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(54) Variable-displacement compressor

(57) A variable-displacement compressor comprises a compressor housing having a crank chamber, a discharge chamber, and a suction chamber. The variable-displacement compressor comprises a driving shaft rotatably supported by the compressor housing to be located in the crank chamber and a slant plate located in the crank chamber to be coupled to the driving shaft. The slant plate has a variable slant angle for the driving shaft. The variable-displacement compressor varies the variable slant angle in accordance with a pressure difference between the crank chamber and the suction chamber to control a compression capacity. The variable-displacement compressor further comprises a first communication path through which the crank chamber communicates with the discharge chamber, a first valve device for adjusting the opening area of the first communication path to control the pressure in the crank chamber, a second communication path through which the crank chamber communicates with the suction chamber, and a second valve device for adjusting the opening area of the second communication path in accordance with the pressure difference. More particularly, the second valve device perfectly closes the second communication path when the pressure difference becomes a predetermined pressure difference.

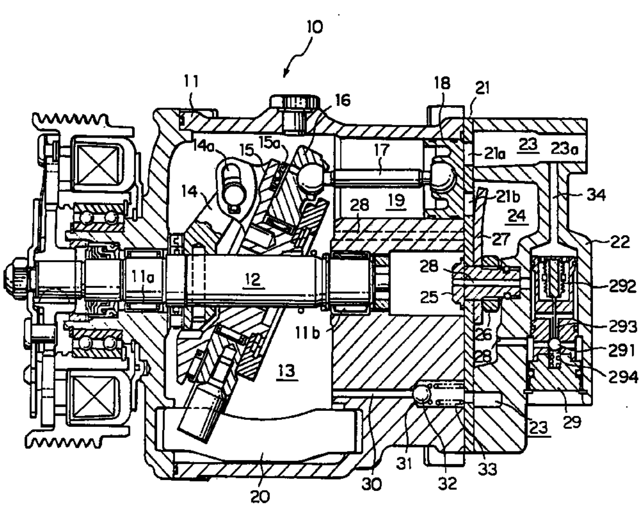

FIG. 1

EP 0 855 506 A2

Description

Background of the Invention:

This invention relates to a variable-displacement compressor and, more particularly, to a variable-displacement compressor for use in an air conditioning apparatus for an automobile.

In general, a variable-displacement compressor is used in an air conditioning apparatus for an automobile. A conventional variable-displacement compressor is disclosed in Japanese Patent Publication (JP-A) Tokko Hei 4-74549 (74549/1992).

The conventional variable-displacement compressor is a variable-displacement compressor of a wobble plate type and comprises a compressor housing in which a crank chamber is formed. A rotor is located in the crank chamber and is attached to a driving shaft. A slant plate is attached to the rotor through a hinge mechanism. The driving shaft penetrates through the slant plate which is attached to a sleeve. The driving shaft is surrounded by the sleeve. A space is formed between the outer surface of the sleeve and the inner surface of the slant plate so that the slant plate has a variable slant angle for the driving shaft. The hinge mechanism makes the variable slant angle be varied in concern with the driving shaft, as will be described later.

A wobble or rock plate is positioned on the slant plate through a bearing. A plurality of piston rods are connected to the wobble plate. The piston rods have piston members, respectively. The piston members are located in cylinder portions which are formed in the compressor housing. More particularly, the cylinder portions are formed in the compressor housing at a predetermined interval so as to surround the driving shaft. A guide rod is supported by the compressor housing to be located in parallel to the driving shaft in the crank chamber. The wobble plate is attached to the guide rod so as to slide along the guide rod.

The rotor is rotated by the rotation of the driving shaft. Inasmuch as the slant plate is connected to the rotor through the hinge mechanism, the slant plate is rotated in accordance with the rotation of the rotor. By the rotation of the slant plate, the wobble plate wobbles or oscillates inasmuch as the wobble plate is slidably attached to the guide rod as described above. On the basis of the wobble of the wobble plate, the piston members are reciprocated in the cylinder portions, respectively.

The compressor housing has a suction chamber and a discharge chamber each of which communicates with the cylinder portions. When the piston members are reciprocated in the cylinder portions, respectively, refrigerant is taken from the suction chamber to cylinder portions to be compressed into a compressed refrigerant which is discharged as a discharged gas to the discharge chamber. Inasmuch as the slant plate has the variable slant angle as described above, it is possible to make the stroke of each piston member vary under control of the variable slant angle. In other words, the conventional variable-displacement compressor varies its compression capacity under control of the variable slant angle.

