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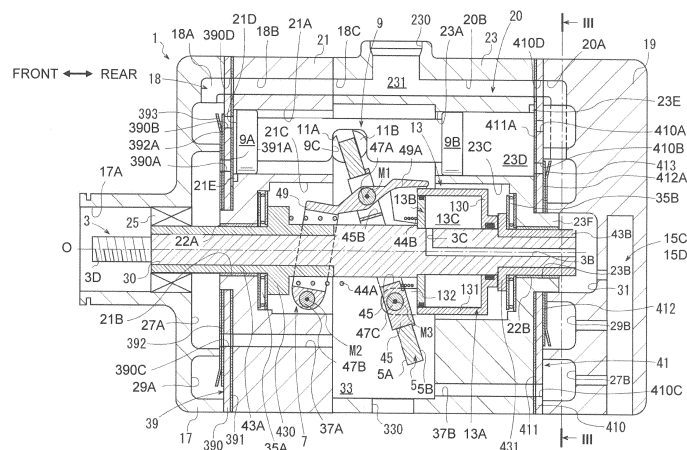
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(54) **Swash plate type variable displacement compressor**

(57) In a swash plate type variable displacement compressor, a rear housing (19) has a pressure regulation chamber (31) into which a rear end of a drive shaft body (30), a projection (23F) of a second cylinder block (23), a second sliding bearing (23B), and a rear end of a second support member (43B) project. When a drive shaft (3) of the compressor is rotated, heat is generated in the drive shaft body (30), the projection (23F), the second sliding bearing (22B), and the second support mem-

ber (43B) to heat the refrigerant gas in the pressure regulation chamber (31), which prevents temperature drop of the refrigerant gas in the pressure regulation chamber (31). Therefore, the pressure of the refrigerant flowing from the pressure regulation chamber (31) to the pressure control chamber (13C) is varied quickly and a movable body (13A) is moved with the pressure in the pressure control chamber (13C).

**FIG. 1****EP 2 853 740 A1**

## Description

### BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to a swash plate type variable displacement compressor.

**[0002]** Japanese Unexamined Patent Application Publication No. 5-172052 discloses a swash plate type variable displacement compressor (hereinafter, referred to as the compressor). The compressor has a housing which includes a front housing, a cylinder block and a rear housing. Each of the front housing and the rear housing has therein a suction chamber and a discharge chamber. The rear housing has therein a pressure regulation chamber which is formed in the center of the rear housing. The suction chamber is formed radially outward of the pressure regulation chamber and the discharge chamber is formed radially outward of the suction chamber.

**[0003]** The cylinder block has therein a swash plate chamber, a plurality of cylinder bores and a main shaft insertion hole. Each cylinder bore has a first cylinder bore which is formed in the rear of the cylinder block and a second cylinder bore which is formed in the front of the cylinder block. The main shaft insertion hole is formed in the rear of the cylinder block and communicates with the swash plate chamber and the pressure regulation chamber.

**[0004]** A drive shaft is disposed extending in the housing and rotatably supported in the cylinder block. A swash plate is mounted on the drive shaft for rotation therewith in the swash plate chamber. A link mechanism is provided between the drive shaft and the swash plate which permits the inclination of the swash plate. The angle of inclination refers to an angle of the swash plate with respect to a plane extending perpendicular to the axis of rotation of the drive shaft.

**[0005]** A plurality of pistons is received in the respective cylinder bores so that the pistons are movable in the reciprocating manner. Specifically, each piston has a first piston head which reciprocates in the first cylinder bore and a second piston head which reciprocates in the second cylinder bore. Therefore, the compressor has a first compression chamber formed by the first cylinder bore and the first piston head and a second compression chamber formed by the second cylinder bore and the second piston head. The compressor further includes a conversion mechanism that converts the rotation of the swash plate into reciprocal movement of the pistons in the respective cylinder bores with a stroke length that is determined by the inclination angle of the swash plate. The inclination angle of the swash plate can be controllably changed by an actuator, which is controlled by a control mechanism of the compressor.

**[0006]** The actuator is disposed on the first cylinder bore side of the swash plate chamber. The actuator includes a non-rotating movable body, a movable body and a thrust bearing. The actuator has therein a pressure control chamber. The non-rotating movable body is dis-

posed in the main shaft insertion hole so that the non-rotating movable body is not rotatable with the drive shaft and covers the rear end of the drive shaft. This non-rotating movable body rotatably supports on the inner peripheral surface thereof the rear end of the drive shaft. The non-rotating movable body is movable back and forth in the main shaft insertion hole in the axial direction of the rotating shaft in sliding contact with the inner peripheral surface of the main drive shaft hole. The non-rotating movable body is configured so as not to slide about the axial center of rotation. The movable body is connected to the swash plate and is movable therewith in the axial direction of the drive shaft. The thrust bearing is disposed between the non-rotating movable body and the movable body.

**[0007]** The main shaft insertion hole in the cylinder block is partitioned by the non-rotating movable body, thereby forming the pressure control chamber on the rear end side of the main shaft insertion hole. The rear end of the drive shaft is rotatably supported on the inner peripheral surface of the non-rotating movable body at a position frontward of the pressure control chamber. The pressure control chamber communicates with the pressure regulation chamber in the rear housing. A pressure spring is provided in the pressure control chamber so as to urge the non-rotating movable body in the frontward direction.

**[0008]** The control mechanism includes a control passage and a control valve provided in the control passage. The control passage provides communication between the discharge chamber and the pressure regulation chamber. By regulating the opening of the control passage, the control valve varies the pressure in the pressure control chamber thereby to move the non-rotating movable body and the movable body move together in the axial direction of the drive shaft.

**[0009]** The link mechanism has the movable body and a lug arm fixed on the drive shaft. The lug arm has at the rear end thereof an elongated hole that extends in the direction perpendicular to the axis of the drive shaft and also radially inwardly from the outer periphery thereof to the axial center. The swash plate is supported at the front thereof such that the swash plate is allowed to pivot about a first pivot pin inserted through the elongated hole. The movable body also has at the front end thereof an elongated hole which extends in the direction perpendicular to the axis of the drive shaft and also in the direction approaching the axis of the drive shaft from the outer periphery thereof. The swash plate is also supported at the rear end thereof such that the swash plate is allowed to pivot about a second pivot pin which is parallel to the center of the first pivot pin and inserted through the elongated hole.

**[0010]** In the compressor, by adjusting the opening of the control passage with the control valve, the pressure in the pressure regulation chamber and hence the pressure in the pressure control chamber can be controlled by the pressure of the refrigerant gas in the discharge

chamber.

**[0011]** Specifically, increasing the pressure in the pressure regulation chamber by the control valve increases the pressure in the pressure control chamber higher than the pressure in the swash plate chamber. As a result, the non-rotating movable body and the movable body in the main shaft insertion hole advance in the axial direction of the rotating shaft. Then, the inclination angle of the swash plate is increased and the stroke of the pistons is increased. Accordingly, the displacement of the compressor per one rotation of the drive shaft is increased.

**[0012]** By reducing the pressure in the pressure regulation chamber by the control valve, the pressure in the pressure control chamber becomes almost the same as the pressure in the swash plate chamber. Accordingly, the non-rotating movable body and the movable body in the main shaft insertion hole retreat in the axial direction of the rotating shaft. Therefore, the inclination angle of the swash plate is reduced and hence the stroke of the pistons is reduced, with the result that the displacement of the compressor per one rotation of the drive shaft is decreased.

