pressure port 48 in a state of communication, as shown in FIG. 3(b).

[0035] Thus, as the degree of openness of the supply passage 40 increases, raising the pressure in the crankcase 24, and the angle of inclination of the swash plate 30 changes to reduce the piston stroke, the discharge capacity becomes smaller and the difference between the pressure at the discharge chamber 27 and the pressure in the intake chamber 26 decreases. As the difference in the pressure becomes smaller than a pressure P1, which is in balance with the force applied by the spring 50, the differential pressure regulating valve 44 is engaged in operation and the crankcase 24 and the intake chamber 26 start to communicate with each other (see FIG. 3(b)). Consequently, the area of the passage communicating between the crankcase 24 and the intake chamber 26 increases, as shown in FIG. 4.

[0036] The effective passage opening area S of the passage between the crankcase 24 and intake chamber 26, which is opened by the differential pressure regulating valve 44 at the minimum discharge capacity, is set within a range of 0.4 mm^2 to 1.5 mm^2, and the spring constant of the spring 50 is set so that the pressure P1 is approximately 0.1 MPa when the coolant is R134a and 0.3 to 1 MPa when the coolant is carbon dioxide (CO2).

[0037] Accordingly, integrated characteristics such as those shown in FIG. 5 are achieved by using the pressure control valve 2 and the differential pressure regulating valve 44 in combination. At the minimum discharge capacity, the bleed passage 41 is fully closed by the pressure control valve 2 but the state of communication between the crankcase 24 and the intake chamber 26 is sustained by the differential pressure regulating valve 44 disposed at the rear head 23, thereby allowing the coolant to circulate inside the compressor. Thus, since the degree of openness of the bleed passage 41 keeps decreasing as the discharge capacity becomes lower until the pressure difference between the discharge chamber 27 and the intake chamber 26 becomes equal to P1, power efficiency is achieved in the highly efficient compressor 3. In addition, since the coolant is allowed to circulate inside the compressor at the minimum discharge capacity, the control device can be adopted with a high level of effectiveness in a clutchless variable-capacity compressor. It is to be noted that while the differential pressure regulating valve 44 allows the crankcase 24 and the intake chamber 26 to communicate with each other when the difference between the pressure Pd at the discharge chamber 27 and the pressure Ps at the intake chamber 26 is equal to or smaller than the predetermined value in the structure described above, the crankcase 24 and the intake chamber 26 may instead be made to communicate with each other when the difference between the pressure Pd at the discharge chamber 27 and the pressure in another area, e.g., the pressure Pc at the crankcase 24, becomes equal to or smaller than a predetermined value.

[0038] While the differential pressure regulating valve 44 is disposed at the housing 20 (rear head 23) of the clutchless variable-capacity compressor 3 in the structural example described above, a differential pressure regulating valve that allows the crankcase and the low pressure chamber to communicate with each other when the difference between the pressure in the discharge chamber, i.e., the discharge pressure area, and the pressure in another area is equal to or smaller than a predetermined value may be installed in a clutch type variable-capacity compressor instead.

(When the compressor is a clutch intake/outlet control compressor)

[0039] A specific structural example that may be adopted in a clutch intake/outlet control-type compressor is presented in FIG. 6. The variable-capacity compressor in the example, having a clutch by which the motive power from the traveling engine is transmitted, comprises a cylinder block 122, a rear head 123 mounted on the rear side (the right side in the figure) of the cylinder block 122 via a valve plate 119 and a front head 121 mounted so as to close off the front side (the left side in the figure) of the cylinder block 122. The front head 121, the cylinder block 122, the valve plate 119 and the rear head 123 are fastened together along the axial direction with a fastening bolt 118, and constitute a housing 120 for the entire compressor.

[0040] In a crankcase 124 defined by the front head 121 and the cylinder block 122, a drive shaft 128 with one and thereof projecting out beyond the front head 121 is housed. A clutch plate 116 is secured to the portion of the drive shaft 128 projecting out beyond the front head 121, via a relay member 117 mounted along the axial direction. A drive pulley 115 externally fitted at a boss portion 121a of the front head 121 so as to be allowed to rotate freely faces opposite the clutch plate 116. As power is supplied to an exciting coil 114 embedded in the drive pulley 115, the clutch plate 116 is attracted to and held at the drive pulley 115 and, as a result, the rotary motive power applied to the drive pulley 115 is transmitted to the drive shaft 128. In addition, the area ranging between the one end of the drive shaft 128 and the front head 121 is sealed with a high level of airtightness via a seal member 113 disposed between the one end and the front head 121 and the one end of the drive shaft 128 is also rotatably supported with a radial bearing 129a, whereas the other end of the drive shaft 128 is rotatably supported with a radial bearing 129b housed inside the cylinder block 122.

[0041] At the cylinder block 122, a through hole 140 within which the radial bearing 129b is disposed and a plurality of cylinder bores 125 disposed over equal intervals on a circumference around the through hole 140 located at the center thereof are formed. A single-ended piston 131 is inserted at each cylinder bore 125 so as to be allowed to slide reciprocally. The single-ended piston 131 is a hollow piston formed by bonding a head portion 131a to be inserted within the cylinder bore 125 to an engaging portion 131b to project out into the crankcase 124 along the axial direction.

[0042] A thrust flange 141 which is to rotate as one with the drive shaft 128 inside the crankcase 124 is fixed to the drive shaft 128. A swash plate 130 is linked via a link member 142 to the thrust flange 141 which is rotatably supported via a thrust bearing 139 so as to be allowed to rotate freely relative to the front head 121. The swash plate 130 is mounted so as to be allowed to tilt around a hinge ball 143 disposed on the drive shaft 128 and is allowed to rotate synchronously as the thrust flange 141 rotates. The peripheral edge of the swash plate 130 is held to the engaging portion 131b of the single-ended piston 131 via a pair of shoes 145 disposed to the front and the rear of the peripheral edge.

[0043] Thus, as the drive shaft 128 rotates, the swash plate 130, too, rotates and the rotating motion of the swash plate 130 is converted to a reciprocal linear movement of the single-ended piston 131 via the shoes 145, thereby causing the volumetric capacity of a compression space 132 formed between the single-ended piston 131 and the valve plate 119 inside the cylinder bore 125 to change.

[0044] At the valve plate 119, an intake hole 134 and a discharge hole 136 are formed in correspondence to each cylinder bore 125, and an intake chamber 126 in which the work fluid to be supplied to the compression space 132 is stored and a discharge chamber 127 in which the work fluid discharged from the compression space 132 is stored are formed at the rear head 123 in correspondence to each cylinder. The intake chambers 126, formed in the central area of the rear head 123, each communicate with an intake port (not shown) connecting to the outlet side of the evaporator and are each allowed to also communicate with the corresponding compression space 132 via the intake hole 134 at the valve plate 119. The discharge chamber 127 formed continuously around the intake chambers 126 communicates with an outlet port 146 connecting to the intake side of the condenser and is allowed to also communicate with the corresponding compression space 132 via the discharge hole 136 at the valve plate 119. The intake hole 134 is opened/closed by an intake valve 133 disposed at the valve plate 119 on its end surface toward the cylinder block, whereas the discharge hole 136 is opened/closed by a discharge valve 135 disposed at the valve plate 119 on its end surface toward the rear head.

[0045] The discharge capacity of the compressor 3 is determined by the stroke of the piston 131 and the stroke, in turn, is determined in correspondence to the difference between the pressure applied to the front surface of each piston 131, i.e., the pressure in the compression space (the pressure inside the cylinder bore), and the pressure applied to the rear surface of the piston 131, i.e., the pressure inside the crankcase 124 (the crankcase pressure Pc). More specifically, when the pressure inside the crankcase is raised, the pressure difference between the compression space 132 and the crankcase 124 becomes smaller to reduce the angle of inclination (the rocking angle) of the swash plate 130. As a result, the stroke of the pistons 131 becomes smaller and the discharge capacity decreases. If, on the other hand, the pressure inside the crankcase 124 is lowered, the pressure difference between the compression space 132 and the crankcase 124 increases, and the angle of inclination (the rocking angle) of the swash plate 130 becomes larger. Thus, the stroke of the piston 131 becomes greater and the discharge capacity increases.

[0046] In this example, a supply passage 40 which communicates between the discharge chamber 127 and the crankcase 124 is constituted with a passage formed at the cylinder block 122, the valve plate 119 and the rear head 123, whereas a bleed passage 41 that communicates between the through hole 140 communicating with the crankcase 124 and the intake chamber 126 is constituted with a passage formed at the valve plate 119 and the rear head 123. In addition, a pressure control valve 2 fitted at a control valve mounting hole 147 formed at the rear head 123 is disposed on the supply passage 40 and the bleed passage 41. The pressure control valve 2, which controls the pressure in the crankcase 124 (the crankcase pressure Pc) by adjusting the degrees of openness at the supply passage 40 and the bleed passage 41, includes an actuator such as an electromagnetic solenoid and implements control so as to achieve the characteristics shown in FIG. 17 with regard to the degrees of openness at the supply passage 40 and the bleed passage 41 by adjusting the level of the electrical current supplied to the solenoid.

[0047] In addition, a communicating passage 150 that communicates between the crankcase 124 and the intake chamber 126 via the cylinder block 122 and the valve plate 119 is formed in the compressor 3, with a differential pressure regulating valve 44 used to open/close the communicating passage 150 disposed halfway through the communicating passage 150. As shown in FIG. 7, the differential pressure regulating valve 44 includes a sleeve 152 slidably housed inside a housing space 151 located halfway through the communicating passage 150, a high pressure port 153 connected to one end of the housing space 151 and communicating with the discharge chamber 127, a communicating port 154 connected to another end of the housing space 151 and communicating with the through hole 140 which, in turn, communicates with the crankcase 124, a low pressure port 155 made to open so as to face a side surface of the sleeve 152 and constituting part of the communicating passage 150 communicating with the intake chamber 126, a control pressure port 156 made to open so as to face a side surface of the sleeve 152 and constituting part of the communicating passage 150 communicating with the crankcase 124 and a spring 157 that applies a force to the sleeve 152 toward the high pressure port. In addition, at the side surface of the sleeve 152, a circular groove 158 that adjusts the state of communication between the low pressure port 155 and the control pressure port 156 as the sleeve 152 is displaced is formed. When the pressure Pd in the discharge chamber 127 is greater than the pressure inside the through role 140, which is equivalent to the crankcase pressure by a sufficient extent, the sleeve 152 is displaced toward the communicating port against the force applied by the spring 157 and the communication is cut off by blocking the low pressure port 155 and the control pressure port 156 with the side surface of the sleeve 152, as shown in FIG. 7(a). When the difference between the pressure Pd in the discharge chamber 127 and the pressure inside the through hole which is equivalent to the crankcase pressure becomes smaller than the force P1 applied by the spring 157, on the other hand, the sleeve 152 is displaced toward the high pressure port and the low pressure port 155 and the control pressure port 156 are allowed to communicate with each other via the circular groove 158, as shown in FIG. 7(b)

[0048] Thus, as the degree of openness of the supply passage 40 increases, raising the pressure in the crankcase 124 and the angle of inclination of the swash plate 130 and the piston stroke both become smaller, the discharge capacity decreases and the pressure difference between the discharge chamber 127 and the crankcase 124, too, becomes smaller. Once the pressure difference becomes smaller than a pressure P1, which is in balance with the level of the force applied from the spring 157, the differential pressure regulating valve 44 is engaged in operation and the crankcase 124 and the intake chamber 126 start to communicate with each other, thereby increasing the passage area of the passage between the crankcase 124 and the intake chamber 126, as shown in FIG. 4.

[0049] As a result, the integrated characteristics shown in FIG. 5 are achieved by using the pressure control valve 2 and the differential pressure regulating valve 44 in combination. At the minimum discharge capacity, the bleed passage 41 is fully closed by the pressure control valve 2 but the state of communication between the crankcase 124 and the intake chamber 126 is sustained via the differential pressure regulating valve 44 disposed at the cylinder block 122. Thus, while a very small quantity of blow-by gas is generated at a startup of the compressor 3 during which the piston stroke is at its smallest, the blow-by gas can be released toward the low pressure side with a high level of effectiveness. Consequently, moment which increases the angle of inclination (rocking angle) of the swash plate 130 can be generated to ensure that the compressor 3 can be started up promptly even when the pressure to be applied to the piston 131 has not been raised to a sufficiently high level. In addition, while the liquid coolant is collected in the crankcase 124 if the compressor 3 remains in an OFF state over an extended period of time, the compressor 3 can be started up from such a state with a high level of reliability by releasing the gasified liquid coolant to the low pressure side promptly via the differential pressure regulating valve and thus lowering the crankcase pressure quickly.