By the way, first and second communication paths are formed in the compressor housing in the conventional variable-displacement compressor. Through the first communication path, the discharge chamber communicates with the crank chamber. The conventional variable-displacement compressor further comprises a switching valve for opening and closing the first communication path. The switching valve opens and closes the first communication path to make a suction pressure become a predetermined pressure. Through the second communication path, the crank chamber always communicates with the suction chamber in order to escape the discharged gas from the crank chamber to the suction chamber.

As described above, the crank chamber always communicates with suction chamber in the conventional variable-displacement compressor. When the conventional variable-displacement compressor has been put out of operation during a long time and when liquid refrigerant exists in a low pressure side of a refrigeration circuit which is connected to the conventional variable-displacement compressor, the liquid refrigerant flows from the refrigeration circuit into the crank chamber through the suction chamber inasmuch as the crank chamber always communicates with the suction chamber. More specifically, an amount of liquid refrigerant flows into the crank chamber through the suction chamber in case where a room temperature is high in an automobile and a temperature of an engine room is low in which the conventional variable-displacement compressor is located.

When the conventional variable-displacement compressor is put in operation in the above-mentioned condition, the opening area of the second communication path lacks in concern with the amount of the liquid refrigerant which exists in the crank chamber. As a result, a pressure difference occurs between the crank chamber and the suction chamber. The variable slant angle becomes a predetermined minimum angle so that the conventional variable-displacement compressor has a minimum compression capacity. Therefore, it is difficult to obtain a desired compression capacity until the liquid refrigerant sufficiently flows out of the crank chamber. In other words, it is difficult to obtain the desired compression capacity just after the conventional variable-displacement compressor is put into operation.

Summary of the Invention:

It is therefore an object of this invention to provide a variable-displacement compressor capable of obtaining a desired compression capacity just after the variable-displacement compressor is put into operation.

Other objects of this invention will become clear as the description proceeds.

On describeing the gist of this invention, it is possible to understand that a variable-displacement compressor comprises a compressor housing having a crank chamber, a discharge chamber, and a suction chamber. The variable-displacement compressor further comprises a driving shaft rotatably supported by the compressor housing to be located in the crank chamber and a slant plate located in the crank chamber to be coupled to the driving shaft. The slant plate has a variable slant angle for the driving shaft. The variable-displacement compressor varies the variable slant angle in accordance with a pressure difference between the crank chamber and the suction chamber to control a compression capacity.

According to this invention, the variable-displacement compressor comprises (A) a first communication path through which the crank chamber communicates with the discharge chamber, the first communication path having a first opening area, (B) a first valve device for adjusting the first opening area to control the pressure in the crank chamber, (C) a second communication path through which the crank chamber communicates with the suction chamber, the second communication path having a second opening area, and (D) a second valve device for adjusting the second opening area in accordance with a pressure difference between the crank chamber and the suction chamber. More specifically, the second valve device perfectly closes the second communication path when the pressure difference becomes a predetermined pressure difference.

Brief Description of the Drawing:

Fig. 1 is a sectional view of a variable-displacement compressor according a first embodiment of this invention;

Fig. 2 is a diagram for describing a pressure control characteristic of a pressure control valve illustrated in Fig. 1; and

Fig. 3 is a sectional view of a variable-displacement compressor according a second embodiment of this invention.

Description of the preferred Embodiments:

Referring to Fig. 1, description will proceed to a variable-displacement compressor 10 according to a first embodiment of this invention. The illustrated variable-displacement compressor comprises a compressor casing 11 at which a penetration portion is formed along a transversal direction of Fig. 1. A driving shaft 12 is inserted from the penetration portion into the compressor casing 11 and is rotatably supported to the compressor casing 11 by bearings 11a and 11b.

The compressor casing 11 has a crank chamber 13 in which a rotor 14 is located. The rotor 14 is attached to the driving shaft 12. A slant plate 15 is attached to the rotor 14 through a hinge mechanism 14a. In the example being illustrated, the driving shaft 12 penetrates through the slant plate 15 so that the driving shaft 12 is in contact with the slant plate 15. More particularly, the surface of the driving shaft 12 is in contact with the inner wall surface of the slant plate 15 so that the slant plate 15 is able to slide along the direction of the driving shaft 12. Furthermore, the slant plate 15 has a variable slant angle for the driving shaft 12 that is varied by the hinge mechanism 14a.