**[0013]** In the above-described swash plate type variable displacement compressor, the suction chamber is disposed radially outward of the pressure regulation chamber. Since the temperature of the refrigerant gas in the suction chamber is lower, the pressure regulation chamber is cooled and, therefore, the temperature of the refrigerant gas in the pressure regulation chamber drops, thus liquefying part of the refrigerant gas in the pressure regulation chamber. Thus, refrigerant of two phases, namely gaseous refrigerant and liquefied refrigerant is present in the pressure regulation chamber. If the proportion of the liquefied refrigerant increases, the pressure in the pressure regulation chamber increases less quickly by the refrigerant flowing from the discharge chamber into the pressure regulation chamber. Due to an increase of the proportion of the liquefied refrigerant, the pressure in the pressure regulation chamber decreases less quickly by the refrigerant flowing from the pressure regulation chamber into the suction chamber. In the compressor of the above-cited publication, therefore, it is difficult to move the non-rotating movable body and the movable body in a desirable manner. Specifically, in the compressor, it is difficult to vary the inclination angle of the swash plate quickly according to a change of the operating conditions of the vehicle on which the compressor is mounted and also the discharge displacement of the compressor is less controllable.

**[0014]** The present invention, which has been made in view of the above-identified circumstances, is directed to providing a swash plate type variable displacement compressor that offers improved controllability.

#### SUMMARY OF THE INVENTION

**[0015]** In accordance with an aspect of the present invention, the swash plate type variable displacement com-

pressor includes a housing having therein a suction chamber, a discharge chamber, a swash plate chamber, and a plurality of cylinder bores; a drive shaft rotatably supported in the housing; a swash plate which is rotatable in the swash plate chamber with the rotation of the drive shaft; a link mechanism which is disposed between the drive shaft and the swash plate and allows a change in an inclination angle of the swash plate with respect to the direction perpendicular to the axis of the drive shaft; a plurality of pistons which is reciprocally received in the respective cylinder bores; a conversion mechanism which converts the rotation of the drive shaft into reciprocal movement of the pistons in the respective cylinder bores in conjunction with the swash plate with a stroke length according to the inclination angle of the swash plate; an actuator for changing the inclination angle of the swash plate; and a control mechanism which controls the actuator. The housing has therein a pressure regulation chamber. The pressure regulation chamber is disposed radially inward of the discharge chamber, which is disposed radially inward of the suction chamber. The actuator includes a fixed body, a movable body, and a pressure control chamber. The fixed body is fixed on the drive shaft in the swash plate chamber. The movable body is connected to the swash plate and movable relative to the fixed body in the direction of the axis of rotation. The pressure control chamber is defined by the fixed body and the movable body and the pressure in the pressure control chamber is changed by introducing the pressure in the discharge chamber into the pressure control chamber such that the movable body is moved. The control mechanism has a control passage and a control valve. The control passage provides communication between the discharge chamber and the pressure control chamber via the pressure regulation chamber. The control valve adjusts an opening of the control passage to vary pressure in the pressure regulation chamber such that the movable body is moved. At least a part of the control passage is formed in the drive shaft, and the drive shaft projects into the pressure regulation chamber such that the control passage connects the pressure regulation chamber and the pressure control chamber.

**[0016]** Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0017]** The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal sectional view of a compressor according to an embodiment of the present in-

vention, showing the maximum displacement of the compressor;

FIG. 2 is a schematic diagram of a control mechanism of the compressor of FIG. 1;

FIG. 3 is a transverse sectional view of the compressor as viewed in arrow direction III-III in FIG. 1; and

FIG. 4 is a longitudinal sectional view of the compressor of FIG. 1 in the minimum displacement.

#### DETAILED DESCRIPTION OF THE EMBODIMENTS

**[0018]** The following will describe a compressor embodying the present invention with reference to the drawings. The compressor of the embodiment is a swash plate type variable displacement compressor which is mounted on a vehicle and forms a part of a refrigeration circuit for an air conditioning system of the vehicle.

**[0019]** Referring to FIG. 1, the compressor according to the present embodiment includes a housing 1, a drive shaft 3, a swash plate 5, a link mechanism 7, a plurality of double-headed pistons 9, pairs of shoes 11A, 11 B, an actuator 13 and a control mechanism 15 which is shown in FIG. 2.

**[0020]** The housing 1 includes a front housing 17 disposed on the front side of the compressor, a rear housing 19 disposed on the rear side of the compressor, first and second cylinder blocks 21, 23 disposed between the front housing 17 and the rear housing 19, and first and second valve forming plates 39, 41.

**[0021]** The front housing 17 has a boss 17A projecting frontward. The boss 17A has a shaft sealing device 25. The front housing 17 has therein a first suction chamber 27A and a first discharge chamber 29A. The first suction chamber 27A is formed in a radially inner region inward of the front housing 17. The first discharge chamber 29A is formed in an annular shape and disposed outward of the first suction chamber 27A in the front housing 17.

**[0022]** The front housing 17 has therein a first front communication passage 18A which communicates at the front end thereof with the first discharge chamber 29A and opens at the rear end thereof at the rear end of the front housing 17.

**[0023]** The control mechanism 15 is disposed in the rear housing 19. As shown in FIG. 3, the rear housing 19 has therein a second suction chamber 27B, a second discharge chamber 29B, and a pressure regulation chamber 31. Specifically, the pressure regulation chamber 31 is disposed in the center of the rear housing 19. The second discharge chamber 29B is formed in an annular shape and formed radially outward of the pressure regulation chamber 31 in the rear housing 19 so as to surround the pressure regulation chamber 31. The second suction chamber 27B is formed into a substantially C shape and disposed radially outward of the second discharge chamber 29B in the rear housing 19.

**[0024]** Furthermore, the rear housing 19 has therein a first rear communication passage 20A which communicates at the rear end thereof with the second discharge chamber 29B. As shown in FIG. 1, the front end of the first rear communication passage 20A is open at the front end of the rear housing 19.

**[0025]** A swash plate chamber 33 is formed between a first cylinder block 21 and the second cylinder block 23. The swash plate chamber 33 is disposed substantially in the center of the housing 1 as seen in the longitudinal direction of the compressor.

**[0026]** A plurality of first cylinder bores 21A is formed substantially at an equal angular distance in the circumferential direction of the first cylinder block 21. The first cylinder block 21 has therethrough a first shaft hole 21 B through which the drive shaft 3 is inserted. The first shaft hole 21 B has a first sliding bearing 22A, although a rolling bearing may alternatively be used.

**[0027]** The first cylinder block 21 further has therein a first recessed portion 21C which is annular and coaxial with the first shaft hole 21 B. The first recessed portion 21C communicates with the swash plate chamber 33. The inner diameter of the annular first recessed portion 21C is reduced in the form of a step toward the front end thereof. A first thrust bearing 35A is provided in the first recessed portion 21C at the front end thereof. The first cylinder block 21 further has therein a first connecting passage 37A which provides communication between the swash plate chamber 33 and the first suction chamber 27A. The first cylinder block 21 has therein a first retaining groove 21 E for regulating the maximum opening of first suction reed valves 391 A, which will be described later.

**[0028]** The first cylinder block 21 further has therein a second front communication passage 18B which is open at the opposite front and rear ends thereof.

**[0029]** The second cylinder block 23 has therein a plurality of second cylinder bores 23A as in the case of the first cylinder block 21. Each second cylinder bore 23A on the rear side is paired with its associated first cylinder bore 21A on the front side. The first cylinder bores 21A and the second cylinder bores 23A are of the same diameter. It is to be noted that the second cylinder block 23 corresponds to the cylinder block of the present invention.

**[0030]** Furthermore, the second cylinder block 23 has a projection 23F extending rearward. With the second cylinder block 23, the second valve forming plate 41 and the rear housing 19 joined together, the projection 23F projects into the pressure regulation chamber 31 projecting beyond the second valve forming plate 41. The distance for which the projection 23F projects into the pressure regulation chamber 31 may appropriately be changed according to the design.

**[0031]** Furthermore, the second cylinder block 23 has therein a second shaft hole 23B through which the drive shaft 3 is inserted. The second shaft hole 23B extends also in the projection 23F and is opened to the pressure regulation chamber 31. The second shaft hole 23B has

therein a second sliding bearing 22B the rear end of which projects to the pressure regulation chamber 31. The second sliding bearing 22B corresponds to the radial bearing of the present invention. It is to be noted that the second sliding bearing 22B may be replaced with a roller bearing.