[0050] It is to be noted that while the differential pressure regulating valve 44 in the example described above allows the crankcase 124 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure in the through hole 140 which reflects the pressure Pc in the crankcase 124 becomes equal to or smaller than a predetermined value, it may instead allow the crankcase 124 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure in another area such as the pressure Ps in the intake chamber 126 becomes equal to or smaller than a predetermined value.

[0051] While the intake/outlet control, through which the degrees of openness of the supply passage 40 and the bleed passage 41 are adjusted with the control valve 2, is implemented in the compressor described above, a similar differential pressure regulating valve 44 may be installed in an intake control-type compressor, in which the degree of openness of the supply passage 40 is adjusted with the control valve 2 and the bleed passage 41 includes a constriction such as a fixed orifice, as well.

(When the compressor is a clutchless intake control-type compressor)

[0052] FIG. 8 presents an example in which the structure described above is adopted in a clutchless variable-capacity compressor. The bleed passage 41 in this compressor is not controlled with the control valve 2, and is constituted with gaps such as a shaft hole 160 formed at a drive shaft 128 one end thereof connecting with the through hole 140 and the other end thereof connecting with the space 159 formed between the seal member 113 and the radial bearing 129a and communicates with the crankcase 124 via the thrust bearing 139 and the radial bearing 129a, and a radial bearing 129b disposed around the drive shaft 128 supported at the cylinder block 122, and a passage having a constriction that allows the crankcase 124 and the intake chamber 126 to communicate with each other via an orifice hole 161 formed at the valve plate 119 and communicating with the through hole 140. A pressure control valve 2 mounted at the control valve mounting hole 147 at the rear head 123 is disposed on the supply passage 40 formed over the cylinder block 122, the valve plate 119 and the rear head 123, which allows the discharge chamber 127 and the crankcase 124 to communicate with each other. The degree of openness of the supply passage 40 is adjusted with the pressure control valve 2 so as to control the pressure in the crankcase 124 (the crankcase pressure Pc).

[0053] In the compressor, a differential pressure regulating valve 44 is disposed parallel to the orifice hole 161 at the bleed passage 41. The differential pressure regulating valve 44 is constituted with a spool 163 slidably housed inside a spool housing unit 162 formed at the cylinder block 122, a ball valve 165 housed inside a ball valve housing unit 164 formed continuous to the spool housing unit 162 and set in contact with the spool 163, a high pressure port 166 connected to the front end of the spool housing unit 162 and allowed to communicate with the discharge chamber 127, a control pressure port 167 made to open at the ball valve housing unit 164 and connected with the through hole 140 leading to the crankcase 124 and a low pressure port 168 formed at the valve plate 119 covering the ball valve housing unit 164, communicating between the ball valve housing unit 164 and the intake chamber 126 and opened/closed by the ball valve 165. A spring 169 is inserted at the ball valve housing unit 164 from the low pressure chamber side via the low pressure port 168 and the spring 169 applies a constant force to the ball valve 165 to place it in contact with the spool 163.

[0054] Since other structural features are similar to those of the compressor shown in FIG. 6 except that the compressor in this example does not include a clutch mechanism, the same reference numerals are assigned to identical features to preclude the necessity for a repeated explanation thereof.

[0055] Accordingly, if the pressure in the discharge chamber 127 is greater than the pressure in the through hole 140 connecting with the crankcase 124 by a sufficient extent, the spool 163 applies a force to the ball valve 165 to displace it toward the low pressure port against the force applied by the spring 169, the low pressure port 168 is thus blocked with the ball valve 165 and the communication between the control pressure port 167 (the through hole 140) and the low pressure port 168 (the intake chamber 126) is cut off. When the difference between the pressure in the discharge chamber 127 and the pressure in the through hole 140 connecting to the crankcase 124 becomes smaller than the force P1 applied by the spring 169, however, the spring force of the spring 169 displaces the spool 163 toward the high pressure port 166, thereby allowing the control pressure port 167 and the low pressure port 168 to communicate with each other.

[0056] Thus, while the bleed passage 41 is sustained in an open state at all times through the orifice hole 161 in this example, the discharge capacity decreases as the degree of openness of the supply passage 40 increases to raise the pressure at the crankcase 124 and the piston stroke as well as the angle of inclination of the swash plate 130 becomes smaller. As a result, the pressure difference between the discharge chamber 127 and the crankcase 124 is reduced and once the pressure difference becomes smaller than the pressure P1, which is in balance with the force applied by the spring 169, the differential pressure regulating valve 44 is engaged in operation. Thus, the crankcase 124 and the intake chamber 126 start to communicate with each other and the passage area of the passage between the crankcase 124 and the intake chamber 126 increases, as shown in FIG. 4.

[0057] The resulting characteristics achieved by using the pressure control valve 2 and the differential pressure regulating valve 44 in combination are as shown in FIG. 10. At the minimum discharge capacity, the bleed passage 41, the passage area of which is determined in correspondence to the opening at the orifice and the like, is in a communicating state. At the same time, a sufficient extent of communication between the crankcase 124 and the intake chamber 126 is assured with the differential pressure regulating valve 44 disposed at the cylinder block 122, ensuring that the coolant is allowed to circulate fully inside the compressor. Thus, by setting the degree of openness of the bleed passage 41 to the smallest possible value until the pressure difference between the discharge chamber 127 and the intake chamber 126 becomes equal to P1, a higher level of efficiency is achieved in the compressor 3 to meet the need for power efficiency. In addition, since the coolant circulation inside the compressor at the minimum discharge capacity is assured, the structure can be effectively adopted in a clutchless variable-capacity compressor. While a very small quantity of blow-by gas is generated at a startup of the compressor during which the piston stroke is at its smallest, the blow-by gas can be released toward the low pressure side with a high level of effectiveness. Consequently, moment which increases the angle of inclination (rocking angle) of the swash plate can be generated to ensure that the compressor can be started up promptly even when the pressure to be applied to the piston has not been raised to a sufficiently high level. In addition, while the liquid coolant is collected in the crankcase 124 if the compressor remains in an OFF state over an extended period of time, the compressor can be started up from such a state with a high level of reliability by releasing the gasified liquid coolant to the low pressure side promptly via the differential pressure regulating valve 44 and thus lowering the crankcase pressure quickly.

[0058] It is to be noted that while the differential pressure regulating valve 44 in the example described above allows the crankcase 124 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure in the through hole 140 which reflects the crankcase pressure Pc becomes equal to or smaller than a predetermined value, it may instead allow the crankcase 24 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure in another area such as the pressure Ps in the low pressure chamber becomes equal to or smaller than a predetermined value.

[0059] In addition, while the clutchless variable-capacity compressor 3 described above is an intake control-type compressor, in which a fixed constriction is included in the bleed passage and the degree of openness all the supply passage is controlled with a control valve, the structure may be adopted in a clutch type variable-capacity compressor that implements intake control by causing the crankcase and the low pressure chamber to communicate with each other through a differential pressure regulating valve when the pressure difference between the discharge pressure area, i.e., the discharge chamber and another area becomes equal to or smaller than a predetermined value.

(When the compressor is a clutch intake control-type compressor)

[0060] As shown in FIG. 11, for instance, a structure similar to that of the clutch type compressor in FIG. 6 may be adopted in a clutchless variable-capacity compressor. The bleed passage 41 in this compressor is not controlled with the control valve, and is constituted with gaps such as a shaft hole 160 is formed at the drive shaft 128, one end thereof connecting with a through hole 140 and the other end thereof connecting with the space 159 formed between a seal member 113 and a radial bearing 129a, which communicates with the crankcase 124 via a thrust bearing 139 and a radial bearing 129a, and the radial bearing 129b disposed around the drive shaft 128 supported at the cylinder block 122, and a passage having a constriction that allows the crankcase 124 and the intake chamber 126 to communicate with each other via an orifice hole 161 formed at the valve plate 119 and communicating with the through hole 140.

[0061] A pressure control valve 2 mounted at a control valve mounting hole 147 at the rear head 123 is disposed on the supply passage (not shown) formed over the cylinder block 122, the valve plate 119 and the rear head 123, which allows the discharge chamber 127 and the crankcase 124 to communicate with each other. The degree of openness of the supply passage is adjusted with the pressure control valve 2 so as to control the pressure in the crankcase 124 (the crankcase pressure Pc). A differential pressure regulating valve similar to that shown in FIG. 7 is disposed parallel to the orifice hole 161 at the bleed passage 41. It is to be noted that since the other structural features are similar to those in FIG. 6, the same reference numerals are assigned to identical features to preclude the necessity for a repeated explanation thereof.

[0062] As a result, as the degree of openness of the supply passage 40 increases to raise the pressure at the crankcase 24 and the piston stroke as well as the angel of inclination of the swash plate 30 becomes smaller, the discharge capacity is lowered and the pressure difference between the discharge chamber 127 and the crankcase 124 is reduced. Once the pressure difference becomes smaller than a pressure P1, which is in balance with the force applied by the spring 50, the differential pressure regulating valve 44 is engaged in operation, the crankcase 24 and the intake chamber 126 start to communicate with each other and the passage area of the passage communicating between the crankcase 124 and the intake chamber 126 increases, as shown in FIG. 4.

[0063] The resulting characteristics achieved by using the pressure control valve 2 and the differential pressure regulating valve 44 in combination are as shown in FIG. 10. At the minimum discharge capacity the bleed passage 41, the passage area of which is determined by the opening at the orifice and the like, is in a communicating state. At the same time, since a sufficient extent of communication between the crankcase 124 and the intake chamber 126 is assured with the differential pressure regulating valve 44 disposed at the cylinder block 122, a very small quantity of blow-by gas generated at a startup of the compressor during which the piston stroke is at its smallest, can be released toward the low pressure side with a high level of effectiveness. Consequently, moment which increases the angle of inclination (rocking angle) of the swash plate can be generated to ensure that the compressor can be started up promptly even when the pressure to be applied to the piston has not been raised to a sufficiently high level. In addition, while the liquid coolant is collected in the crankcase if the compressor remains in an OFF state over an extended period of time, the compressor can be started up from such a state with a high level of reliability by releasing the gasified liquid coolant toward the low pressure side promptly via the differential pressure regulating valve and thus lowering the crankcase pressure quickly.

[0064] It is to be noted that while the differential pressure regulating valve 44 in the example described above allows the crankcase 124 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure Pc in the crankcase 124 becomes equal to or smaller than a predetermined value, it may instead allow the crankcase 124 and the intake chamber 126 to communicate with each other when the difference between the pressure Pd in the discharge chamber 127 and the pressure in another area such as the pressure Ps in the low pressure chamber becomes equal to or smaller than a predetermined value.

[0065] While the differential pressure regulating valve 44 is disposed at the housing (the cylinder head or the cylinder block) in a clutchless or clutch type compressor that implements intake/outlet control or intake control in the explanation provided above, the differential pressure regulating valve may instead be provided as an integrated part of the pressure control valve 2.

[0066] FIG. 12 shows a structural example in which a differential pressure regulating valve 44 is included at a pressure control valve 2. The pressure control valve 2 is constituted with a drive unit 60, a central block unit 70 and a valve element unit 80. The drive unit 60 includes a cylindrical case 61 which is locked to one end of the central block unit 70 through caulking, a cylindrical cylinder 62 housed inside the case 61 and fixed to one end of the central block unit 70, an electromagnetic coil 63 wound around the cylinder 62, a plunger 64 slidably inserted within the cylinder 62 and having one end surface located toward the central block unit 70, which comes in contact with a valve element drive rod 68, and another end surface at which a spring receptacle hole 65 is formed, a spring 66 inserted at the spring receptacle hole 65 and having one end that comes in contact with the plunger 64 and a lid body 67 locked to the other end of the case 61 through caulking so as to hold the spring 66 on the other end and seal the other end of the cylinder 62.