A wobble plate 16 is attached to the slant plate 15 through a bearing 15a. A plurality of piston rods 17 is connected to the wobble plate 16. The piston rods 17 are connected to piston members 18, respectively. A plurality of cylinder portions 19 are formed in the compressor casing 11 at a predetermined interval so as to surround the driving shaft 12. The piston members 18 are positioned in the cylinder portions 19, respectively.

A guide rod 20 is supported by the compressor casing 11 to be located in parallel to the driving shaft 12 in the crank chamber 13. The wobble plate 16 is attached to the guide rod 20 at its one end so as to slide along the guide rod 20.

A valve plate 21 and a cylinder head 22 are positioned at the right end portion of the compressor casing 11 in Fig. 1. As a result, the right opening portion of the compressor casing 11 is closed by the cylinder head 22 in Fig. 1. A compressor housing is composed of the compressor casing 11 and the cylinder head 22. A suction chamber 23 and a discharge chamber 24 are formed in the cylinder head 22. The suction chamber 23 is connected to an inlet port 23a. The discharge chamber 24 is connected to an outlet port (not shown). Although no illustration is made in Fig. 1, each of the inlet port 23a and the outlet port is connected to a refrigeration circuit. A suction hole 21a and a discharge hole 21b are formed on the valve plate 21. The suction chamber 23 and the discharge chamber 24 are connected to the cylinder portions 19 through the suction hole 21a and the discharge hole 21b, respectively. By a bolt 25 and a nut 26, a suction valve and a discharge valve (not shown) are fixed together with a valve retainer 27 on the valve plate 21 at the central portion of the valve plate 21.

A first communication path 28 is formed in the bolt 25 and the cylinder head 22. The crank chamber 13 communicates with the discharge chamber 24 through the first communication path 28. In the example being illustrated, a pressure control valve device 29 is positioned in the first communication path 28. As will be described later, the pressure control valve device 29 makes the crank chamber 13 selectively communicate with the discharge chamber 24 through the first communication path 28.

In the compressor casing 11, a second communication path 30 is formed through which the crank chamber

13 communicates with the suction chamber 23. As shown in Fig. 1, a valve seat 31 is formed in the second communication path 30. A valve body 32 is mounted on the valve seat 31. By a spring 33, the valve body 32 is pushed towards a direction at which the second communication path 30 is closed. The valve seat 31, the valve body 32, and the spring 33 collectively serves as an open and close valve device which operates in response to a pressure difference between the crank chamber 13 and the suction chamber 23. In the example being illustrated, the spring 33 has a predetermined spring force. When the pressure difference between the crank chamber 13 and the suction chamber 23 is greater than a predetermined pressure difference, the valve body 32 is moved towards a right hand of Fig. 1 against the predetermined spring force to open the second communication path 30. When the pressure difference between the crank chamber 13 and the suction chamber 23 is not greater than the predetermined pressure difference, the valve body 32 is moved towards a left hand of Fig. 1 by the predetermined spring force to close the second communication path 30. More particularly, the second communication path 30 has an opening area. The valve body 32 adjusts the opening area of the second communication path 30 in accordance with the pressure difference between the crank chamber 13 and the suction chamber 23. The predetermined pressure difference is less than a pressure difference at which the slant plate 15 starts varying the variable slant angle.

As readily understood from the above description, the second communication path 30 is perfectly closed when the pressure difference between the crank chamber 13 and the suction chamber 23 is not greater than the predetermined pressure difference. As a result, the crank chamber 13 does not communicate with the suction chamber 23.

Again referring to Fig. 1, description will be made as regards the pressure control valve device 29. The pressure control valve device 29 comprises a valve body 291 for use in opening and closing the first communication path 28. The pressure control valve device 29 further comprises a bellows valve 292. The bellows valve 292 maintains a vacuum therein and has a spring (not shown) therein. The bellows valve 292 senses the pressure in the suction chamber 23 as a sensed suction pressure through a third communication path 34 which is for use in connecting the pressure control valve device 29 to the suction chamber 23. The bellows valve 292 has a transmission rod 293 which drives the valve body 291 in accordance with a telescopic motion of the bellows valve 292, in order to open and close the first communication path 28. More particularly, the first communication path 28 has an opening area. The bellows valve 292 adjusts the opening area of the first communication path 28 in accordance with the sensed suction pressure.

