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(54) **SCREW COMPRESSOR**

SCHRAUBENVERDICHTER

COMPRESSEUR À VIS

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Description

Technical Field

[0001] The present invention relates to a screw compressor including a variable mechanism whose internal volume ratio is variable.

Background Art

[0002] A hitherto known screw compressor includes a variable-internal-volume-ratio valve (hereinafter referred to as variable Vi valve) as a slide valve that adjusts the timing of starting discharge and by which internal volume ratio of the screw compressor is variable. In such a screw compressor, the position of the variable Vi valve is adjusted with a driving force applied from a driving device depending on the operating pressure ratio. Herein, the internal volume ratio refers to the ratio between the volume of a compression chamber at the completion of suction and the volume of the compression chamber at the completion of discharge.

[0003] In general, if the screw compressor is operated at an appropriate compression ratio, appropriate for the internal volume ratio thereof, no inappropriate compression loss occurs. The compression volume is expressed as (discharge pressure)/(suction pressure). However, if the screw compressor is operated at a compression ratio that is lower than the appropriate compression ratio, gas that has been compressed to such a degree as to open a discharge port is overcompressed to a degree higher than discharge pressure, resulting in excessive compression work. Conversely, if the screw compressor is operated at a compression ratio that is higher than the appropriate compression ratio, the discharge port opens before discharge pressure is reached, resulting in an insufficient compression that causes the backflow of the gas. Such situations both cause power loss that leads to a reduction in efficiency. To suppress such a reduction in efficiency due to power loss, the screw compressor needs to be operated at an optimum internal volume ratio.

[0004] Accordingly, a screw compressor is known whose internal volume ratio is variable by adjusting the position of a variable Vi valve (see Patent Literature 1, for example). According to Patent Literature 1, the position of the variable Vi valve is adjusted between two positions by opening or closing each of two solenoid valves, with no complicated control mechanism for adjusting the position of the variable Vi valve. Specifically, according to Patent Literature 1, a piston is coupled to the variable Vi valve through a rod. Suction pressure or discharge pressure is switchably supplied to each of the forward side and the backward side of the piston by using the two solenoid valves, the sides being defined in the direction of movement of the piston. Since a pressure difference is produced between the forward side and the backward side of the piston, the piston is movable between two different positions. Thus, the position of the variable Vi valve is adjustable between two levels.

[0005] JP H11 13675 A discloses varying an external connection part of a screw compressor, in which the slide valve side of a cylinder chamber to contain a piston coupled to a slide valve is communicated with the high pressure side. During step control, the anti-slide valve side is communicated with the high pressure side and the high pressure side through solenoid valves and a capillary tube and control is performed by a solenoid valve.

Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Patent No. 5881403

Summary of Invention

Technical Problem

[0007] According to Patent Literature 1, to adjust the position of the variable Vi valve between two levels, two solenoid valves are necessary. To realize adjustment among more levels, more number of solenoid valves are necessary.

[0008] The present invention is to overcome the above problem and provides a screw compressor having a simple configuration with a reduced number of solenoid valves while realizing a multi-level adjustment of internal volume ratio.

Solution to Problem

[0009] This problem is solved by a screw compressor according to claim 1. Further improvements of the screw compressor according to the invention are provided in the dependent claims.

[0010] According to an embodiment of the present invention, there is, inter alia, provided a screw compressor including a casing in which a discharge chamber and a suction chamber are provided; a screw rotor in an outer peripheral surface of which a plurality of grooves forming a compression chamber are provided, the screw rotor being rotatable in the casing; a variable Vi valve movable in an axial direction of the screw rotor and whose stopping position is switched in changing an internal volume ratio that is a ratio between a volume of the compression chamber at completion of suction and a volume of the compression chamber at completion of discharge; a driving device including a Vi piston coupled to the variable Vi valve, and a driving cylinder that houses the Vi piston movably in the driving cylinder; and a pressure-switching mechanism that switches pressure to be introduced into the driving device. An inside of the driving cylinder is divided by the Vi piston into two cylinder chambers. The driving device controls a position of the variable Vi valve while moving the Vi piston by changing pressure in one of the two cylinder chambers. The pressure-switching mechanism includes a solenoid valve that switches whether to enable or disable introduction of discharge pressure from the discharge chamber into the one cylinder chamber by opening or closing a first passage through which the discharge chamber and the one cylinder chamber communicate with each other; a switching cylinder communicating with the first passage extending between the solenoid valve and the one cylinder chamber; a switching piston movably housed in the switching cylinder; and a spring that is compressed with a movement of the switching piston. An inside of the switching cylinder is divided by the switching piston into a first switching cylinder chamber into which suction pressure is constantly introduced and in which the spring is provided, and a second switching cylinder chamber that communicates with the first passage. A second passage through which the first switching cylinder chamber and the one cylinder chamber communicate with each other is opened or closed depending on a position of the switching piston that receives a spring force exerted by the spring. The pressure in the one cylinder chamber changes when the first passage is opened or closed with opening or closing of the solenoid valve while the second passage is opened or closed with the movement of the switching piston.