[0067] The central block unit 70 is constituted with a cylindrical block 71 having a cylindrical projection 71a that secures the cylinder 62 and an outer ring portion 71b to which the case 61 is fixed through caulking. The central block unit includes a through hole 74 through which the valve element drive rod 68 slidably passes, a low pressure chamber 73 formed at the center of the block 71 and a low pressure side communicating hole 72 extending from the low pressure chamber 73 along the radial direction. The low pressure side communicating hole 72 communicates with the intake chamber 26 of the compressor 3 via a passage (not shown) formed at the rear head so as to substantially match the pressure inside the low pressure chamber 73 with the pressure in the low pressure line 8 in the refrigerating cycle 1.

[0068] The valve element unit 80 includes a substantially cylindrical outer case 81 and an inner case 83 fitted inside the outer case 81. A pressure adjustment chamber 86 is formed at the outer case 81 at a position toward the central block unit and a switching portion 91 of a valve element 90 is housed in the pressure adjustment chamber 86. A sliding portion 93 of the valve element 90 is slidably inserted at the inner case 82 and a high pressure chamber 84 is formed between the inner case 82 and a small diameter portion 92 of the valve element 90. The pressure adjustment chamber 86 communicates with the crankcase 24 via a crankcase communicating hole 85 opening at the outer case 81 and a passage (not shown) formed at the rear head 23, whereas the high pressure chamber 84 communicates with the discharge chamber 27 via a through hole 83 passing through the outer case 81 and the inner case 82 and a passage (not shown) formed at the rear head 23.

[0069] In addition, the pressure adjustment chamber 86 is formed so as to have an internal diameter greater than the internal diameter of the low pressure chamber 73 and the internal diameter of the inner case 82 is set smaller than the internal diameter of the pressure adjustment chamber 86. As a result, a low pressure side valve seat 76 is formed between the low pressure chamber 73 and the pressure adjustment chamber 86 and a high pressure side valve seat 77 is formed between the high pressure chamber 84 and the pressure adjustment chamber 86. As the switching portion 91 of the valve element 90 housed inside the pressure adjustment chamber 86 sits at the low pressure side valve seat 76 or the high pressure side valve seat 77, communication with the low pressure side/high pressure side is achieved/cut off.

[0070] A low pressure space 87 is formed between an end of the sliding portion 93 at the valve element 90 and the inner case 82, and the low pressure space 87 communicates with the intake chamber 26 via a communicating hole 89 formed at a lid portion 88 used to lock the inner case 82 to the outer case 81 and a passage (not shown) formed at the rear head 23. In addition, a spring 94 which applies a force to the valve element 90 so as to press it toward the low pressure side valve seat 76 is disposed in the low pressure space 87. It is to be noted that since the level of the force applied from the spring 94 is greater than the level of the force applied from the spring 66, the switching portion 91 is pressed onto the low pressure side valve seat 76 as long as no power is supplied to the electromagnetic coil 63.

[0071] Between the communicating hole 83 communicating with the discharge chamber 27 and the low pressure side communicating hole 72 communicating with the intake chamber 26, a differential pressure valve 44 such as that shown in FIG. 3 is disposed so as to allow the crankcase 24 and the intake chamber 26 to communicate with each other by connecting the pressure adjustment chamber 86 to the low pressure side communicating hole 72 when the difference between the pressure Pd in the discharge chamber 27 and the pressure Ps in the intake chamber 26 becomes equal to or smaller than a predetermined level.

[0072] Accordingly, if it is necessary to increase the discharge capacity, the ratio of the time length over which power is supplied to the electromagnetic coil 63 at the pressure control valve 2 increases. In this situation, the plunger 64 is attracted toward the electromagnetic coil 63, the valve element 90 is caused to move via the valve element drive rod 68 against the force applied from the spring 94, and the ratio of the time length over which the switching portion 91 remains away from the low pressure side valve seat 76 and seated on the high pressure side valve seat 77 increases. Since this increases the length of time over which the crankcase 24 remains in communication with the intake chamber 26 via the pressure adjustment chamber 86 and the low pressure chamber 73, the pressure in the crankcase becomes lower, which increases the piston stroke and the discharge capacity of the compressor 3.

[0073] In contrast, if it is necessary to decrease the discharge capacity, the ratio of the time length over which power is supplied to the electromagnetic coil 63 at the pressure control valve 2 decreases. In this situation, the plunger 64 is attracted toward the electromagnetic coil 63, the valve element 90 is caused to move via the valve element drive rod 68 against the force applied from the spring 94, and the ratio of the time length over which the switching portion 91 remains away from the low pressure side valve seat 76 and seated on the high pressure side valve seat 77 decreases. Since this decreases the length of time over which the crank case 24 remains in communication with the intake chamber

26 via the pressure adjustment chamber 86 and the low pressure chamber 73, the pressure in the crankcase becomes higher, which reduces the piston stroke and the discharge capacity of the compressor 3. At the minimum discharge capacity, the power supplied to the pressure control valve 2 is cut off, leaving the switching portion 91 seated at the low pressure side valve seat 76 and cutting off communication between the crankcase 24 and the intake chamber 26. The pressure Pc in the crankcase 24 thus becomes substantially equal to the pressure Pd in the discharge chamber 27.

[0074] As the discharge capacity of the compressor 3 becomes smaller, the pressure difference between the discharge chamber 27 and the intake chamber 26 at the compressor 3, too, becomes smaller. Once the pressure difference becomes equal to or less than P1, the differential pressure regulating valve 44 is engaged in operation and the crankcase 24 and the intake chamber 26 start to communicate with each other. Thus, while the passage between the crankcase 24 and the intake chamber 26 is blocked by the valve element 90 of the pressure control valve 2 at the minimum discharge capacity, the communication between the crankcase 24 and the intake chamber 26 is still sustained via the differential pressure regulating valve 44 to allow the coolant to circulate inside the compressor.

[0075] It is to be noted that while the differential pressure regulating valve 44 is engaged in operation based upon the pressure difference between the discharge chamber 27 and the intake chamber 26 in the structure described above, it may instead be engaged in operation based upon the pressure difference between the discharge chamber 27 and the crankcase 24. In addition, a structure other than that shown in FIG. 6 may be adopted to communicate between the crankcase 24 and the intake chamber 26 when the difference between the pressure Pd and the pressure Ps or Pc becomes equal to or smaller than the predetermined value.

[0076] While the coolant circulation inside the compressor at the minimum discharge capacity is assured through the use of the differential pressure regulating valve 44 without modifying the valve opening characteristics of the pressure control valve 2 itself in the structures described above, the valve opening characteristics of the pressure control valve itself may be modified, as shown in FIG. 13 so as to increase the degree of openness of the supply passage 40 as the discharge capacity of the compressor 3 decreases and to initially reduce the degree of openness of the bleed passage 41 as the discharge capacity of the compressor 3 becomes smaller, set the degree of openness to 0 at a predetermined discharge capacity, then raise the degree of openness as the discharge capacity becomes even smaller and reliably set the bleed passage 41 in an open state at the minimum discharge capacity.

[0077] FIG. 14 presents a structural example that may be adopted in a pressure control valve 2 having such opening characteristics. FIG. 4 schematically shows the structure of the pressure control valve 2 without including the illustration of the drive unit and the like. The pressure control valve 2 is constituted as an integrated part of the case 100 by forming at the case 100 a supply side opening adjustment unit 101 that adjusts the degree of openness of the supply passage and a bleed-side opening adjustment unit 102 that adjusts the degree of openness of the bleed passage.

[0078] The supply side opening adjustment unit 101 includes a supply communicating hole 103 communicating with the crankcase 24, a supply valve hole 104 that connects with the supply communicating hole 103 and communicates with the discharge chamber 27 and a supply side valve element unit 105 that varies the passage area of the supply valve hole 104. The bleed side opening adjustment unit 102, on the other hand, includes a valve element moving space 106 formed at the case 100, a bleed communicating hole 107 that connects with the valve element moving space 106 and communicates with the crankcase 24, a bleed valve hole 108 that connects with the valve element moving space 106 and communicates with the intake chamber 26 and a bleed-side valve element unit 109 that varies the degree of openness of the bleed valve hole by sliding into and out of the bleed valve hole 108.

[0079] The supply side valve element unit 105 can be displaced between a position at which it is in contact with the opening end of the supply valve hole 104 blocking the supply valve hole 104 and a position at which it is away from the opening end, maximizing the degree of openness of the supply valve hole 104. The shape of the valve element is designed so as to change the degree of openness substantially in proportion to the extent of its displacement. In addition, the bleed side valve element unit 109 can be displaced from the outside to the inside of the valve element moving space 106 via the bleed valve hole 108 and the shape of the valve element is designed so as to substantially match its largest diameter with the diameter of the bleed valve hole 108 and to change the degree of openness substantially in proportion to the extent of its displacement to the outside or the inside from the bleed valve hole 108.

[0080] The supply side valve element unit 105 and the bleed side valve element unit 109 are linked with each other via a linking rod 110 passing through the case 100 and projecting out into the supply valve hole 104 and the valve element moving space 106 to constitute an integrated valve element 111. When the supply side valve element unit 105 assumes the position at which it blocks the supply valve hole 104, the bleed side valve element unit 109 is positioned outside the valve element moving space 106, whereas the bleed side valve element unit 109 is positioned inside the valve element moving space 106 when the lift of the supply side valve element unit 105 is at the largest.

[0081] In addition, the effective opening area S of the bleed passage 41 controlled with the pressure control valve 2 at the minimum discharge capacity is set within a range of 0.4 mm^2 to 1.5 mm^2 and, at the same time, it is ensured that the effective opening area S is smaller than the effective opening area of the supply passage 40 controlled with the pressure control valve 2.

[0082] In the structure, the discharge capacity is at its maximum level at position A in FIG. 13 at which the supply side valve element unit 105 at the valve element 111 is in contact with the opening end of the supply valve hole 104 to set the passage area between the discharge chamber 27 and the crankcase 24 to 0 and the bleed side valve element unit 109 at the valve element 111 is positioned outside the valve element moving space 106 to maximize the passage area between the crankcase 24 and the intake chamber 26, as shown in FIG. 14(a).

[0083] As the discharge capacity decreases to achieve a state B in FIG. 13, the supply side valve element unit 105 at the valve element 111 departs the opening end of the supply valve hole 104 to increase the passage area between the discharge chamber 27 and the crankcase 24 and the bleed side valve element unit 109 is positioned inside the bleed valve hole 108 to set the passage area between the crankcase 24 and the intake chamber 26 to 0, as shown in FIG. 14(b). As the discharge capacity further decreases, the supply side valve element unit 105 at the valve element 111 moves further away from the opening end of the supply valve hole 104 and the bleed side valve element unit 109 at the valve element 111 moves into the valve element moving space 106, thereby increasing the passage area between the crankcase 24 and the intake chamber 26, as shown in FIG. 14(c).

[0084] Thus, the structure described above, in which the effective passage area of the bleed passage 41 is gradually reduced as the discharge capacity decreases until the effective passage area becomes 0 and then the effective passage area is gradually increased, an excessively large quantity of compressed gas is not required to sustain the pressure inside the control pressure chamber at a specific level and thus, a higher level of efficiency is achieved in the compressor 3. In addition, since the communication between the crankcase 24 and the intake chamber 26 is sustained, the coolant is allowed to circulate inside the compressor even at the minimum discharge capacity.

[0085] It is to be noted that while the characteristics shown in FIG. 7 are achieved by adjusting the shape of the valve element 111, the bleed side valve element unit 109 at the valve element 111 may assume a poppet shape and the passage section of the bleed valve hole 108 may be altered along the axial direction so as to adjust the passage area between the bleed side valve element unit 109 and the bleed valve hole 108 as the valve element 111 is displaced, as shown in FIG. 9(a), instead.

[0086] In addition, the supply communicating hole 103 at the pressure control valve 2 may be made to communicate with the discharge chamber 27, the supply valve hole 104 may be made to communicate with the crankcase 24, the bleed communicating hole 107 may be made to communicate with the intake chamber 26 and the bleed valve hole 108 may be made to communicate with the crankcase 24, as shown in FIG. 9(b), instead. As a further alternative, the positional relationship between the supply side opening adjustment unit 101 and the bleed side opening adjustment unit 102 may be reversed, as shown in FIG. 9(c). In this case, the bleed side opening adjustment unit 102 may adopt a structure similar to that shown in FIG. 8, whereas the supply side opening adjustment unit 101 may include a valve element moving space 112 formed at the case 100, a supply communicating hole 103 which connects to the valve element moving space 112 and communicates with the crankcase 24, a supply valve hole 104 which connects to the valve element moving space 112 and communicates with the discharge chamber 27 and a supply side valve element unit 105 which slides into and out of the supply valve hole 104 to vary the degree of openness of the supply valve hole 104.