In the example being illustrated, the valve body 291 is pushed by a spring 294 towards a direction at which the first communication path 28 is closed. As described above, the pressure control valve device 29 controls the valve body 291 in response to the pressure in the suction chamber 23 that is sensed by the bellows valve 292. The pressure control valve device 29 may have, for example, a pressure control characteristic shown in Fig. 2. In Fig. 2, a suction pressure (Ps) linearly drops as a discharge pressure (Pd) becomes high. In the example being illustrated, the suction pressure (Ps) becomes 1.7kg/cm^{2}G when the discharge pressure (Pd) is 15kg/cm^{2}G.

Reviewing Fig. 1, description will proceed to operation of the variable-displacement compressor 10. When the variable-displacement compressor 10 is put out of operation, the pressure is well balanced in the refrigeration circuit. It will be assumed that the pressure is well balanced at 6kg/cm^{2}G in the refrigeration circuit. Namely, it will be assumed that a balanced pressure is equal to 6kg/cm^{2}G in the refrigeration circuit. The pressure control valve device 29 has the pressure control characteristic which is higher than the balanced pressure. Therefore, the bellows valve 292 shrinks in the pressure control valve device 29 so that the valve body 291 closes the first communication path 28. Inasmuch as the pressure is well balanced in the refrigeration circuit, the valve body 32 closes the second communication path 30.

As readily understood from the above description, the refrigerant does not flow from the discharge chamber 24 to the crank chamber 13 through the first communication path 28 when the variable-displacement compressor 10 is put out of operation. Similarly, the refrigerant does not flow from the suction chamber 23 to the crank chamber 13 through the second communication path 30 when the variable-displacement compressor 10 is put out of operation.

When the variable-displacement compressor 10 is put into operation in the above-mentioned state, the discharged gas does not flow from the discharge chamber 24 to the crank chamber 13 inasmuch as the pressure control valve device 29 closes the first communication path 28. Only blow-by gas exists in the crank chamber 13. The blow-by gas is supplied from the cylinder portions 19 to the crank chamber 13 on reciprocating the piston members 18. As a result, the pressure reduces in the suction chamber 23. When the pressure difference between the crank chamber 13 and the suction chamber 23 becomes a predetermined pressure difference, the valve body 32 opens the second communication path 30 so that the gas flows from the crank chamber 13 to the suction chamber 23.

Inasmuch as only the blow-by gas exist in the crank chamber 13 just after the variable-displacement compressor 10 is put into operation, the gas is a little which flows the crank chamber 13 to the suction chamber 23 through the second communication path 30. As a result, the pressure difference between the crank chamber 13 and the suction chamber 23 does not rise to a pressure at which the variable slant angle starts variation. The variable-displacement compressor 10 is driven in a maximum compression capacity with the maximum slant angle of the slant plate 15.

It will be assumed that the pressure in the suction chamber 23 lowers to a prescribed pressure. In the example being illustrated, the bellows valve 292 stretches to make the transmission rod 293 push the valve body downwardly of Fig. 1 when the suction pressure lowers to 1.7kgcm^{2}G in Fig. 2. As a result, the valve body 291 opens the first communication path 28. When the first communication path 28 is opened by the valve body 291, an amount of the discharged gas flows from the discharge chamber 24 to the crank chamber 13 through the first communication path 28.

Even if an amount of the discharged gas flows from the discharge chamber 24 to the crank chamber 13, it is difficult to escape an amount of the discharged gas from the crank chamber 13 to the suction chamber 23 through the second communication path 30. Therefore, the pressure rises in the crank chamber 13. When the pressure difference between the crank chamber 13 and the suction chamber 23 increases to a pressure at which the variable slant angle decreases, the variable slant angle of the slant plate 15 decreases so that the piston stroke decreases. As a result, the variable-displacement compressor 10 is driven at a decreased compression capacity.

When the piston stroke decreases as described above, the pressure rises in the suction chamber 23. As a result, the bellows valve 292 shrinks in the pressure control valve device 29 so that the valve body 291 moves towards a direction at which the first communication path 28 is closed. The amount of the discharged gas decreases which flows from the discharge chamber 24 to the crank chamber 13. The pressure difference between the crank chamber 13 and the suction chamber 23 decreases so that the variable slant angle of the slant plate 15 decreases. The piston stroke increases as the variable slant angle of the slant plate 15 decreases. As a result, the variable-displacement compressor 10 is driven at an increased compression capacity.