Advantageous Effects of Invention

[0011] According to the embodiment of the present invention, the pressure to be supplied to the Vi piston coupled to the variable Vi valve through the rod is changeable with a single solenoid valve. Therefore, a screw compressor in which the internal volume ratio is adjustable among a plurality of levels with a simple configuration can be obtained.

[0012] In the following, Embodiments 3, 4 and 6 and the corresponding Figs. 7 to 13 and 15 are not part of the present invention, but present relevant background art necessary for understanding the invention.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a schematic diagram of a screw compressor according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a schematic diagram illustrating a driving device and a pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention that operate at a high internal volume ratio.

[Fig. 4] Fig. 4 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention that operate at a low internal volume ratio.

[Fig. 5] Fig. 5 is a schematic diagram illustrating a driving device and a pressure-switching mechanism operate included in a screw compressor according to Embodiment 2 of the present invention that operate at a high internal volume ratio.

[Fig. 6] Fig. 6 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 2 of the present invention that operate at a low internal volume ratio.

[Fig. 7] Fig. 7 is a schematic diagram illustrating a driving device and pressure-switching mechanisms included in a screw compressor according to Embodiment 3.

[Fig. 8] Fig. 8 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a high internal volume ratio.

[Fig. 9] Fig. 9 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a moderate internal volume ratio.

[Fig. 10] Fig. 10 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a low internal volume ratio.

[Fig. 11] Fig. 11 is a schematic diagram illustrating a driving device and pressure-switching mechanisms included in a screw compressor according to Embodiment 4 that operate at a high internal volume ratio.

[Fig. 12] Fig. 12 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 4 that operate at a moderate internal volume ratio.
[Fig. 13] Fig. 13 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 4 that operate at a low internal volume ratio.
[Fig. 14] Fig. 14 is a schematic diagram of a screw compressor according to Embodiment 5 of the present invention.
[Fig. 15] Fig. 15 is a schematic diagram of a screw compressor according to Embodiment 6.

Description of Embodiments

Embodiment 1

[0014] Fig. 1 is a schematic diagram of a screw compressor according to Embodiment 1 of the present invention.

[0015] A screw compressor 1 according to Embodiment 1 is a single-screw compressor and includes a cylindrical casing 2, a cylindrical screw rotor 5 housed in the casing 2, and a motor 3 that drives the screw rotor 5 to rotate. The motor 3 includes a stator 3a provided in contact with and fixed to the inner wall of the casing 2, and a motor rotor 3b provided on the inner side of the stator 3a. The motor 3 may be of an inverter type in which the rotation speed is controlled by an inverter, or a constant-speed type in which the rotation speed is constant.

[0016] The screw rotor 5 and the motor rotor 3b are positioned coaxially with each other and are both fixed to a screw shaft 4. The screw rotor 5 has a plurality of helical screw grooves 5a in the outer peripheral surface thereof. The screw rotor 5 is coupled to the motor rotor 3b fixed to the screw shaft 4, thereby being driven to rotate. Spaces in the screw grooves 5a provided in the screw rotor 5 are enclosed by the inner peripheral surface of the casing 2 and a pair of gate rotors (not illustrated) that are in mesh with the screw grooves 5a, thereby forming a compression chamber 6.

[0017] The inside of the casing 2 is divided by a partition (not illustrated) into a discharge-pressure side and a suction-pressure side. The discharge-pressure side has a discharge chamber 7 and a discharge port 8 provided in the discharge chamber 7. A suction chamber 16 is provided at the suction-pressure side. Discharge pressure is a pressure exerted by refrigerant compressed in the compression chamber 6 and discharged from the compression chamber 6. Suction pressure is a pressure exerted by refrigerant taken into the compression chamber 6. The relationship between discharge pressure and suction pressure is that discharge pressure is greater than suction pressure.