[0087] It is to be noted that the variable-capacity compressor 3 may adopt a structure other than the swash plate system described above and the structure according to the present invention may be adopted in another type of compressor in which the discharge capacity decreases as the pressure in the crankcase 24 rises and the discharge capacity increases as the pressure in the crankcase 24 becomes lower.

INDUSTRIAL APPLICABILITY

[0088] The present invention is ideal in applications in various types of variable-capacity compressors in which the discharge capacity is varied by adjusting the pressure in the control pressure chamber (crankcase) via a supply passage that allows a discharge pressure area and the control pressure chamber to communicate with each other and a bleed passage that allows the control pressure chamber and an intake pressure area to communicate with each other.

Claims

1. A control device for a variable-capacity compressor, the discharge capacity of which decreases as the pressure in a control pressure chamber rises and increases as the pressure in said control pressure chamber becomes lower, adopting a structure having a supply passage (40) that allows a discharge pressure area and said control pressure chamber to communicate with each other and a bleed passage (41) that allows said control pressure chamber and an intake pressure area to communicate with each other so as to adjust the pressure in said control pressure chamber via said supply passage (40) and the bleed passage (41), **characterized in:**

that a differential pressure regulating valve (44) which communicates between said control pressure chamber and the intake pressure area when the difference between the pressure in the discharge pressure area and the pressure in another area becomes equal to or smaller than a predetermined value is included.

2. A control device (2) for a variable-capacity compressor according to claim 1, having:

a control valve used to adjust the state of communication achieved with said supply passage (40) and the state of communication achieved with said bleed passage (41) **characterized in:**

that said control valve (2) is controlled by using a control signal provided from outside so as to adjust the pressure in said control pressure chamber.

3. A control device for a variable-capacity compressor according to claim 1, having:

a control valve (2) used to adjust the state of communication achieved with said supply passage (40) and said bleed passage (41) which includes a constriction, **characterized in:**

that said control valve (2) is controlled by using a control signal provided from outside so as to adjust the pressure in said control pressure chamber.

4. A control device for a variable-capacity compressor according to any of claims 1 through 3, **characterized in:**

that said differential pressure regulating valve (44) is disposed at a housing (20) of said variable-capacity compressor.

5. A control device for a variable-capacity compressor according to any of claims 1 through 3, **characterized in:**

that said differential pressure regulating valve (44) is disposed at said control valve (2).

6. A control device for a variable-capacity compressor, a discharge capacity of which decreases as the pressure in a control pressure chamber rises and increases as the pressure in said control pressure chamber becomes lower, adopting a structure having a supply passage (40) that allows a discharge pressure area and said control pressure chamber to communicate with each other, a bleed passage (41) that allows said control pressure chamber and an intake pressure area to communicate with each other and a control valve (2) that adjusts the state of communication achieved with said supply passage (40) and the state of communication achieved with the bleed passage (41), with said control valve (2) controlled by using a control signal provided from outside so as to adjust the pressure in said control pressure chamber, the opening is **characterized in:**

that said control valve (2) achieves opening characteristics whereby the degree of openness of the supply passage (40) is increased and the degree of openness of said bleed passage (41) is decreased as the discharge capacity decreases and communication between said control pressure chamber and said intake pressure area is assured at a minimum discharge capacity.

FIG. 1

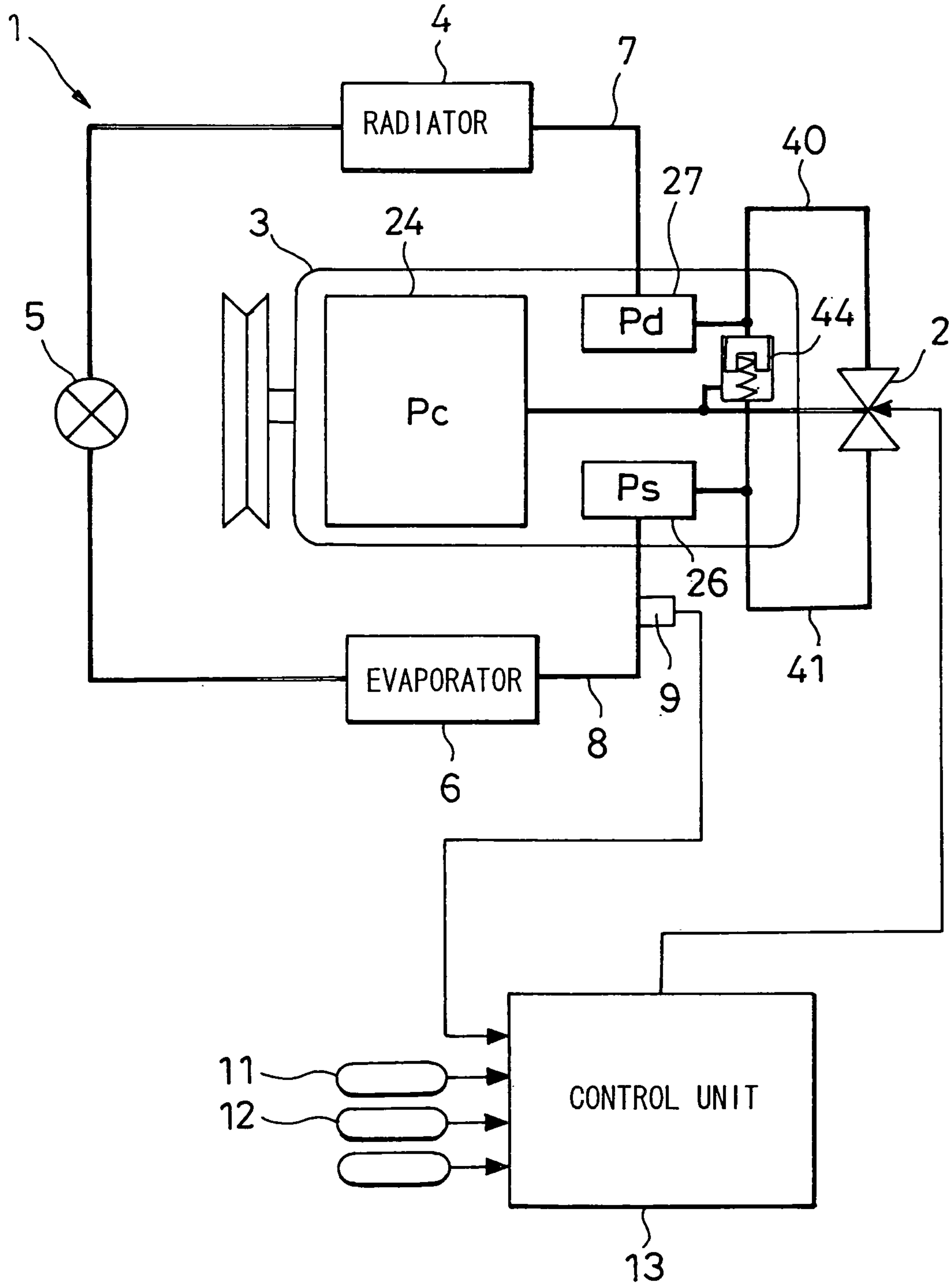

RADIATOR
EVAPORATOR
Pd
Pc
Ps
CONTROL UNIT
1
2
3
4
5
6
7
8
9
11
12
13
24
26
27
40
41
44

FIG. 2

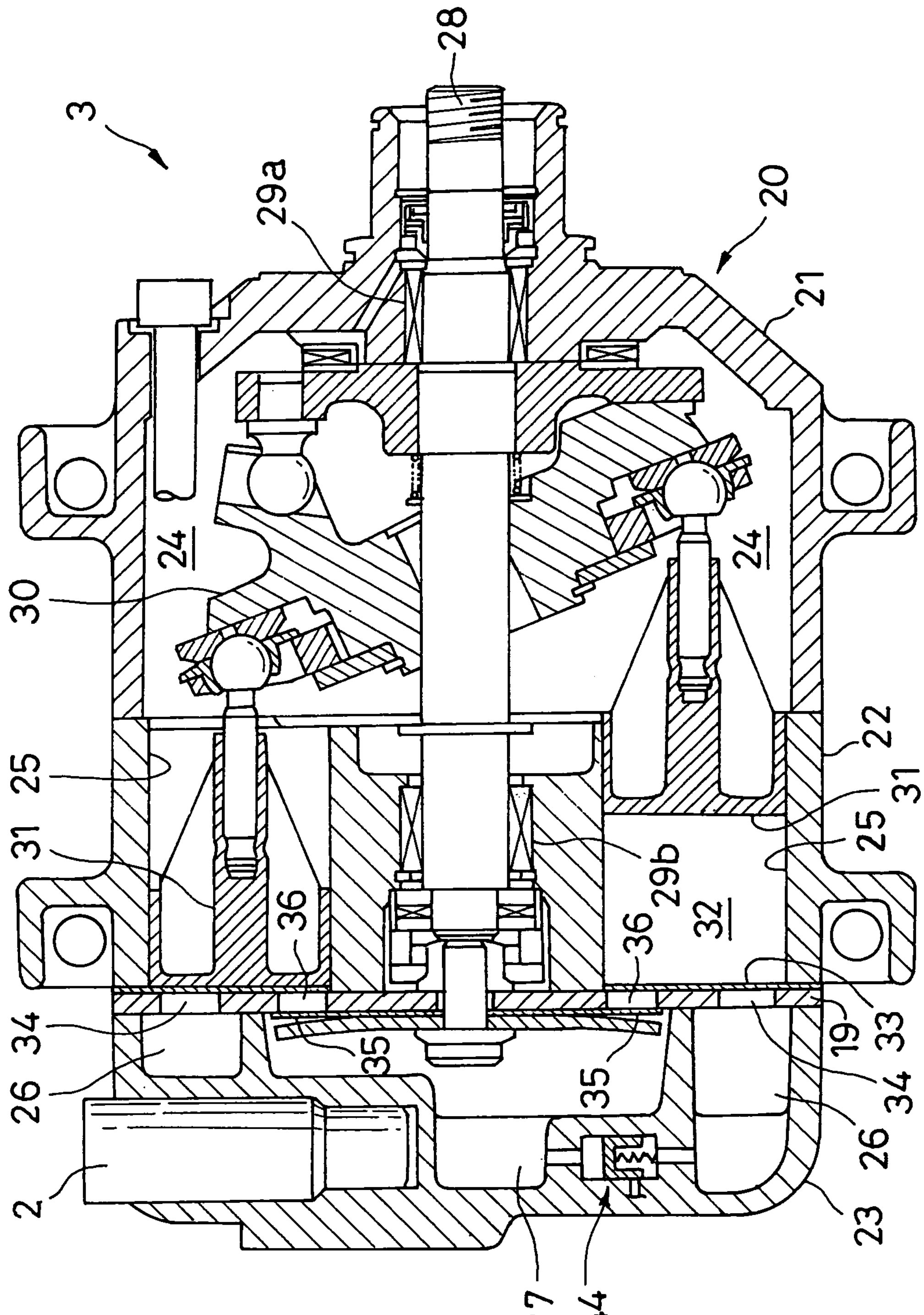
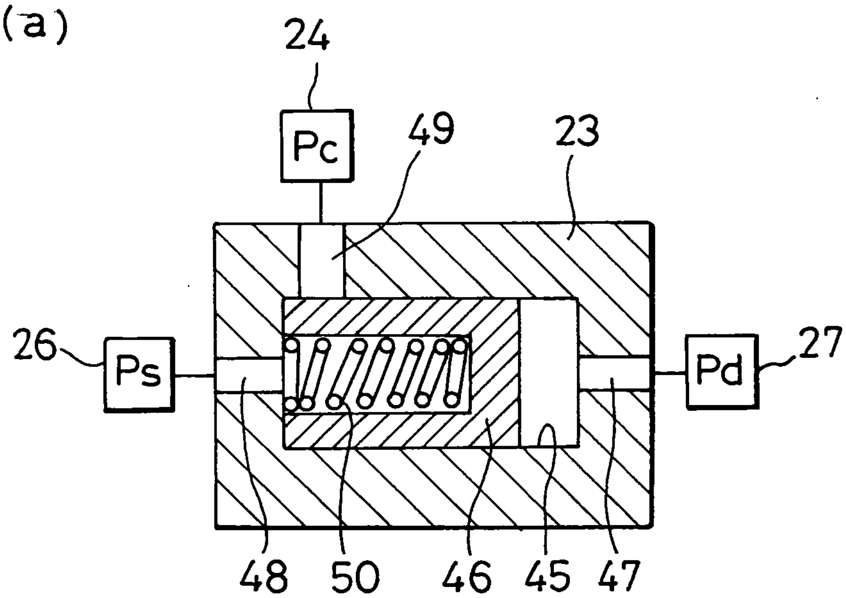