As described above, the variable-displacement compressor 10 controls the pressure control valve device 29 so as to make the pressure in the suction chamber 23 become the prescribed pressure.

Referring to Fig. 3, description will proceed to a variable-displacement compressor according to a second embodiment of this invention. The illustrated variable-displacement compressor is different in structure from the variable-displacement compressor illustrated in Fig. 1 and is therefore designated afresh by a reference numeral 40. More particularly, the pressure control valve device illustrated in Fig. 3 is different in structure from the pressure control valve device 29 illustrated in Fig. 1. The variable-displacement compressor 40 comprises similar parts which are designated by like reference numerals. For a matter of convenience, the pressure control valve device illustrated in Fig. 3 will be designated by the reference numeral 29.

As described in conjunction with Fig. 1, the pressure control valve device 29 comprises the valve body 291 which is for use in opening and closing the first communication path 28. Furthermore, the pressure control valve device 29 comprises the bellows valve 292. The bellows valve 292 maintains a vacuum therein and has the spring therein. The bellows valve 292 senses the pressure in the the suction chamber 23 through the third communication path 34 which is for use in connecting the pressure control valve device 29 to the suction chamber 23. The bellows valve 292 has the transmission rod 293 which drives the valve body 291 in accordance with the telescopic motion of the bellows valve 292, in order to open and close the first communication path 28.

The pressure control valve device 29 comprises an electromagnetic coil 294 positioned in the cylinder head 22. The pressure control valve device 29 further comprises a plunger 297 which is surrounded by the electromagnetic coil 294. The plunger 297 is movably supported by cylinder head 22 to slide upwardly and downwardly of Fig. 3. The plunger 297 has a transmission rod 295 which is for use in pushing the valve body 291. As shown in Fig. 3, the transmission rod 293 is opposite to the transmission rod 295 through the valve body 291.

The plunger 297 has a spring 296. The plunger 297 is pushed upwardly by the spring force of the spring 296. When an electric power is supplied to the electromagnetic coil 294, an electromagnetic force is generated around the plunger 297. The electromagnetic force makes the plunger 297 push downwardly of Fig. 3. therefore, the plunger 297 makes the transmission rod 295 selectively move upwardly and downwardly of Fig. 3 in accordance with the electromagnetic force of the electromagnetic coil 294 and the spring force of the spring 296.

As readily understood from the above description, the valve body 291 is selectively moved upwardly and downwardly of Fig. 3 by a combination of the bellows valve 292, the plunger 297, the electromagnetic coil 294, and the spring 296. Therefore, the pressure control valve device 29 illustrated in Fig. 3 controls the valve body 291 in response to the pressure in the suction chamber 23 that is sensed by the bellows valve 292. It will be assumed that the bellows valve 292 operates at a prescribed suction pressure. The prescribed suction pressure will be varied on the basis of the electromagnetic force of the electromagnetic coil 294.

Although description is made as regards the variable-displacement compressor of the wobble plate type in each of the first and the second embodiments, it is possible to apply this invention to another type variable-displacement compressor.

While this invention has thus far been described in conjunction with the preferred embodiments thereof, it will readily be possible for those skilled in the art to put this invention into practice in various other manners.

Claims

1. A variable-displacement compressor (10) comprising a compressor housing (11, 22) having a crank chamber (13), a discharge chamber (24), and a suction chamber (23), said variable-displacement compressor further comprising a driving shaft (12) supported by said compressor housing to be located in said crank chamber (13) and a slant plate (15) located in said crank chamber (13) to be coupled to said driving shaft (12), said slant plate (15) having a variable slant angle for said driving shaft (12), said variable-displacement compressor varying said variable slant angle in accordance with a pressure difference between said crank chamber (13) and said suction chamber (23) to control a compression capacity, which is characterized by:

   a first communication path (28) through which said crank chamber (13) communicates with said discharge chamber (24), said first communication path (28) having a first opening area;
   a first valve device (29) for adjusting said first opening area to control the pressure in said crank chamber (13);
   a second communication path (30) through which said crank chamber (13) communicates with said suction chamber (23), said second communication path (30) having a second opening area; and
   a second valve device (31, 32, 33) for adjusting said second opening area in accordance with a pressure difference between said crank chamber (13) and said suction chamber (23).