**[0032]** The second cylinder block 23 has therein a second recessed portion 23C which is annular and coaxial with the second shaft hole 23B. The second recessed portion 23C also communicates with the swash plate chamber 33. The inner diameter of the second annular recessed portion 23C is reduced in the form of a step toward the rear end thereof. A second thrust bearing 35B is provided in the second recessed portion 23C at the rear end thereof. The second thrust bearing 35B corresponds to the thrust bearing of the present invention. The second cylinder block 23 further has therein a second connecting passage 37B which provides communication between the swash plate chamber 33 and the second suction chamber 27B. The second cylinder block 23 has therein a second retaining groove 23E for regulating the maximum opening of second suction reed valves 411A, which will be described later.

**[0033]** The second cylinder block 23 has therein an outlet port 230, a combined discharge chamber 231, a third front communication passage 18C, a second rear communication passage 20B and an inlet port 330. The outlet port 230 and the combined discharge chamber 231 are in direct communication with each other. The outlet port 230 and the combined discharge chamber 231 are formed in the second cylinder block 23 at positions adjacent to the front end of the second cylinder block 23 so that they are disposed substantially in the longitudinal center of the housing 1. The combined discharge chamber 231 is connected through the discharge port 230 to a condenser (not shown).

**[0034]** The third front communication passage 18C is open at the front end thereof in the front end of the second cylinder block 23 and communicates directly at the rear end thereof with the combined discharge chamber 231. With the first cylinder block 21 and the second cylinder block 23 joined together, the third front communication passage 18C communicates with the second front communication passage 18B at the rear end thereof.

**[0035]** The second rear communication passage 20B communicates directly at the front end thereof with the combined discharge chamber 231 and open at the rear end thereof in the rear end of the second cylinder block 23.

**[0036]** The inlet port 330 is formed at a position adjacent to the front end of the second cylinder block 23 so that the inlet port 330 is disposed substantially in the longitudinal center of the housing 1. The swash plate chamber 33 is connected through the suction port 330 to an evaporator (not shown) connected in the external refrigeration circuit.

**[0037]** The first valve forming plate 39 is interposed between the front housing 17 and the first cylinder block 21. The second valve forming plate 41 is provided be-

tween the rear housing 19 and the second cylinder block 23. The second valve forming plate 41 corresponds to the valve unit of the present invention.

**[0038]** The first and second valve forming plates 39, 41 are formed in an annular shape. The first valve forming plate 39 is mounted on a projection at the front end of the first cylinder block 21 and the second valve forming plate 41 is mounted on the projection 23F of the second cylinder block 23.

**[0039]** The first valve forming plate 39 includes a first valve plate 390, a first suction valve plate 391, a first discharge valve plate 392, and a first retainer plate 393. At least one first suction hole 390A is formed through the first valve plate 390, the first discharge valve plate 392, and the first retainer plate 393. The first suction hole 390A corresponds to each first cylinder bore 21A. At least one first discharge hole 390B is formed through the first valve plate 390 and the first suction valve plate 391. The first discharge hole 390B corresponds to each first cylinder bore 21A. Furthermore, at least one first suction communication hole 390C is formed through the first valve plate 390, the first suction valve plate 391, the first discharge valve plate 392, and the first retainer plate 393. At least one first discharge communication hole 390D is formed through the first valve plate 390 and the first suction valve plate 391..

**[0040]** Each first cylinder bore 21A is communicable with the first suction chamber 27A through its associated first suction hole 390A. Each first cylinder bore 21A is communicable with the first discharge chamber 29A through its associated first discharge hole 390B. The first suction chamber 27A and the first connecting passage 37A are communicable with each other through the first suction communication hole 390C. The first front communication passage 18A and the second front communication passage 18B are communicable with each other through the first discharge communication hole 390D.

**[0041]** The first suction valve plate 391 is provided on a rear surface of the first valve plate 390 and has the plurality of first suction reed valves 391A which are elastically deformable to open and close the first suction holes 390A. The first discharge valve plate 392 is provided on a front surface of the first valve plate 390 and has a plurality of first discharge reed valves 392A which are elastically deformable to open and close the first discharge holes 390B. The first retainer plate 393 is provided on the front surface of the first discharge plate 392 for regulating the maximum opening of the first discharge reed valves 392A.

**[0042]** The second valve forming plate 41 includes a second valve plate 410, a second suction valve plate 411, a second discharge valve plate 412 and a second retainer plate 413. At least one second suction hole 410A is formed through the second valve plate 410. The second suction hole 410A corresponds to each second cylinder bore 23A. At least one second discharge hole 410B is formed through the second valve plate 410 and the second suction valve plate 411. The second discharge

hole 410B corresponds to each second cylinder bore 23A. Furthermore, at least one second suction communication hole 410C and at least one second discharge communication hole 410D are formed through the second valve plate 410 and the second suction valve plate 411.

**[0043]** Each second cylinder bore 23A is communicable with the second suction chamber 27B through its associated second suction hole 410A. Each second cylinder bore 23A is communicable with the second discharge chamber 29B through its associated second discharge hole 410B. The second suction chamber 27B and the second connecting passage 37B are communicable with each other through the second suction communication hole 410C. The first rear communication passage 20A and the second rear communication passage 20B are communicable with each other through the second discharge communication hole 410D.

**[0044]** The second suction valve plate 411 is provided on the front surface of the second valve plate 410 and has a plurality of second suction reed valves 411A which are elastically deformable to open and close the second suction holes 410A. The second discharge valve plate 412 is provided on the rear surface of the second valve plate 410 and has a plurality of second discharge reed valves 412A which are elastically deformable to open and close the second discharge holes 410B. The second retainer plate 413 is provided on the rear surface of the second discharge valve plate 412 for regulating the maximum opening of the second discharge reed valves 412A.

**[0045]** In the compressor, a first communication passage 18 is formed by the first front communication passage 18A, the first discharge communication hole 390D, the second front communication passage 18B, and the third front communication passage 18C. A second communication passage 20 is formed by the first rear communication passage 20A, the second discharge communication hole 410D, and the second rear communication passage 20B.

**[0046]** In the compressor, the swash plate chamber 33 communicates with the first and second suction chambers 27A, 27B via the first and second connection passage 37A, 37B and the first and second suction communication holes 390C, 410C. Therefore, the pressures are substantially the same among the first suction chamber 27A, the second suction chamber 27B, and the swash plate chamber 33. Since the refrigerant gas which has passed through the evaporator is introduced into the swash plate chamber 33 through the inlet port 330, the pressures in the first and second suction chambers 27A, 27B and the swash plate chamber 33 are lower than the pressures in the first and second discharge chambers 29A, 29B.

**[0047]** The drive shaft 3 includes a drive shaft body 30 (a drive shaft main body 30), a first support member 43A and a second support member 43B. The drive shaft body 30 extending rearward from the boss 17A is inserted through the first and second sliding bearings 22A, 22B.

The drive shaft 3 is supported in the first and second cylinder blocks 21, 23 so as to be rotatable about the axis of rotation O. The front end of the drive shaft body 30 extends into the boss 17A, and the rear end of the drive shaft body 30 projects beyond the projection 23F and the second sliding bearing 22B and into the pressure regulation chamber 31.

**[0048]** The first support member 43A is press-fitted on the front end part of the drive shaft body 30. With the rotation of the drive shaft 3 about the axis of rotation O, the first support member 43A is rotated with the drive shaft 3 in sliding contact with the first sliding bearing 22A. The first support member 43A is formed at the rear end part thereof with a flange 430 and a mounting (not shown) into which a second pin 47B, which will be described later, is inserted. The flange 430 serves as a retainer for the first thrust bearing 35A. Specifically, the flange 430 and the inner wall surface of the first recessed portion 21C cooperate to hold therebetween the first thrust bearing 35A. The front end of a first return spring 44A is fixed on the first support member 43A. The first return spring 44A extends in the direction of the axis of rotation O toward the swash plate chamber 33 from the flange 430 of the first support member 43A.