3
20
21
22
23
2
19
24
24
25
25
26
26
27
28
29a
29b
30
31
31
32
33
34
34
35
35
36
36
44

FIG. 3

(a)


24
Pc
49
23
26
Ps
Pd
27
48
50
46
45
47

(b)

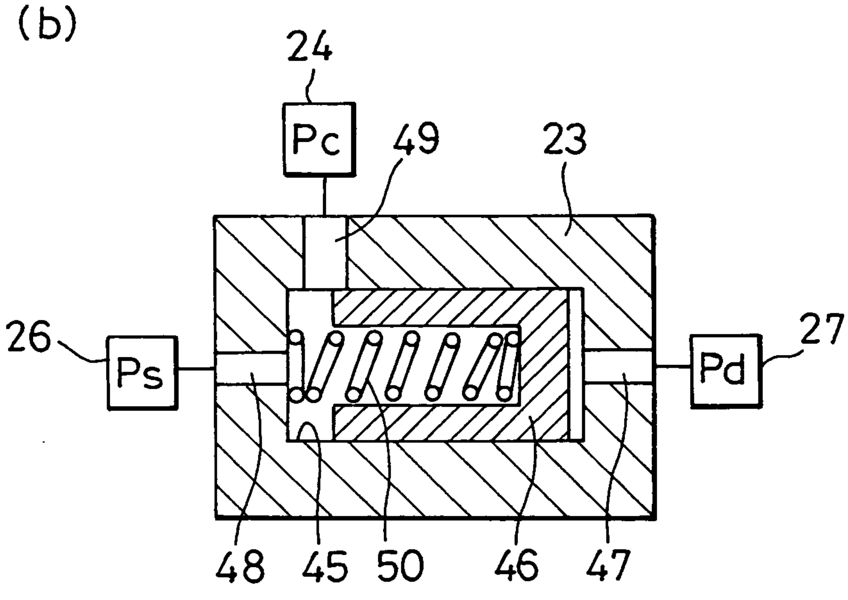

24
Pc
49
23
26
Ps
Pd
27
48
45
50
46
47

FIG. 4

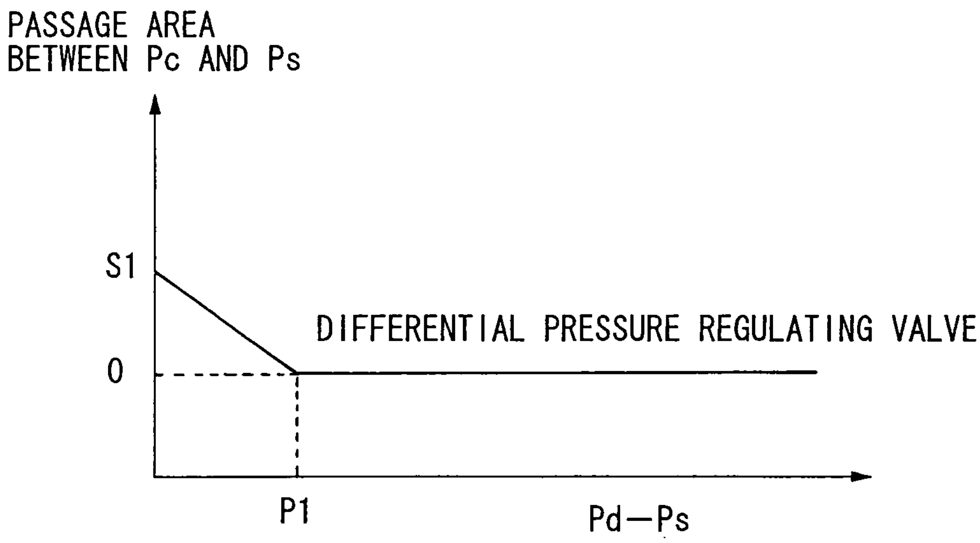

PASSAGE AREA
BETWEEN Pc AND Ps
S1
0
DIFFERENTIAL PRESSURE REGULATING VALVE
P1
Pd−Ps

FIG. 5

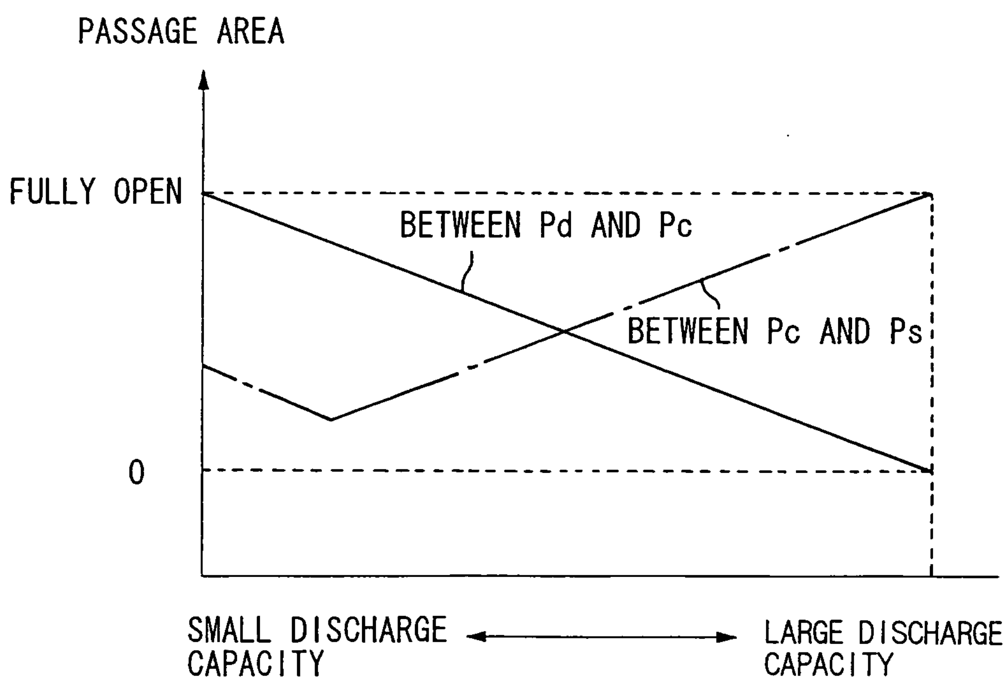

PASSAGE AREA
FULLY OPEN
BETWEEN Pd AND Pc
BETWEEN Pc AND Ps
0
SMALL DISCHARGE CAPACITY
LARGE DISCHARGE CAPACITY

FIG. 6

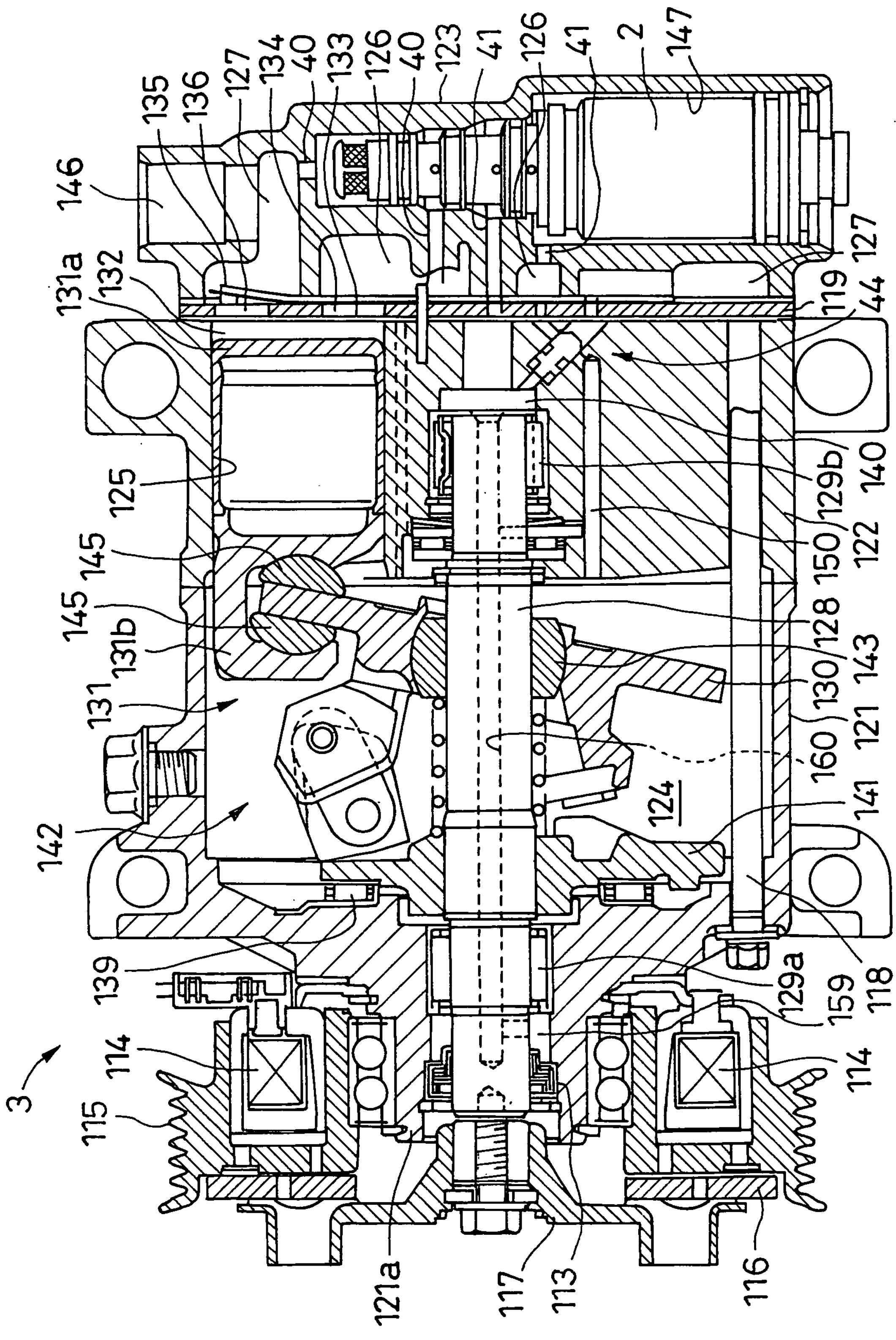

3
2
40
41
44
113
114
115
116
117
118
119
121
121a
122
123
124
125
126
127
128
129a
129b
130
131
131a
131b
132
133
134
135
136
139
140
141
142
143
145
146
147
150
159
160