2. A variable-displacement compressor as claimed in claim 1, wherein said first valve device (29) senses the pressure of said suction chamber (23) as a sensed suction pressure to adjust said first opening area in accordance with said sensed suction pressure.

3. A variable-displacement compressor as claimed in claim 2, wherein said first valve device (29) comprises:

   valve means for selectively opening and closing said first communication path (28) to adjust said first opening area; and
   bellows means (292) for sensing said sensed suction pressure to make said valve means selectively open and close said first communication path (28) in accordance with said sensed suction pressure.

4. A variable-displacement compressor as claimed in claim 3, wherein said bellows means (292) makes said valve means close said first communication path (28) when said sensed suction pressure becomes a prescribed pressure.

5. A variable-displacement commpressor as claimed in claim 3 or 4, wherein:

   said valve means comprises:

      a first valve body (291) for adjusting said first opening area; and
      force supplying means for supplying a force to said valve body (291) to make said valve body (291) close said first communication path;
      said bellows means (292) driving said first valve body (291) against the force of said force supplying means to make said first valve body (291) open said first communication path (28).

6. A variable-displacement compressor as claimed in claim 5, wherein said force supplying means is a spring (294) or

   said force supplying means comprises:

      electromagnetic coil means (294) for generating an electromagnetic force in accordance with the amount of electric power; and
      converting means for converting said electromagnetic force into said force.

7. A variable-displacement compressor as claimed in one of claims 1 to 6, wherein said second valve device (31, 32, 33) perfectly closes said second communication path (30) when said pressure difference becomes a predetermined pressure difference.

8. A variable-displacement compressor as claimed in one of claims 1 to 7, wherein said second valve device comprises:

   a second valve body (32) for adjusting said second opening area; and
   force supplying means for supplying a force to said second valve body to make said valve body (32) close said second communication path (30),
   said force supplying means preferably is a spring (33).

9. A variable-displacement compressor as claimed in claim 8, wherein said second valve body (32) moves towards a predetermined direction against said force to open said second communication path (30) when said pressure difference becomes a predetermined pressure.

10. A variable-displacement compressor as claimed in one of claims 7 to 9, wherein said predetermined pressure difference is determined to a pressure difference less than a pressure difference at which said variable slant angle starts varying.

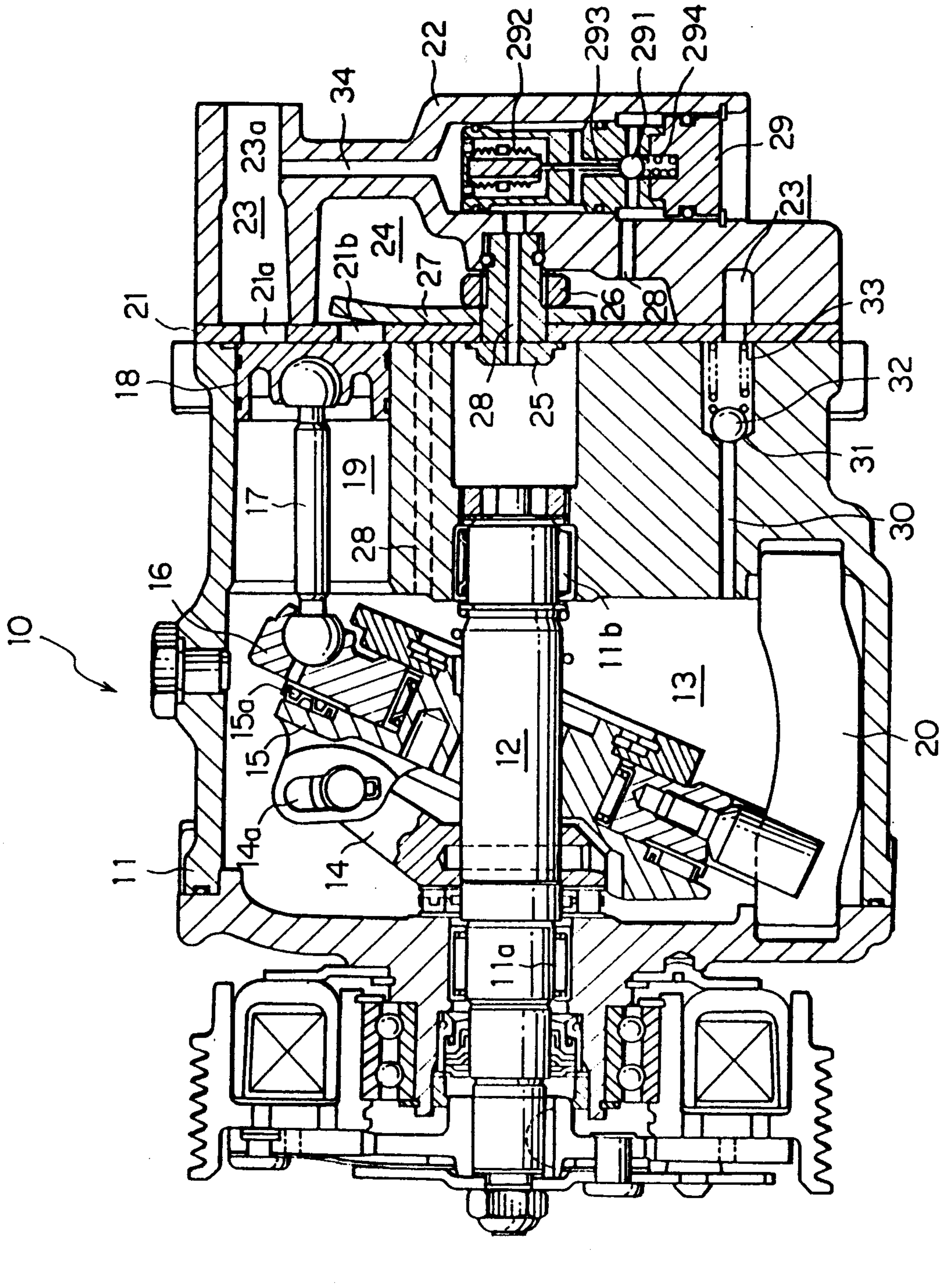
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FIG. 1