**[0049]** The second support member 43B is press-fitted on the rear end part of the drive shaft body 30 so that the rear end surface of the second support member 43B is flush with the rear end surface of the drive shaft body 30. The rear end of the second support member 43B projects beyond the projection 23F and the second sliding bearing 22B and into the pressure regulation chamber 31.

**[0050]** With the rotation of the drive shaft 3 about the axis of rotation O, the second support member 43B is rotated in sliding contact with the second sliding bearing 22B. A flange 431 is formed at the front end of the second support member 43B. The flange 431 is disposed between the second thrust bearing 35B and the actuator 13 and serves as a retainer for the second thrust bearing 35B. Specifically, the flange 431 and the inner wall surface of the first recessed portion 21C cooperate to hold therebetween the second thrust bearing 35B. The second support member 43B corresponds to the cap of the present invention.

**[0051]** The swash plate 5 is a circular, flat plate having a front surface 5A and a rear surface 5B. In the swash plate chamber 33, the front surface 5A faces frontward and the rear surface 5B faces rearward.

**[0052]** The swash plate 5 is fixed to a ring plate 45. The ring plate 45 is a circular, flat plate having an insertion hole 45A in the center thereof. The swash plate 5 is mounted to the drive shaft 3 with the drive shaft body 30 passed through the insertion hole 45A of the swash plate 5.

**[0053]** The aforementioned link mechanism 7 includes a lug arm 49. The lug arm 49 is disposed frontward of the swash plate 5 in the swash plate chamber 33 and located between the swash plate 5 and the first support member 43A. The lug arm 49 is formed substantially in

an L shape as viewed toward the rear end thereof. When the swash plate 5 is positioned at the minimum inclination angle with respect to a plane extending perpendicular to the axis of rotation O of the drive shaft 3, the lug arm 49 is in contact the flange 430 of the first support member 43A, as shown in FIG. 4. Thus, the minimum inclination angle position of the swash plate 5 is determined by the contact of the lug arm 49 with the flange 430. The lug arm 49 has in the rear part thereof a weight portion 49A extending for half the circumference of the actuator 13. It is to be noted that the weight portion 49A may be formed in any shape appropriately through design.

**[0054]** As shown in FIG. 1, the lug arm 49 is connected at the rear end thereof to one end of the ring plate 45 through a first pin 47A. With this configuration, the lug arm 49 is supported at the front end thereof so as to be swingable about a first pivot axis M1 which is the axial center of the first pin 47A with respect to the one end of the ring plate 45, i.e., the swash plate 5. The first pivot axis M1 extends in the direction perpendicular to the axis of rotation O of the drive shaft 3.

**[0055]** The lug arm 49 is connected at the front end thereof to the first support member 43A through the second pin 47B. With this configuration, the lug arm 49 is supported at the rear end thereof so as to be swingable about a second pivot axis M2 which is the axial center of the second pin 47B with respect to the first support member 43A, i.e., the drive shaft 3. The second pivot axis M2 extends parallel to the with the first pivot axis M1. The lug arm 49, the first pin 47A and the second pin 47B correspond to the link mechanism 7 of the present invention.

**[0056]** The weight portion 49A extends rearward from the first pivot axis M1, and therefore, the weight portion 49A of the lug arm 49 is supported on the ring plate 45 with the first pin 47A. The weight portion 49A is passed through a groove portion 45B of the ring plate 45 and positioned behind the ring plate 45, that is, on the rear surface 5B side of the swash plate 5. With this configuration, the centrifugal force generated by the rotation of the swash plate 5 about the axis of rotation O acts on the weight portion 49A on the rear surface 5B side of the swash plate 5.

**[0057]** In the compressor, the swash plate 5 is connected to the drive shaft 3 via the link mechanism 7 for rotation with the drive shaft 3. The inclination angle of the swash plate 5 is variable with the swinging motion of the opposite ends of the lug arm 49 about the first pivot axis M1 and the second pivot axis M2, respectively.

**[0058]** Each piston 9 has a first piston head 9A at the front end thereof and a second piston head 9B at the rear end thereof. Each first piston head 9A is received in its associated first cylinder bore 21A so as to be reciprocally movable. Each first cylinder bore 21A has therein a first compression chamber 21 D which is formed between the first piston head 9A and the first valve forming plate 39. Each second piston head 9B is received in its associated second cylinder bore 23A so as to be reciprocally mov-

able. Each second cylinder bore 23A has therein a second compression chamber 23D which is formed between the second piston head 9B and the second valve forming plate 41. Since the first cylinder bores 21A and the second cylinder bores 23A have the same diameter as mentioned above, the first piston head 9A and the second piston head 9B are formed to have the same diameter.

**[0059]** Each piston 9 has at the longitudinal center thereof a recessed portion 9C and the pair of hemispherical shoes 11 A, 11 B is received in the recessed portion 9C. The shoes 11A, 11 B convert the rotation of the swash plate 5 into the reciprocating motion of the pistons 9 in the respective cylinder bores 21A, 23A. The shoes 11A, 11B correspond to the conversion mechanism of the present invention. The first and second piston heads 9A, 9B are reciprocable in the first and second cylinder bores 21A, 23A, respectively, for a stroke length according to the inclination angle of the swash plate 5.

**[0060]** With the change of the stroke length of the respective pistons 9 according to the change of the inclination angle of the swash plate 5, the top dead center of the respective first piston heads 9A and the second piston heads 9B is shifted. Specifically, in the state of FIG. 1 where the inclination angle of the swash plate 5 and the stroke length of the pistons 9 are the maximum, the top dead centers of the first piston heads 9A and the second piston head 9B are located at positions closest to the first valve forming plate 39 and the second valve forming plate 41, respectively. As will be appreciated from comparison of FIGS. 1 and 4, the top dead center of the second piston heads 9B becomes more distant from the second valve forming plate 41 with a decrease of the inclination angle of the swash plate 5 and hence of the stroke length of the pistons 9. Whereas, the top dead center of the first piston heads 9A is shifted very little when the stroke of the pistons 9 is the maximum and the position which is close to the first valve forming plate 39 is maintained. In other words, in the compressor of the present embodiment, as the inclination angle of the swash plate 5 decreases, the shifting of the top dead center of the second piston head 9B becomes greater than that of the first piston head 9A.

**[0061]** As shown in FIG. 1, the actuator 13 is disposed in the swash plate chamber 33. The actuator 13 is located behind the swash plate 5 and movable into the second recessed portion 23C. The actuator 13 includes a movable body 13A and a fixed body 13B and a pressure control chamber 13C is formed between the movable body 13A and the fixed body 13B.

**[0062]** The movable body 13A includes a body 130 and a peripheral wall 131. The body 130 forms the rear part of the movable body 13A and extends radially from the drive shaft 3. The peripheral wall 131 is connected to the outer circumferential edge of the body 130 and extends in the axial direction of the drive shaft 3. Furthermore, the peripheral wall 131 has at the front end thereof a connecting portion 132. The body 130, the peripheral wall 131 and the connecting portion 132 cooperate to form

the movable body 13A of a shape of a closed-end cylinder.

**[0063]** The fixed body 13B is formed of a circular plate having substantially the same diameter as the inner diameter of the movable body 13A. A second return spring 44B is provided between the fixed body 13B and the ring plate 45. Specifically, the return spring 44B is fixed at the rear end thereof to the fixed body 13B and fixed at the front end thereof to the other end of the ring plate 45, or the end of the ring plate 45 that is opposite from the end thereof to which the lug arm 49 is connected.