FIG. 7

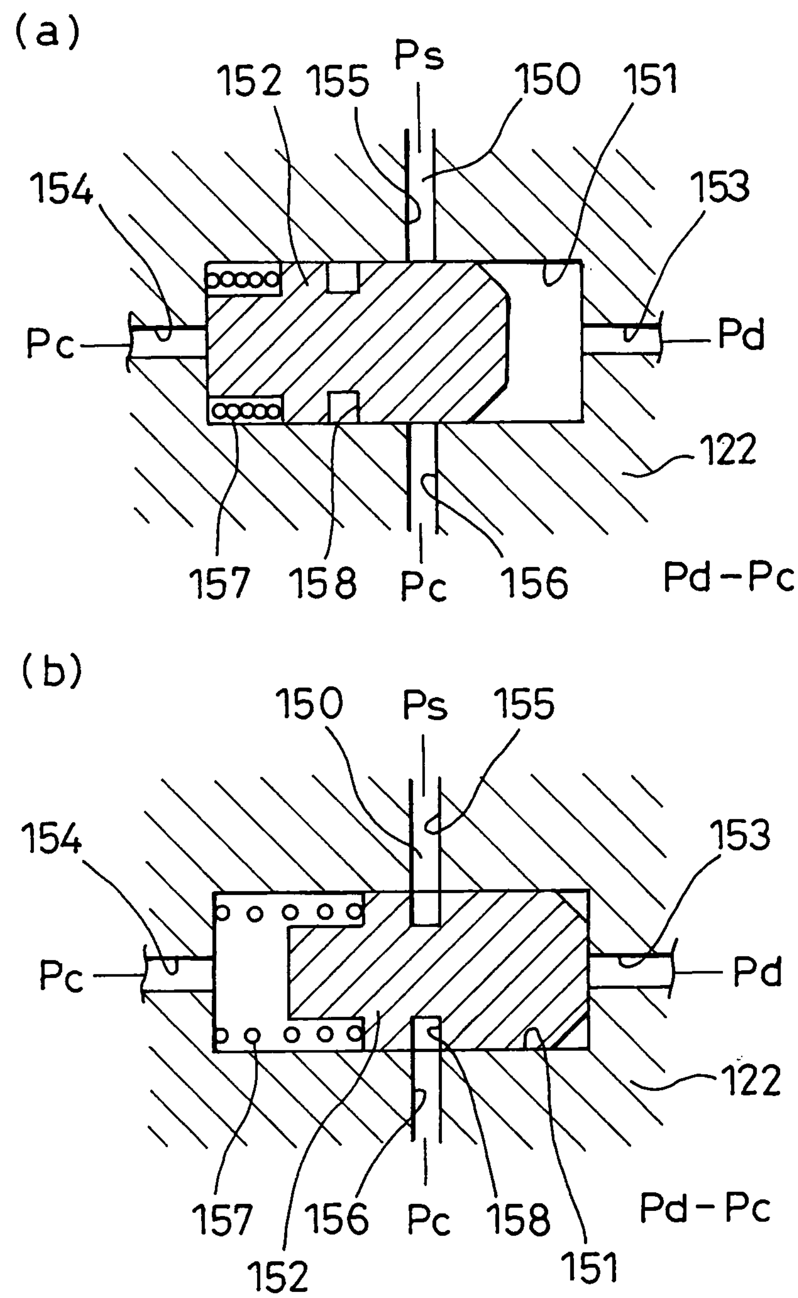

(a)
152
155
Ps
150
151
154
153
Pc
Pd
122
157
158
Pc
156
Pd-Pc
(b)
150
Ps
155
154
153
Pc
Pd
122
157
156
Pc
158
151
152
Pd-Pc

FIG. 8

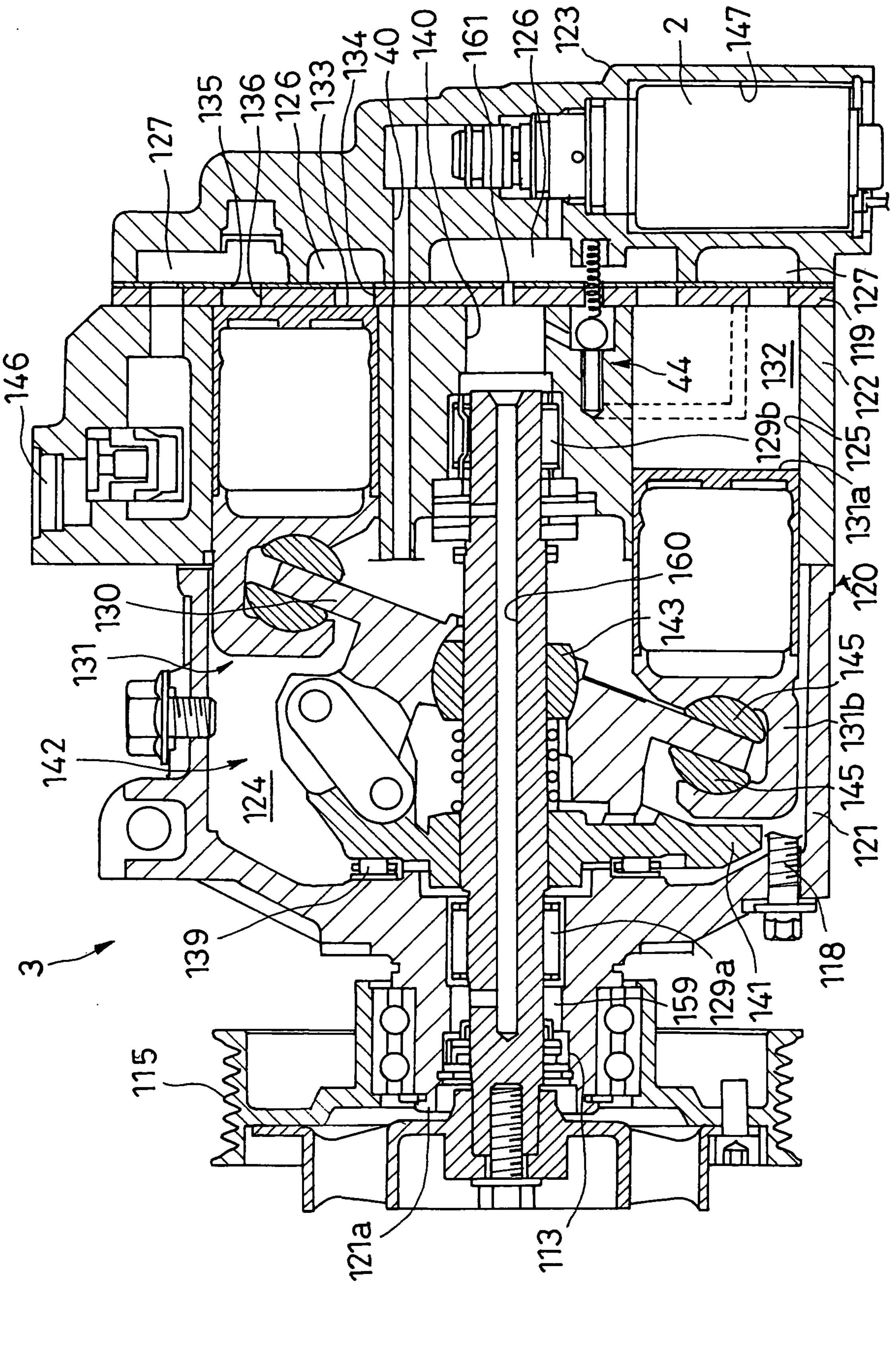

3
115
121a
113
139
142
131
130
124
146
127
135
136
126
133
134
40
140
161
126
123
2
147
127
119
122
44
132
125
129b
131a
120
160
143
145
131b
145
121
118
141
129a
159

FIG. 9

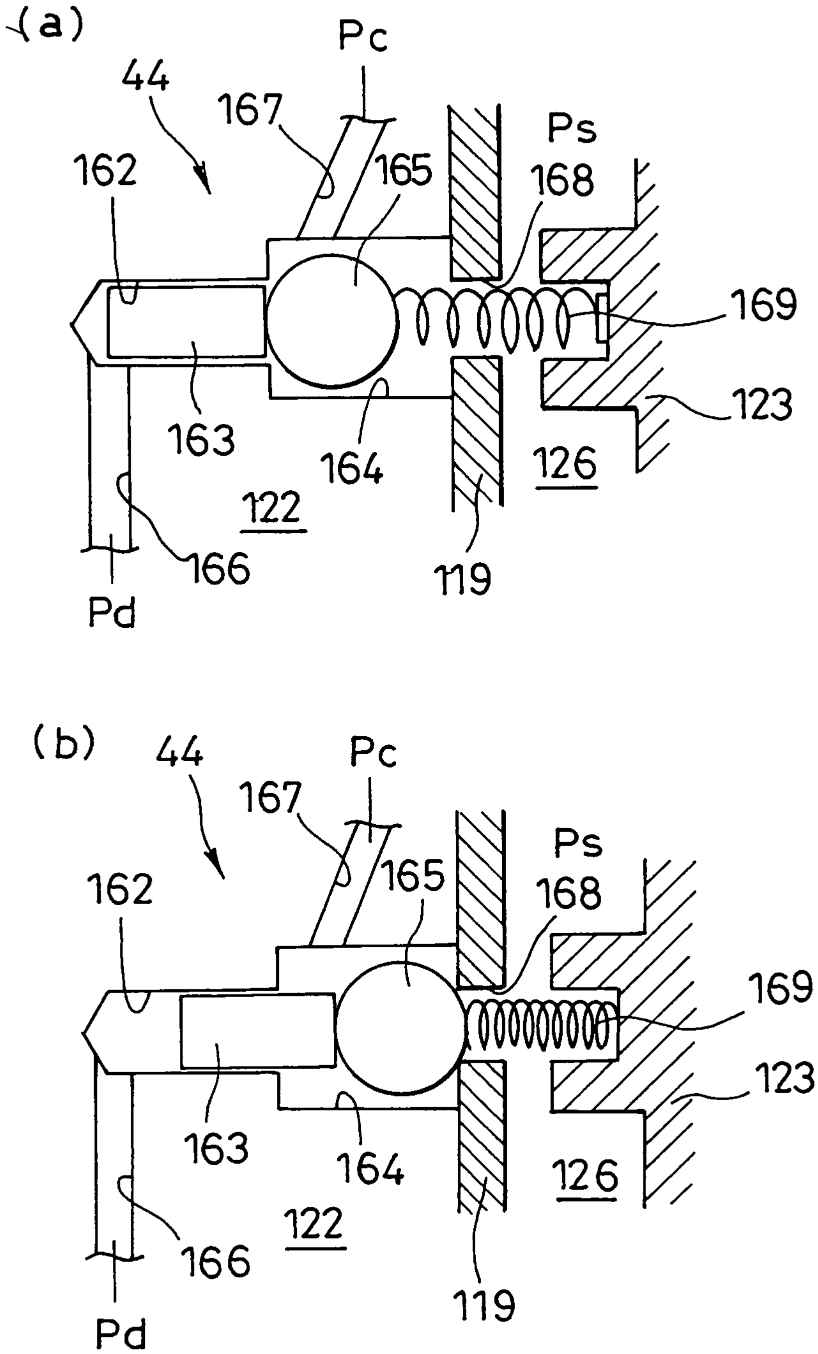

(a)
44
Pc
167
162
165
Ps
168
169
163
164
123
126
122
166
119
Pd
(b)
44
Pc
167
162
165
Ps
168
169
123
163
164
126
122
166
119
Pd