[0018] A pair of variable Vi valves 9 that are movable in the axial direction of the screw shaft 4 are provided between the inner peripheral surface of the casing 2 and the outer peripheral surface of the screw rotor 5. The variable Vi valves 9 form part of the discharge port 8 and is coupled to a driving device 11 through a rod 10. In Fig. 1, only the driving device 11 coupled to one of the variable Vi valves 9 is illustrated, and another driving device 11 coupled to the other variable Vi valve 9 is not illustrated.

[0019] The driving device 11 is driven with gas pressure and includes a cylinder 12 and a Vi piston 13 housed in the cylinder 12. The Vi piston 13 is movable in the axial direction in the cylinder 12. The Vi piston 13 is coupled to the variable Vi valve 9 through the rod 10, thereby being movable in the axial direction in the cylinder 12. The Vi piston 13 corresponds to the Vi piston or the first Vi piston according to the present invention.

[0020] Embodiment 1 includes a pressure-switching mechanism 21 illustrated in Fig. 2 to be referred to below. The pressure-switching mechanism 21 switches the pressure to be introduced into the driving device 11 and has a simpler configuration than a mechanism including two solenoid valves.

[0021] The screw compressor 1 further includes a controller 50 (see Fig. 1) that opens and closes a solenoid valve 27, to be described below, included in the pressure-switching mechanism 21. The controller 50 may be a piece of hardware such as a circuit device that realizes the function thereof, or a combination of an arithmetic device such as a CPU and a piece of software to be executed thereon.

[0022] Referring to Fig. 2, configurations of the driving device 11 and the pressure-switching mechanism 21 will now be described. Hereinafter, an element "passage" may be provided as a hole in the wall of the casing 2 or the cylinder 12, or as a pipe.

[0023] Fig. 2 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention. In Fig. 2, the right side of the variable Vi valve 9 is under suction pressure, and the left side of the variable Vi valve 9 is under discharge pressure.

[0024] First, the variable Vi valve 9 will be described. The variable Vi valve 9 includes a valve body 9a, a guide portion 9b, and a coupling portion 9c. The valve body 9a and the guide portion 9b are coupled to each other through the coupling portion 9c. One end of the rod 10 is coupled to a driving-device-side end 9h of the guide portion 9b. The other end of the rod 10 is coupled to an end face of the Vi piston 13 that is nearer to the variable Vi valve 9. A space between a discharge-port-side end 9d of the valve body 9a and a discharge-port-side end 9e of the guide portion 9b forms a discharge air gap 9f communicating with the discharge port 8.

[0025] The space in the cylinder 12 of the driving device 11 is divided by the Vi piston 13 into a cylinder chamber 14a on a variable-Vi-valve side (the right side in the drawing) and a cylinder chamber 14b on the other side (the left side in the drawing). The cylinder 12 corresponds to the driving cylinder according to the present invention. The cylinder chamber 14a corresponds to the first cylinder chamber according to the present invention. The cylinder chamber 14b corresponds to the second cylinder chamber according to the present invention.

[0026] The cylinder 12 has a pressure-introducing hole 114a at the cylinder chamber 14a, and another pressure-introducing hole 114b and a pressure-releasing hole 114c at the cylinder chamber 14b. The cylinder chamber 14a communicates with the discharge chamber 7, illustrated in Fig. 1, through the pressure-introducing hole 114a and a passage 15a. Furthermore, discharge pressure is constantly introduced from the discharge chamber 7 into the cylinder chamber 14a.

[0027] The cylinder chamber 14b is connected to the pressure-switching mechanism 21 through the pressure-introducing hole 114b and a passage 15b. The pressure-switching mechanism 21 switches to enable or disable the introduction of discharge pressure into the cylinder chamber 14b. The cylinder chamber 14b communicates with the discharge chamber 7 through the pressure-switching mechanism 21 and a passage 30. The pressure-switching mechanism 21 switches to enable or disable the introduction of discharge pressure from the discharge chamber 7 into the cylinder chamber 14b. The passage 30 includes the passage 15b, a passage 28c, and a passage 28d and corresponds to the first passage according to the present invention.

[0028] The cylinder chamber 14b communicates with the suction chamber 16 through the pressure-releasing hole 114c and a passage 15c. The passage 15c is provided at a halfway position thereof with an expansion mechanism 15ca. The expansion mechanism 15ca is provided for preventing the pressure in the cylinder chamber 14b from being released through the pressure-releasing hole 114c toward the suction-chamber side. Specifically, the expansion mechanism 15ca is, for example, a capillary tube or an orifice. The expansion mechanism 15ca corresponds to the second expansion mechanism according to the present invention.