**[0064]** The drive shaft body 30 extends through the center holes of the movable body 13A and the fixed body 13B, so that the movable body 13A in the second recessed portion 23C is located opposite from the link mechanism 7 with respect to the swash plate 5. The fixed body 13B is disposed within the movable body 13A at a position rearward of the swash plate 5 and the periphery of the fixed body 13B is covered by the peripheral wall 131 of the movable body 13A. With such configuration of the actuator 13, the pressure control chamber 13C is formed between the movable body 13A and the fixed body 13B. Specifically, the pressure control chamber 13C is defined by the body 130 and the peripheral wall 131 of the movable body 13A and the fixed body 13B, thereby being separated from the swash plate chamber 33.

**[0065]** The movable body 13A is mounted on the drive shaft body 30 in such a way that the movable body 13A is rotatable with the drive shaft 3 and also slidable in the swash plate chamber 33 in the axial direction O of the drive shaft 3. Whereas, the fixed body 13B is fixedly mounted on the drive shaft body 30 with the drive shaft body 30 inserted in the fixed body 13B, so that the fixed body 13B is rotatable with the drive shaft 3, but immovable in the axial direction O. Therefore, the movable body 13A is movable relative to the fixed body 13B in the axial direction O of the drive shaft 3.

**[0066]** The connecting portion 132 of the movable body 13A is connected to the other end of the ring plate 45 through a third pin 47C, so that the other end of the ring plate 45 is supported, that is, the swash plate 5 is supported by the movable body 13A so as to be swingable about a pivot axis M3 of the third pin 47C. The pivot axis M3 extends parallel to the first and second pivot axes M1, M2. The movable body 13A is thus connected to the swash plate 5. The movable body 13A is in contact with the flange 431 of the second support member 43B when the swash plate 5 is placed at the maximum inclination angle position.

**[0067]** Furthermore, the drive shaft body 30 has therein an axial passage 3B extending in the axial direction O and opened in the rear end surface of the drive shaft body 30 and a radial passage 3C extending from the front end of the axial passage 3B and opened in the peripheral surface of the drive shaft body 30. Because the rear end of the drive shaft body 30 projects into the pressure regulation chamber 31, the rear end of the axial passage 3B

is also located and is opened to the pressure regulation chamber 31. The radial passage 3C is opened to the control chamber 13C. With this configuration, the pressure control chamber 13C communicates with the pressure regulation chamber 31 through the radial passage 3C and the axial passage 3B.

**[0068]** The drive shaft body 30 has at the front end thereof a threaded portion 3D. The drive shaft 3 is connected to a pulley or an electromagnetic clutch (not shown) at the threaded portion 3D.

**[0069]** As shown in FIG. 2, the control mechanism 15 includes a low-pressure passage 15A, a high-pressure passage 15B, a control valve 15C, an orifice 15D and the aforementioned axial and radial passages 3B, 3C. The axial passage 3B and the radial passage 3C correspond to the pressure-changing passages of the present invention. The low-pressure passage 15A, the high-pressure passage 15B, the axial passage 3B and the radial passage 3C correspond to the control passages of the present invention.

**[0070]** The low-pressure passage 15A is connected to the pressure regulation chamber 31 and the second suction chamber 27B. The pressure control chamber 13C, the pressure regulation chamber 31 and the second suction chamber 27B communicate with each other through the low-pressure passage 15A, the axial passage 3B and the radial passage 3C. The high-pressure passage 15B is connected to the pressure regulation chamber 31 and the second discharge chamber 29B. The pressure control chamber 13C, the pressure regulation chamber 31 and the second discharge chamber 29B communicate with each other through the high-pressure passage 15B, the axial passage 3B and the radial passage 3C. The orifice 15D is formed in the high-pressure passage 15B for restricting the flow rate of the refrigerant gas flowing in the high-pressure passage 15B.

**[0071]** The control valve 15C is formed in the low-pressure passage 15A and regulates the opening of the low-pressure passage 15A based on the pressure in the second suction chamber 27B.

**[0072]** The aforementioned evaporator is connected to the inlet port 330 of the compressor through a tube and the condenser is connected to the outlet port 230 through a tube. The condenser is connected to the evaporator through a tube and an expansion valve. The compressor, the evaporator, the expansion valve, the condenser and the like cooperate to form the refrigeration circuit of a vehicle air conditioning system. It is to be noted that the evaporator, the expansion valve, the condenser and the tubes are omitted from illustration in the drawings.

**[0073]** During the operation of the above-described compressor, the rotation of the drive shaft 3 rotates the swash plate 5, causing the pistons 9 to reciprocate in the first and second cylinder bores 21A, 23A, so that compression of refrigerant gas is performed in the first and second compression chambers 21D, 23D. The displacement of the compressor varies according to the stroke length of the pistons 9. In the compressor, the suction

phase in which refrigerant gas is drawn into the first and second cylinder bores 21A, 23A, the compression phase in which compressing the refrigerant gas is performed in the first and second cylinder bores 21A, 23A, and the discharge phase in which the compressed refrigerant gas is discharged from the first and second cylinder bores 21A, 23A are repeated.

**[0074]** In the suction phase, the refrigerant gas which is drawn from the evaporator into the swash plate chamber 33 through the inlet port 330 is flowed into the first suction chamber 27A through the first connecting passage 37A. The refrigerant gas in the first suction chamber 27A is then drawn into the first cylinder bore 21A through the first suction hole 390A due to the pressure difference which is created between the first cylinder bore 21A and the first suction chamber 27A and opens the first suction reed valves 391 A. On the other hand, the refrigerant gas in the swash plate chamber 33 is also flowed into the second suction chamber 27B through the second connecting passage 37B and then drawn into the second cylinder bore 23A through the second suction hole 410A due to the pressure difference which is created between the second cylinder bore 23A and the second suction chamber 27B and opens the second suction reed valves 411 A.

**[0075]** In the discharge phase, the refrigerant gas compressed in the first compression chamber 21 D is discharged into the first discharge chamber 29A and flowed toward the combined discharge chamber 231 through the first communication passage 18. Similarly, the refrigerant gas compressed in the second compression chamber 23D is discharged into the second discharge chamber 29B and flowed toward the combined discharge chamber 231 through the second communication passage 20. The refrigerant gas in the combined discharge chamber 231 is discharged out through the outlet port 230 toward the condenser.

**[0076]** During the suction phase, the compression force of the pistons 9 acts on the swash plate 5, the ring plate 45, the lug arm 49, and the first pin 47A in such a way that reduces the inclination angle of the swash plate 5. A change in the inclination angle of the swash plate 5 increases or decreases the stroke length of the pistons 9 thereby to change the discharge displacement.

**[0077]** Specifically, when the opening of the low-pressure passage 15A is increased by the control valve 15C shown in FIG. 2, the pressures in the pressure regulation chamber 31 and hence the pressure control chamber 13C become substantially the same as the pressure in the second suction chamber 27B. As a result, the movable body 13A of the actuator 13 moves frontward in the swash plate chamber 33 and, therefore, toward the lug arm 49, as shown in FIG. 4, due to the compression force of the pistons 9 acting on the swash plate 5.

**[0078]** The end of the ring plate 45 that is opposite from the end thereof to which the lug arm 49 is connected, that is, the other end of the swash plate 5 swings clockwise about the pivot axis M3 while overcoming against

the urging force of the second return spring 44B. Furthermore, the rear end of the lug arm 49 swings clockwise about the first pivot axis M1, while the front end of the lug arm 49 swings counterclockwise about the second pivot axis M2. Accordingly, the lug arm 49 moves toward the flange 430 of the first support member 43A and the swash plate 5 swings about the first pivot axis M1 with the pivot axis M3 as the point of action and the first pivot axis M1 as the fulcrum point. The inclination angle of the swash plate 5 with respect to a plane extending perpendicular to the axis of rotation O of the drive shaft 3 decreases and the stroke length of the pistons 9 decreases. Accordingly, the displacement of the compressor per one rotation of the drive shaft 3 is decreased. It is to be noted that the inclination angle of the swash plate 5 shown in FIG. 4 corresponds to the minimum inclination angle.