FIG. 10

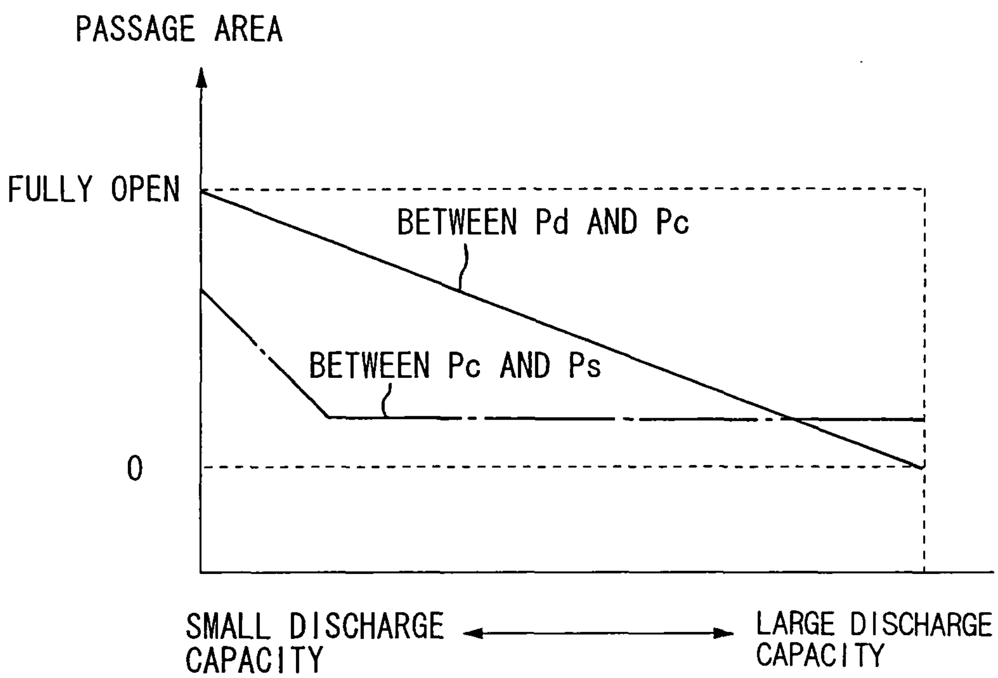
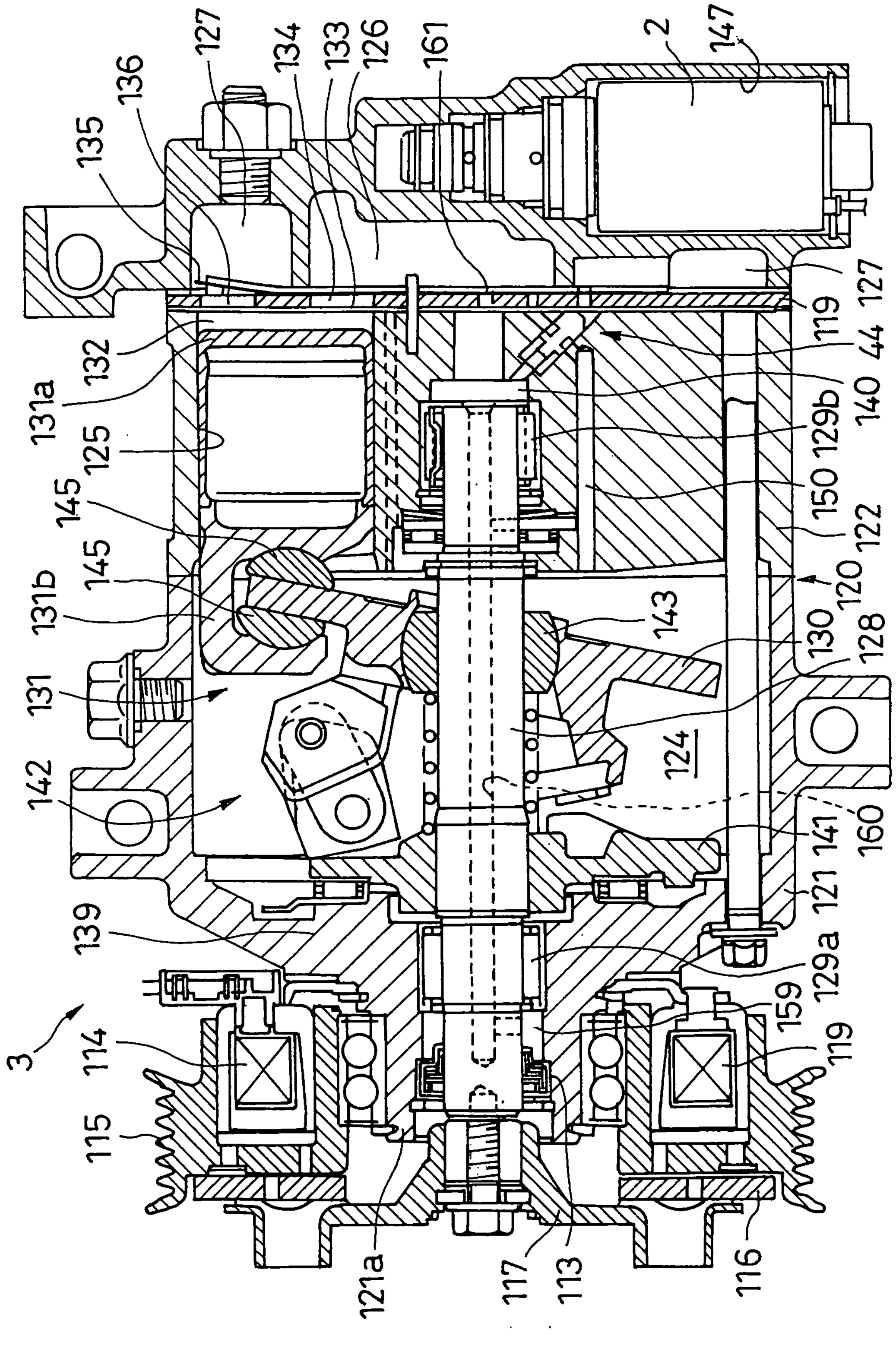

PASSAGE AREA
FULLY OPEN
BETWEEN Pd AND Pc
BETWEEN Pc AND Ps
0
SMALL DISCHARGE CAPACITY
LARGE DISCHARGE CAPACITY

FIG. 11



3
114
115
139
142
131
131b
145
145
125
131a
132
135
136
127
134
133
126
161
2
147
127
119
44
140
129b
150
122
120
143
130
128
124
160
141
121
129a
159
119
116
113
117
121a

FIG. 12

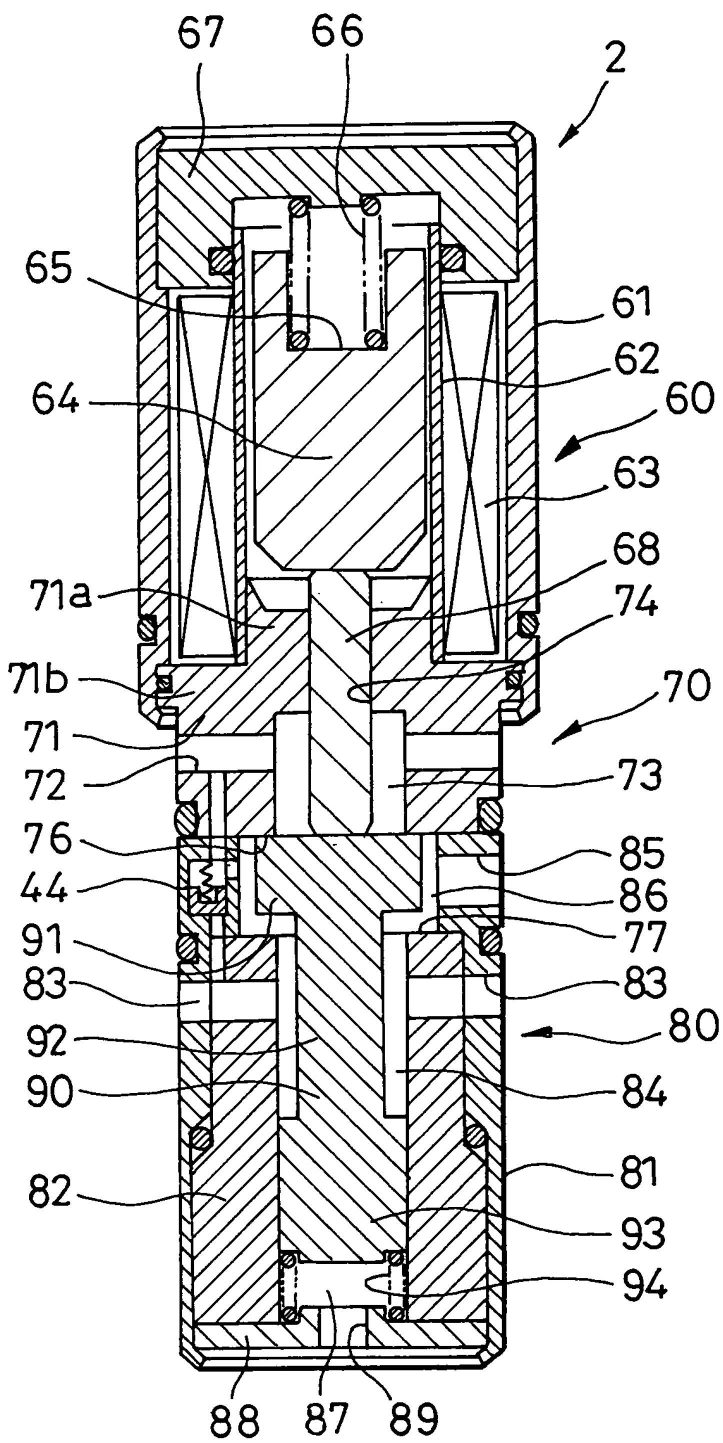

67
66
2
65
61
62
60
64
63
68
71a
74
71b
70
71
72
73
76
85
44
86
91
77
83
83
92
80
90
84
82
81
93
94
88
87
89