[0029] The pressure-switching mechanism 21 includes the solenoid valve 27, a cylinder 22, a switching piston 23, a rod 24 coupled to the switching piston 23, and a spring 25 that is compressed with the movement of the switching piston 23. The cylinder 22 houses the switching piston 23 such that the switching piston 23 is movable in the axial direction. The spring 25 is provided around the rod 24 and is positioned in a cylinder chamber 26a to be described below. When the spring 25 has a natural length, the switching piston 23 is positioned as illustrated in Fig. 3 to be referred to below. The switching piston 23 and the rod 24 do not necessarily need to be separate components and may be provided as an integrally molded component. The pressure-switching mechanism 21 corresponds to the first mechanism according to the present invention.

[0030] As described above, the pressure-switching mechanism 21 includes a single solenoid valve and has a simpler configuration than a mechanism including two solenoid valves. Specifically, a solenoid valve not only includes a cylinder, a piston, a rod, a spring, and so forth but also requires a solenoid unit that converts electrical energy for opening and closing the solenoid valve with a magnetic force into a mechanical motion. The solenoid unit includes a coil, a yoke, a sleeve, a core, and a plug nut. The core is formed of a movable iron core of a plunger. The plug nut is formed of a fixed iron core. Hence, the mechanism including two solenoid valves tends to be expensive. In contrast, the pressure-switching mechanism 21 includes a single solenoid valve and other elements, namely, the cylinder 22, the switching piston 23, the rod 24, and the spring 25. Therefore, the pressure-switching mechanism 21 can be made less expensive than the mechanism including two solenoid valves.

[0031] Now, the pressure-switching mechanism 21 will be described in detail.

[0032] The solenoid valve 27 opens to form the passage 28d through which the discharge chamber 7 and the cylinder 22 communicate with each other, and closes to block the passage 28d, and is switched to open to enable the introduction of discharge pressure from the discharge chamber 7 into a cylinder chamber 26b, to be described below, of the cylinder 22, or disable the introduction of discharge pressure from the discharge chamber 7 into the cylinder chamber 26b. The cylinder chamber 26b communicates with the cylinder chamber 14b of the driving device 11 through the passage 28c. Therefore, it can also be said that the solenoid valve 27 switches whether to enable or disable the introduction of discharge pressure from the discharge chamber 7 into the cylinder chamber 14b.

[0033] The inside of the cylinder 22 is divided by the switching piston 23 into the cylinder chamber 26a and the cylinder chamber 26b. The cylinder 22 has a pressure-introducing hole 214a at the cylinder chamber 26a, and a pressure-introducing hole 214d and a pressure-releasing hole 214c at the cylinder chamber 26b. Furthermore, the cylinder 22 has a pressure-releasing hole 214b that is opened or closed depending on the position of the switching piston 23. The cylinder 22 corresponds to the switching cylinder according to the present invention. The cylinder chamber 26a corresponds to the first switching cylinder chamber according to the present invention. The cylinder chamber 26b corresponds to the second switching cylinder chamber according to the present invention.

[0034] The cylinder chamber 26a communicates with the suction chamber 16, illustrated in Fig. 1, through the pressure-introducing hole 214a and a passage 28a, and suction pressure is constantly introduced from the suction chamber 16 into the cylinder chamber 26a. The cylinder chamber 26b communicates with the discharge chamber 7, illustrated in Fig. 1, through the pressure-introducing hole 214d, the passage 28d, and the solenoid valve 27. When the solenoid valve 27 is open, discharge pressure is introduced into the cylinder chamber 26b.

[0035] The pressure-releasing hole 214b communicates with the passage 28c through a passage 28b. An expansion mechanism 28ba is provided at the passage 28b. The expansion mechanism 28ba is provided for preventing the introduction of discharge pressure in the cylinder chamber 14b into the cylinder chamber 26a when the state of the solenoid valve 27 is switched from open to close. The expansion mechanism 28ba is a component such as an orifice or a capillary tube. The passage 28b corresponds to the second passage according to the present invention. The expansion mechanism 28ba corresponds to the first expansion mechanism according to the present invention.

[0036] Now, an operation of the variable Vi valve 9 will be described, in association with piston motions of the driving device 11 and the pressure-switching mechanism 21. In Embodiment 1, the value of the internal volume ratio (hereinafter referred to as Vi value) is settable between two levels of high and low. The internal volume ratio refers to the ratio between the volume of the compression chamber at the completion of suction and the volume of the compression chamber at the completion of discharge.