**[0079]** In this case, the centrifugal force acting on the weight portion 49A is imparted to the swash plate 5 in such a way that the swash plate 5 tends to shift easily in the direction that reduces the inclination angle of the swash plate 5. The movable body 13A moves frontward in the swash plate chamber 33 to a position where the front end of the movable body 13A is located radially inner side of the weight portion 49A. In the compressor, when the inclination angle of the swash plate 5 is reduced to minimum, about front half of the front end of the movable body 13A is covered with the weight portion 49A.

**[0080]** As the inclination angle of the swash plate 5 is decreased, the ring plate 45 is brought into contact with the rear end of the first return spring 44A. Then the first return spring 44A is elastically deformed and the rear end of the first return spring 44A approaches the first support member 43A.

**[0081]** With a decrease of the inclination angle of the swash plate 5 and hence of the stroke length of the pistons 9, the top dead center of the second piston heads 9B is shifted away from the second valve forming plate 41. Therefore, when the inclination angle of the swash plate 5 is approximately zero, compression for a small displacement is performed in the first compression chamber 21D, and no compression is performed in the second compression chamber 23D.

**[0082]** As the control valve 15C shown in FIG. 2 reduces the opening of the low-pressure passage 15A, the pressure in the pressure control chamber 13C becomes substantially the same as the pressure in the second discharge chamber 29B. Accordingly, the movable body 13A moves rearward in the swash plate chamber 33 against the compression force of the pistons acting on the swash plate 5, so that the movable body 13A is moved away from the lug arm 49.

**[0083]** Consequently, the lower end of the swash plate 5 is pulled at the pivot axis M3 by the movable body 13A rearward in the swash plate chamber 33 through the connecting portion 132, so that the other end of the swash plate 5 swings counterclockwise about the pivot axis M3. Furthermore, the rear end of the lug arm 49 swings counterclockwise about the first pivot axis M1, while the front

end of the lug arm 49 swings clockwise about the second pivot axis M2. Accordingly, the lug arm 49 moves away from the flange 430 of the first support member 43A and the swash plate 5 swings about the first pivot axis M1 with the pivot axis M3 as the point of action and the pivot axis M1 as the fulcrum point in the direction that is opposite to the direction that decreases the inclination angle of the swash plate 5. Therefore, the inclination angle of the swash plate 5 increases and the stroke length of the pistons 9 is lengthened, with the result that the displacement of the compressor per one rotation of the drive shaft 3 is increased. It is to be noted that the inclination angle of the swash plate 5 shown in FIG. 1 corresponds to the maximum inclination angle.

**[0084]** As described above, the refrigerant gas in the second discharge chamber 29B is drawn into the pressure regulation chamber 31 through the high-pressure passage 15B of the control mechanism 15. The refrigerant gas in the second discharge chamber 29B, which has been just compressed in the second compression chamber 23D, has a high temperature and a high pressure.

**[0085]** As shown in FIG. 3, the pressure regulation chamber 31 is disposed in the rear housing 19 at a position radially inward of the second discharge chamber 29B and surrounded by the second discharge chamber 29B. In such structure of the compressor, the refrigerant in the pressure regulation chamber 31 is heated by high-temperature refrigerant gas in the second discharge chamber 29B and part of the rear housing 19 in the vicinity of the second discharge chamber 29B and, therefore, the refrigerant gas in the pressure regulation chamber 31 will also be heated. In the compressor wherein the second suction chamber 27B is disposed radially outward of the second discharge chamber 29B in the rear housing 19, the refrigerant gas in the pressure regulation chamber 31 tends to be less cooled by the second suction chamber 27B because the refrigerant gas in the pressure regulation chamber 31 is less susceptible to the influence of low-temperature refrigerant gas in the second suction chamber 27B.

**[0086]** Furthermore, during the operation of the compressor when the drive shaft 3 is being rotated, the first and second cylinder blocks 21, 23, the first and second sliding bearings 22A, 22B, and the first and second support members 43A, 43B are heated by friction. The drive shaft body 30 is also heated by the heat transmitted from the second support member 43B and the like. The first and second thrust bearings 35A, 35B are also heated by the friction caused during the rotation of the drive shaft 3. In the compressor wherein the second thrust bearing 35B is provided between the second recessed portion 23C of the second cylinder block 23 and the flange 431 of the second support member 43B, the heat generated in the second thrust bearing 35B is transmitted to the second cylinder block 23 and the second support member 43B.

**[0087]** In the compressor, the refrigerant gas in the pressure regulation chamber 31 may be heated directly

by the members projecting into the pressure regulation chamber 31, such as the projection 23F of the second cylinder block 23, the second sliding bearing 22B, the rear end of the second support member 43B and the rear end of the drive shaft body 30 that project into the pressure regulation chamber 31.

**[0088]** In the compressor according to the present embodiment, the temperature of the refrigerant gas which is drawn from the second discharge chamber 29B into the pressure regulation chamber 31 is hard to drop. Therefore, in the compressor wherein the drive shaft body 30 is heated as described above and the rear end of the axial passage 3B is located in the pressure regulation chamber 31, the refrigerant gas flowed from the pressure regulation chamber 31 into the pressure control chamber 13C is hard to be cooled in the axial passage 3B and the radial passage 3C. If liquefied refrigerant exists in the pressure regulation chamber 31 due to cooling, the pressure change in the pressure control chamber 13C is inhibited. In the compressor according to the present embodiment, the refrigerant in the pressure regulation chamber 31 is hardly to be liquefied, with the result that the pressure of the refrigerant gas flowed into the pressure control chamber 13C through the pressure regulation chamber 31 is varied quickly and the movable body 13A is moved smoothly in response to a change of the pressure in the pressure control chamber 13C and, therefore, the inclination angle of the swash plate is changed quickly according to a change of the operating condition of the compressor.

**[0089]** Thus, the compressor according to the embodiment exhibits good controllability.

**[0090]** Furthermore, in the compressor, the drive shaft including the drive shaft body and the cap maintains the simple form of the drive shaft main body to thereby provide a simplified manufacturing process of the compressor, while heating the refrigerant with the cap.

**[0091]** The present invention has been described according to the embodiment shown in the drawings. However, the present invention is not limited to the embodiment above, but it may appropriately be modified without departing from the gist of the invention.

**[0092]** For example, as in the case of the rear housing 19, the first discharge chamber 29A may be formed radially inward of the front housing 17 and the first suction chamber 27A radially outward of the first discharge chamber 29A.

**[0093]** The configuration of the control mechanism 15 may be such that the control valve 15C is formed in the high-pressure passage 15B and the orifice 15D is formed in the low-pressure passage 15A. In this case, the opening of the high-pressure passage 15B is regulated by the control valve 15C. In the compressor of such configuration, the pressure in the pressure control chamber 13C is raised quickly by the high pressure in the second discharge chamber 29B, so that an increase of the displacement of the compressor may be accomplished quickly.

**[0094]** The compressor may be configured such that

the actuator 13 is disposed on the front surface 5A side and the lug arm 49 on the rear surface 5B side of the swash plate 5.

**[0095]** The compressor may further be configured such that the compression chamber is formed in either the first cylinder block 21 or the second cylinder block 23.