FIG. 13

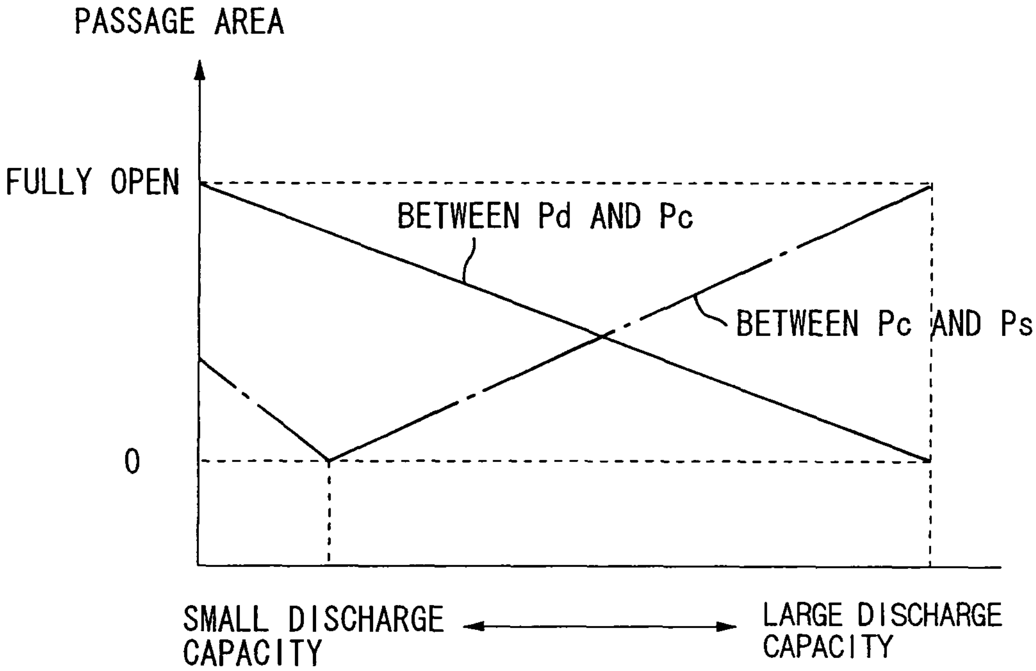

PASSAGE AREA
FULLY OPEN
BETWEEN Pd AND Pc
BETWEEN Pc AND Ps
0
SMALL DISCHARGE CAPACITY
LARGE DISCHARGE CAPACITY

FIG. 14

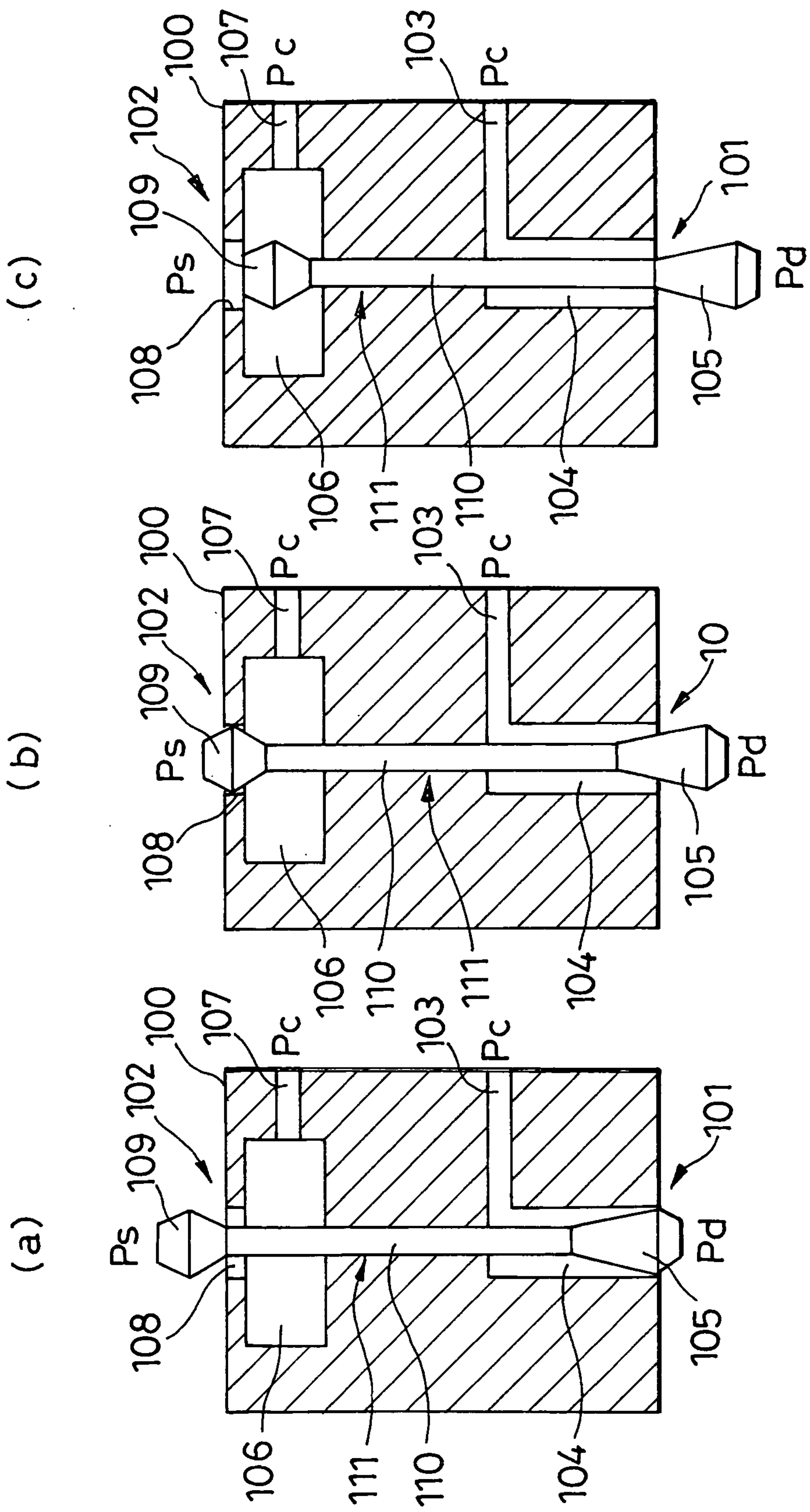


FIG. 15

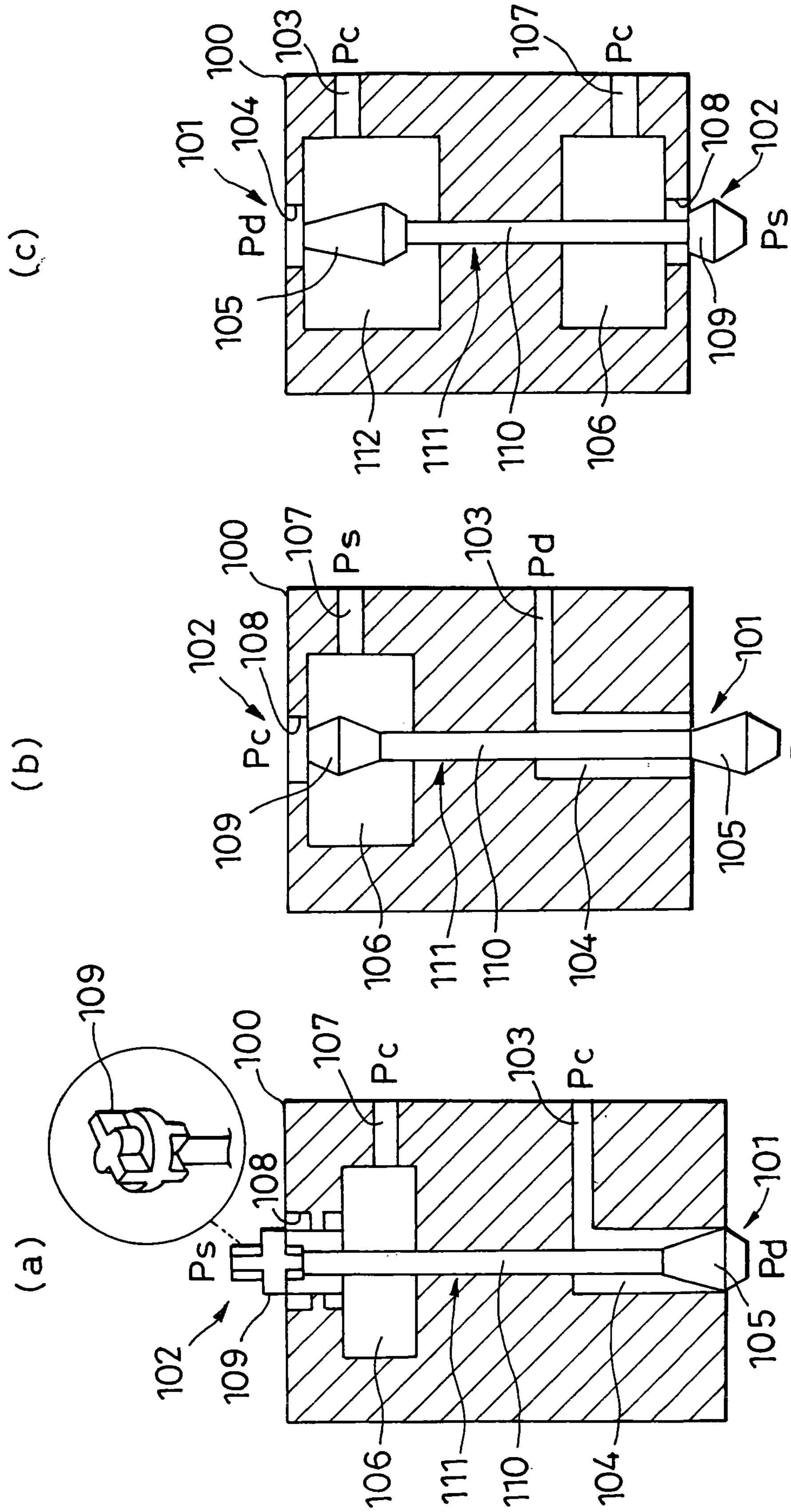


FIG. 16

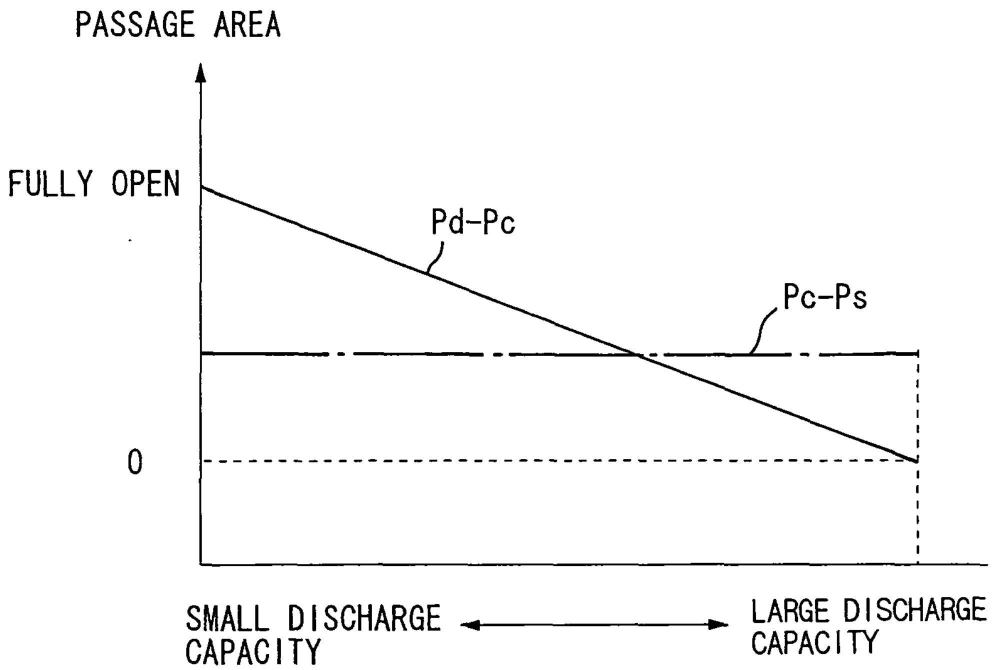
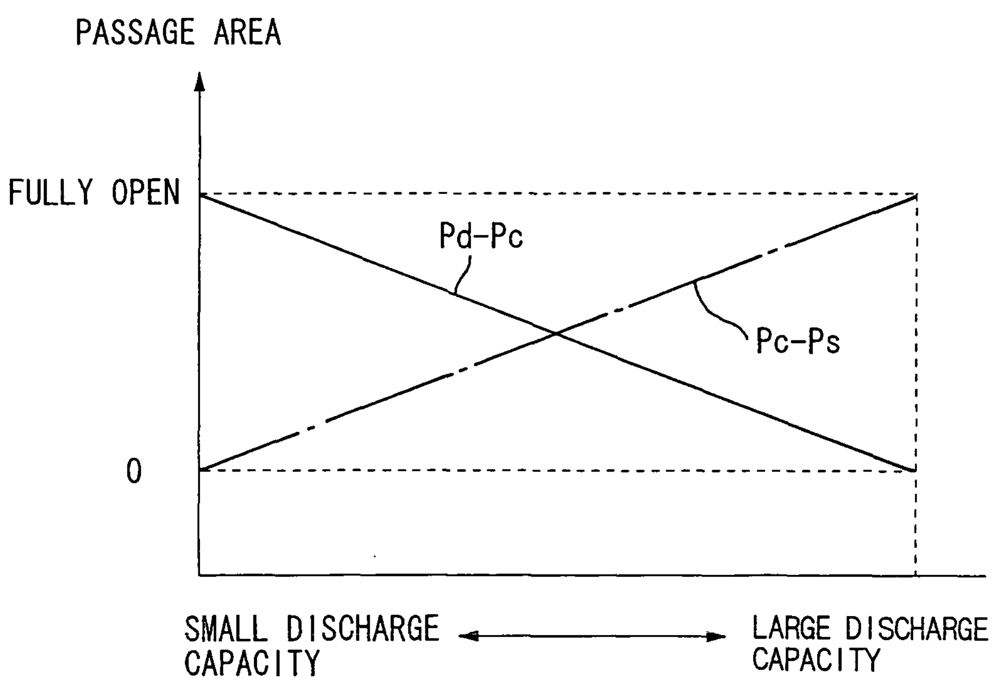

PASSAGE AREA
FULLY OPEN
Pd-Pc
Pc-Ps
0
SMALL DISCHARGE CAPACITY
LARGE DISCHARGE CAPACITY

FIG. 17


PASSAGE AREA
FULLY OPEN
Pd-Pc
Pc-Ps
0
SMALL DISCHARGE CAPACITY
LARGE DISCHARGE CAPACITY

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/14428

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] F04B27/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] F04B27/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2004
Kokai Jitsuyo Shinan Koho 1971-2004 Jitsuyo Shinan Toroku Koho 1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1172559 A2 (Kabushiki Kaisha Toyoda Jidoshokki), 16 January, 2002 (16.01.02), Full text; Figs. 11 to 13 & US 2002/0006337 A1 & CN 1333430 A & JP 2002-21721 A	1,2,5
X Y	JP 2003-106252 A (Kabushiki Kaisha Zexel Vareo Kuraimeto Control), 09 April, 2003 (09.04.03), Full text; all drawings (Family: none)	1,3-4 3

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search 22 January, 2004 (22.01.04)	Date of mailing of the international search report 03 February, 2004 (03.02.04)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP03/14428

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 57440/1988(Laid-open No. 160181/1989) (Calsonic Corp.), 07 November, 1989 (07.11.89), Description, page 16, lines 4 to 8; Fig. 3 (Family: none)	1,4 3
A	EP 1059443 A2 (Kabushiki Kaisha Toyoda Jidoshokki Seisakusho), 13 December, 2000 (13.12.00), Full text; Fig. 4 & US 6361283 B1 & JP 2000-345961 A	5
A	US 5584670 A (Kabushiki Kaisha Toyoda Jidoshokki Seisakusho), 17 December, 1996 (17.12.96), Column 14, lines 25 to 43; Fig. 17 & JP 7-286581 A	5

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