(1) Operation with High Vi Value

[0037] Fig. 3 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention that operate at a high internal volume ratio. In Fig. 3 and other drawings to be referred to below, the solid-black solenoid valve indicates that the solenoid valve is in the "closed" state, and the solid-white solenoid valve indicates that the solenoid valve is in the "open" state. Furthermore, the arrow illustrated in each of Fig. 3 and other drawings to be referred to below indicates the direction of movement of the Vi piston.

[0038] When the Vi value is high, the solenoid valve 27 is closed. Accordingly, the driving device 11 causes the variable Vi valve 9 to move leftward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is slowed.

[0039] First, an operation of the pressure-switching mechanism 21 will be described. When the Vi value is high, the solenoid valve 27 is closed. Accordingly, the pressure in the cylinder chamber 26b is made equal to the pressure in the cylinder chamber 14b of the driving device 11 that communicates with the cylinder chamber 26b through the passage 28c. Specifically, immediately after the state of the solenoid valve 27 is switched from being open to being closed, the cylinder chamber 26b and the cylinder chamber 14b are under discharge pressure. However, since the cylinder chamber 14b communicates with the suction chamber 16 through the expansion mechanism 15ca, the pressure in the cylinder chamber 26b and the cylinder chamber 14b becomes closer to suction pressure with time. Furthermore, suction pressure is constantly introduced into the cylinder chamber 26a. Therefore, as the pressure in the cylinder chamber 26b becomes closer to suction pressure, the switching piston 23 is moved toward the cylinder chamber 26b by the spring 25. Consequently, the pressure-releasing hole 214b is opened.

[0040] When the pressure-releasing hole 214b is opened, the cylinder chamber 26a and the cylinder chamber 14b come to communicate with each other through the passage 28b and the passage 15b. Accordingly, the cylinder chamber 14b of the driving device 11 comes to have suction pressure, as with the cylinder chamber 26a. Thus, when the solenoid valve 27 is closed, the pressure-switching mechanism 21 introduces suction pressure into the cylinder chamber 14b.

[0041] Now, operations of the driving device 11 and the variable Vi valve 9 will be described. The cylinder chamber 14a is coupled to the discharge chamber 7. Therefore, discharge pressure is constantly introduced into the cylinder chamber 14a. Hence, there is a pressure difference in the cylinder 12, and the Vi piston 13 therefore tends to move leftward in the drawing.

[0042] Regarding two ends, defined in the moving direction, of the variable Vi valve 9 coupled to the Vi piston 13, a suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out. Consequently, the variable Vi valve 9 tends to move rightward in the drawing because of the difference between the pressures acting on the driving-device-side end 9h and the suction-side end 9g.

[0043] The area of each of the front and rear surfaces of the Vi piston 13, the front and rear directions being defined in the moving direction is greater than the area of the driving-device-side end 9h at which the variable Vi valve 9 receives discharge pressure. Hence, the Vi piston 13 and the variable Vi valve 9 move leftward in the drawing because of the difference between the pressures received by the front and rear surfaces of the Vi piston 13 that are defined in the moving direction. The variable Vi valve 9 stops at a position where the Vi piston 13 comes into contact with the wall of the cylinder chamber 14b. Therefore, the variable Vi valve 9 is accurately positioned for the high Vi value.