**[0096]** The present invention is applicable to an air conditioning apparatus or and the like.

## Claims

1. A swash plate type variable displacement compressor comprising:

a housing (1) having therein a suction chamber (27A, 27B), a discharge chamber (29A, 29B), a swash plate chamber (33), and a plurality of cylinder bores (21A, 23A);

a drive shaft (3) rotatably supported in the housing (1);

a swash plate (5) which is rotatable in the swash plate chamber (33) with the rotation of the drive shaft (3);

a link mechanism (7) which is disposed between the drive shaft (3) and the swash plate (5) and allows a change in an inclination angle of the swash plate (5) with respect to the direction perpendicular to the axis of the drive shaft (3);

a plurality of pistons (9) which is reciprocally received in the respective cylinder bores (21 A, 23A);

a conversion mechanism (11A, 11 B) which converts the rotation of the drive shaft (3) into reciprocal movement of the pistons (9) in the respective cylinder bores (21A, 23A) in conjunction with the swash plate (5) with a stroke length according to the inclination angle of the swash plate (5); an actuator (13) for changing the inclination angle of the swash plate (5); and

a control mechanism (15) which controls the actuator (13), **characterized in that**

the housing (1) has therein a pressure regulation chamber (31), the pressure regulation chamber (31) is disposed radially inward of the discharge chamber (29A, 29B), which is disposed radially inward of the suction chamber (27A, 27B);

the actuator (13) includes a fixed body (13B), a movable body (13A), and a pressure control chamber (13C), wherein the fixed body (13B) is fixed on the drive shaft (3) in the swash plate chamber (33), the movable body (13A) is connected to the swash plate (5) and movable relative to the fixed body (13B) in the direction of the axis of rotation, and the pressure control chamber (13C) is defined by the fixed body (13B) and the movable body (13A) and the pressure in the pressure control chamber (13C) is

changed by introducing the pressure in the discharge chamber (29A, 29B) into the pressure control chamber (13C) such that the movable body (13A) is moved;

the control mechanism (15) has a control passage (3B, 3C, 15A, 15B) and a control valve (15C), the control passage (3B, 3C, 15A, 15B) providing communication between the discharge chamber (29A, 29B) and the pressure control chamber (13C) via the pressure regulation chamber (31), the control valve (15C) adjusting an opening of the control passage (3B, 3C, 15A, 15B) to vary the pressure in the pressure regulation chamber (31) such that the movable body (13A) is moved;

at least a part of the control passage (3B, 3C, 15A, 15B) is formed in the drive shaft (3); and the drive shaft (3) projects into the pressure regulation chamber (31) such that the control passage (3B, 3C, 15A, 15B) connects the pressure regulation chamber (31) and the pressure control chamber (13C).

2. The compressor according to claim 1, **characterized in that** the housing (1) has therein a cylinder block (21, 23) and a rear housing (19), the cylinder block (21, 23) having the cylinder bores (21 A, 23A), rotatably supporting the drive shaft (3), the rear housing (19) being connected to the cylinder block (21, 23) through a valve unit (41) and having at least the discharge chamber (29A, 29B); and the cylinder block (21, 23) projects into the pressure regulation chamber (31).

3. The compressor according to claim 2, **characterized in that** the drive shaft (3) includes a drive shaft body (30) and a cap (43B) which is fitted on the drive shaft body (30) and disposed between the drive shaft body (30) and the cylinder block (21, 23), the drive shaft body (30) and the cap (43B) projecting into the pressure regulation chamber (31).

4. The compressor according to claim 3, **characterized in that** a radial bearing (22B) is provided between the cylinder block (21, 23) and the cap (43B) and projects into the pressure regulation chamber (31).

5. The compressor according to claim 3 or 4, **characterized in that** a thrust bearing (35B) is provided between the cylinder block (21, 23) and the cap (43B).

6. The compressor according to any one of claims 1 to 5, **characterized in that** the suction chamber (27A, 27B) and the swash plate chamber (33) form a low-pressure chamber;

the control passage (3B, 3C, 15A, 15B) includes a high-pressure passage (15B) which provides communication between the discharge chamber (29A, 29B) and the pressure regulation chamber (31), a low-pressure passage (15A) which has the control valve (15C) and provides communication between the low-pressure chamber and the pressure regulation chamber (31), and a pressure-changing passage (3B, 3C) which is formed in the drive shaft (3) and provides communication between the pressure regulation chamber (31) and the pressure control chamber (13C); and a part of the pressure-changing passage (3B, 3C) projects into the pressure regulation chamber (31) together with the drive shaft (3).