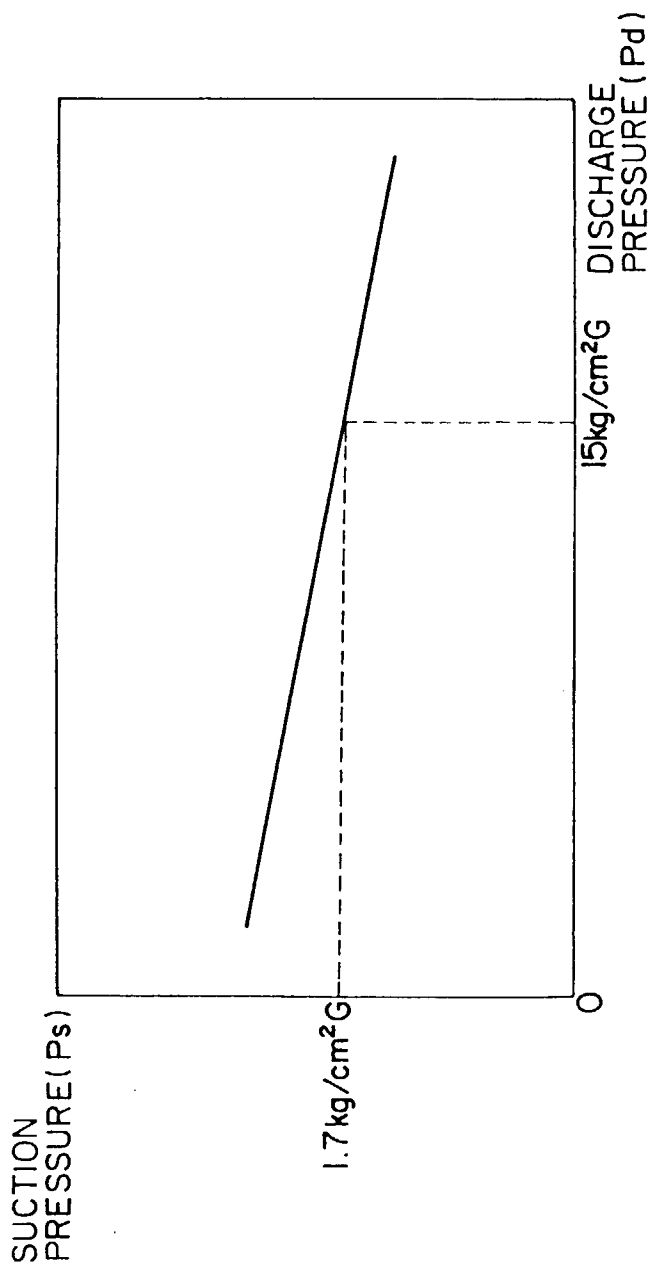
SUCTION PRESSURE (Ps)
1.7kg/cm²G
0
15kg/cm²G
DISCHARGE PRESSURE (Pd)

FIG. 2

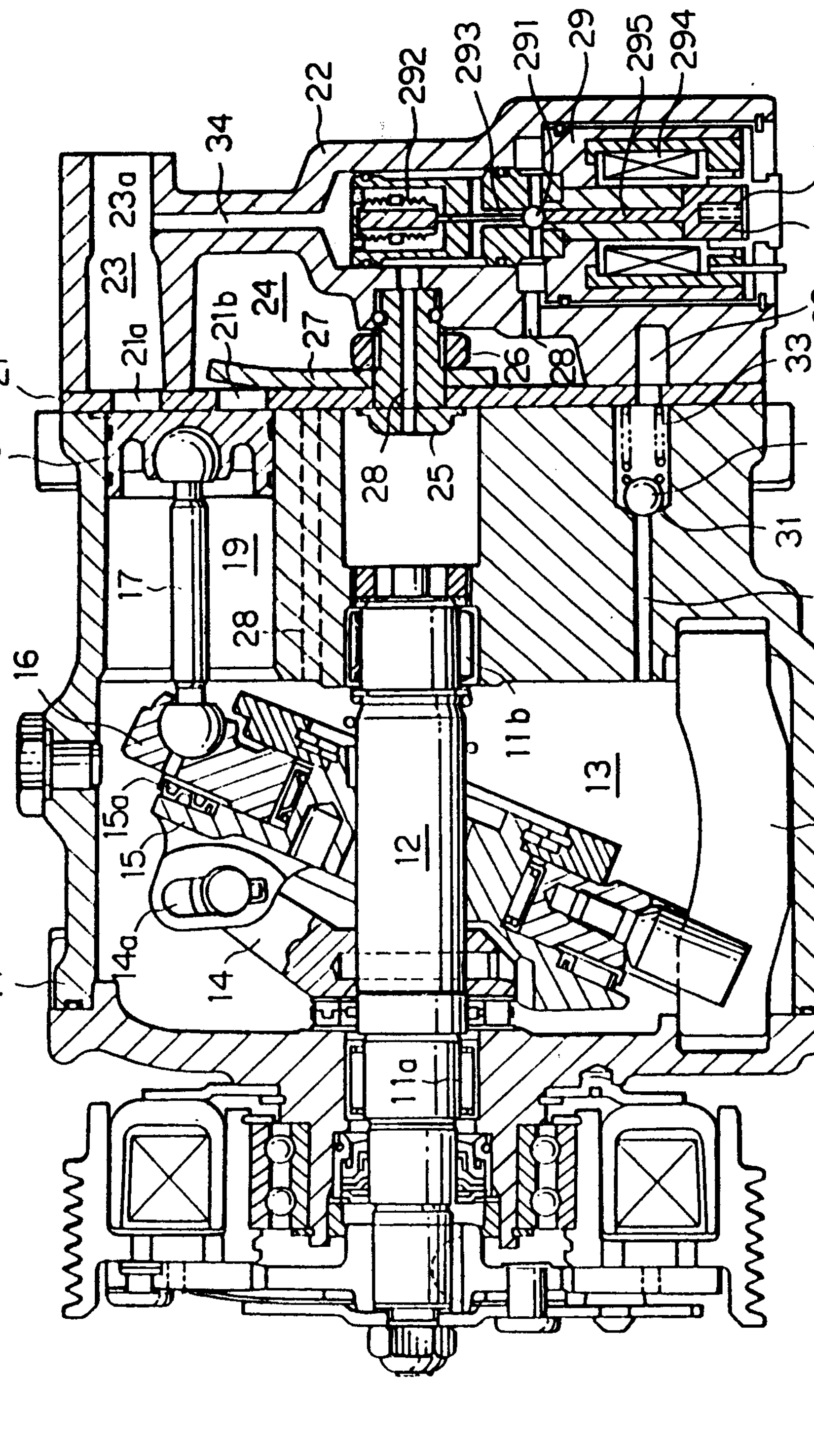
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FIG. 3