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FIG. 1

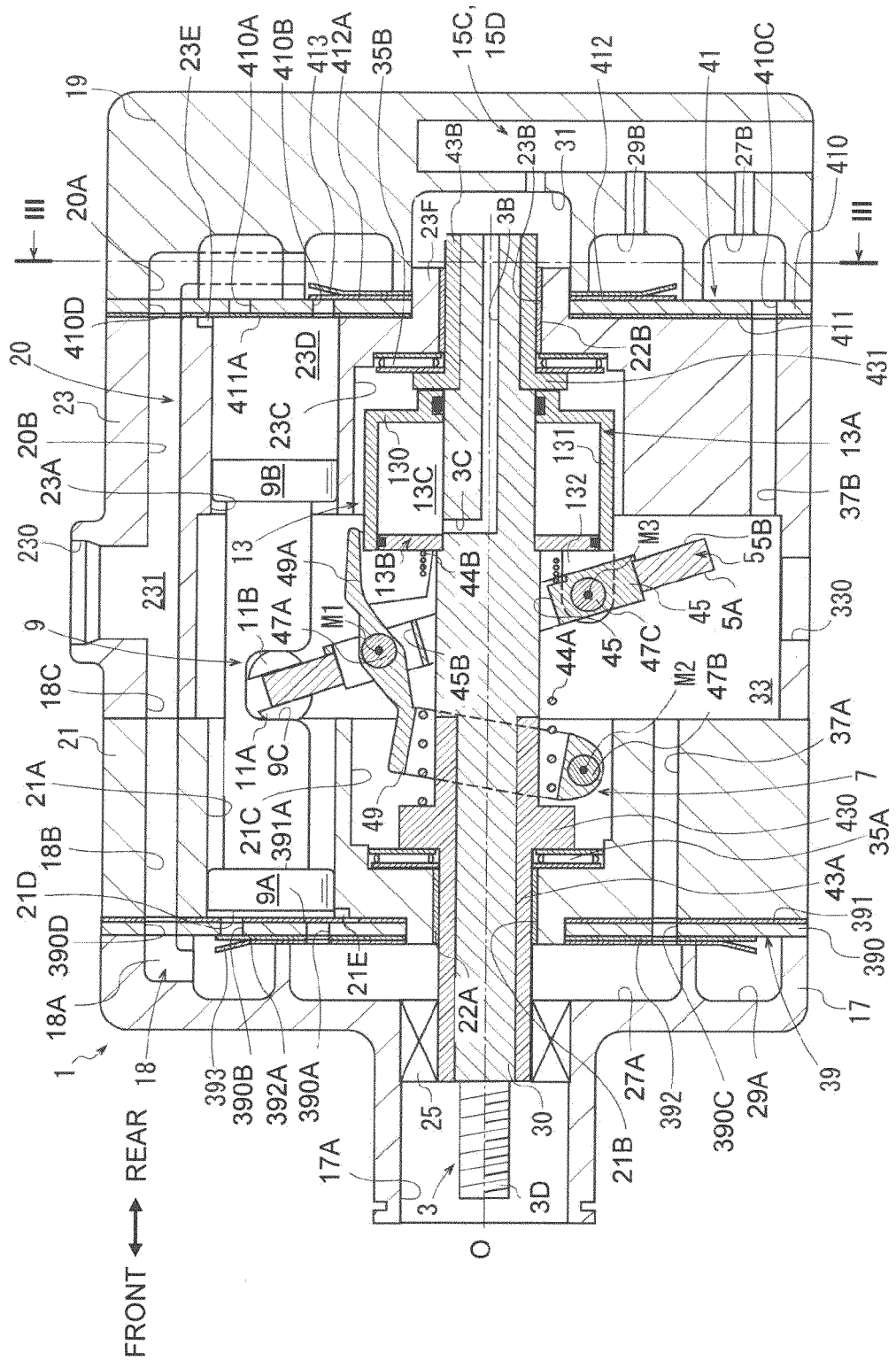


FIG. 2

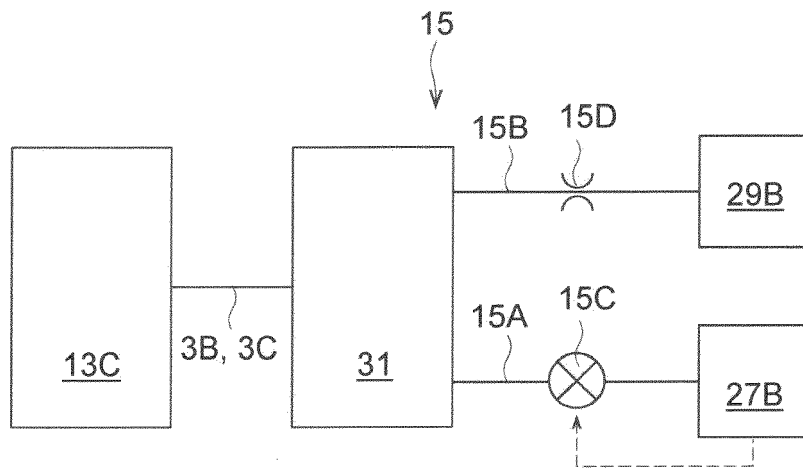


FIG. 3

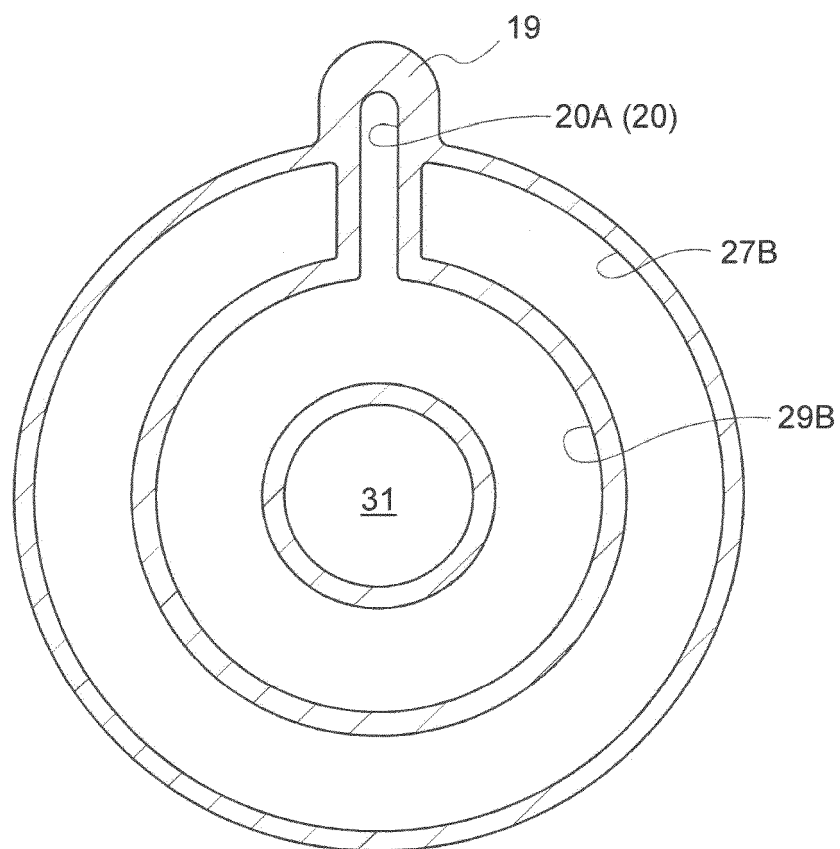
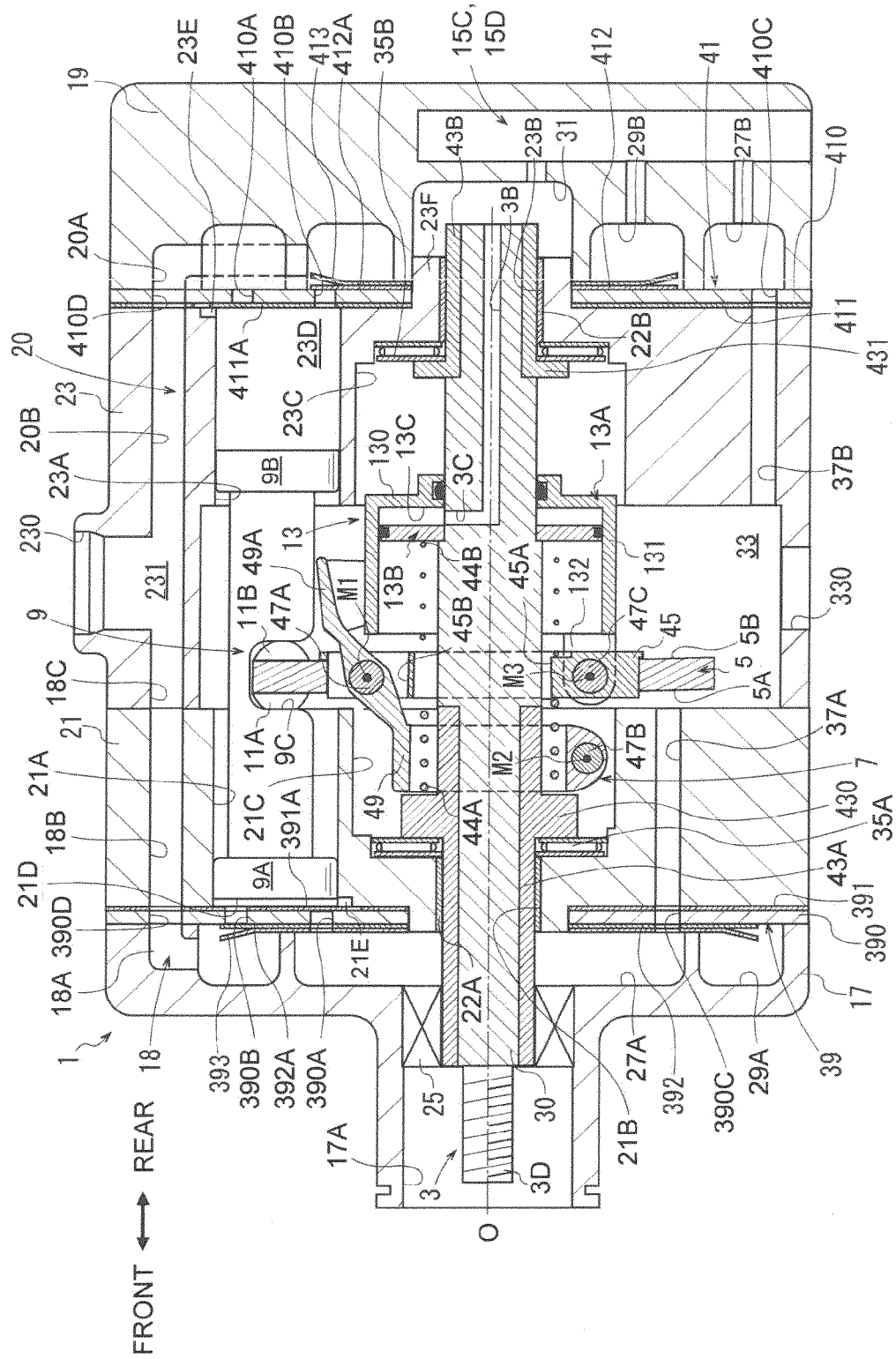


FIG. 4





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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                        |                                                      |                                         |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                        |                                                      | F04B                                    |
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| Place of search<br>Munich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                        | Date of completion of the search<br>13 February 2015 | Examiner<br>Jurado Orenes, A            |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                        |                                                      |                                         |

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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