(2) Operation with Low Vi Value

[0044] Fig. 4 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 1 of the present invention that operate at a low internal volume ratio.
[0045] When the Vi value is low, the solenoid valve 27 is open. Accordingly, the driving device 11 causes the variable Vi valve 9 to move rightward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is advanced.
[0046] First, an operation of the pressure-switching mechanism 21 will be described. When the Vi value is low, the solenoid valve 27 is open. Accordingly, the cylinder chamber 26b is under discharge pressure. Furthermore, the cylinder chamber 26a is under suction pressure that is introduced constantly thereinto, whereas the switching piston 23 is under suction pressure and a spring force that act in a direction opposite to the direction of a force applied from the cylinder chamber 26b. Such a relationship among the forces acting on the switching piston 23 causes the switching piston 23 to move toward the cylinder chamber 26a and thus close the pressure-releasing hole 214b.
[0047] Since the pressure-releasing hole 214b is closed, the cylinder chamber 14b of the driving device 11 communicates with the cylinder chamber 26b of the pressure-switching mechanism 21 without communicating with the cylinder chamber 26a, and comes to receive discharge pressure as with the cylinder chamber 26b. Note that the cylinder chamber 14b communicates with the suction chamber 16 through the pressure-releasing hole 114c and the passage 15c. However, since the expansion mechanism 15ca is provided at the passage 15c, the inside of the cylinder chamber 14b is kept under discharge pressure while the solenoid valve 27 is open.
[0048] Thus, when the solenoid valve 27 is open, the pressure-switching mechanism 21 introduces discharge pressure into the cylinder chamber 14b.
[0049] Now, operations of the driving device 11 and the variable Vi valve 9 will be described. The cylinder chamber 14a is coupled to the discharge chamber 7, and discharge pressure is constantly introduced into the cylinder chamber 14a. Hence, there is no pressure difference in the cylinder 12.
[0050] Regarding the variable Vi valve 9 coupled to the Vi piston 13, the suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out.
[0051] Since there is no pressure difference in the cylinder 12, the variable Vi valve 9 moves rightward in the drawing because of the difference between the discharge pressure acting on the driving-device-side end 9h and the suction pressure acting on the suction-side end 9g. The variable Vi valve 9 stops at a position where the suction-side end 9g comes into contact with the wall of the casing 2. Therefore, the variable Vi valve 9 is accurately positioned for the low Vi value.
[0052] As described above, according to Embodiment 1, the position of the variable Vi valve 9 is controlled by changing the pressure in one of the cylinder chamber 14a and the cylinder chamber 14b by opening or closing the single solenoid valve 27. In the above case, the pressure in the cylinder chamber 14b is changed. The change of the pressure in the cylinder chamber 14b is realized as follows. The passage extending from the discharge chamber 7 to the cylinder chamber 14b is allowed to communicate or blocked by opening or closing the solenoid valve 27. Accordingly, the switching piston 23 moves against the spring force exerted by the spring 25 in such a manner as to allow the passage 28b that is under suction pressure to communicate or block the passage 28d. In other words, the pressure in the cylinder chamber 14b can be changed by controlling the movement of the switching piston 23 with a simple mechanism utilizing the difference between the discharge pressure and the suction pressure that act on the switching piston 23 and the spring force exerted by the spring 25. Hence, the pressure in the cylinder chamber 14b can be changed without using two solenoid valves. Consequently, a screw compressor that is inexpensive and has a simple configuration can be obtained.
[0053] Furthermore, compared with the configuration according to Patent Literature 1 in which the internal volume ratio is adjustable between two levels, the number of solenoid valves to be controlled is reduced from two to one. Therefore, the process of controlling the solenoid valve is also simplified.

Embodiment 2

[0054] Embodiment 2 of the present invention is different from Embodiment 1 in that the pressure-switching mechanism 21 is connected to the cylinder chamber 14a instead of the cylinder chamber 14b. More specifically, the pressure-switching mechanism 21 is connected to the pressure-introducing hole 114a, and the pressure-introducing hole 114b is made to communicate with the suction chamber 16.
[0055] Now, an operation of the variable Vi valve 9 according to Embodiment 2 will be described. As with Embodiment 1, the Vi value is settable between two levels of high and low.

(1) Operation with High Vi Value

[0056] Fig. 5 is a schematic diagram illustrating a driving device and a pressure-switching mechanism included in a screw compressor according to Embodiment 2 of the present invention that operate at a high internal volume ratio.

[0057] When the Vi value is high, the driving device 11 causes the variable Vi valve 9 to move leftward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is slowed.

[0058] Specifically, when the Vi value is high, the solenoid valve 27 is open. Accordingly, the inside of the cylinder chamber 14a is under discharge pressure. On the other hand, the cylinder chamber 14b is coupled to the suction chamber 16, and suction pressure is constantly introduced into the cylinder chamber 14b. Hence, there is a pressure difference in the cylinder 12, and the Vi piston 13 therefore tends to move leftward in the drawing.

[0059] Regarding the variable Vi valve 9 coupled to the Vi piston 13, the suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out. Consequently, the variable Vi valve 9 tends to move rightward in the drawing because of the difference between the pressures acting on the driving-device-side end 9h and the suction-side end 9g. However, as described above, since the area of the Vi piston 13 is set greater than the area of the driving-device-side end 9h of the variable Vi valve 9, the Vi piston 13 and the variable Vi valve 9 move leftward in the drawing because of the difference between the pressures applied to the two surfaces of the Vi piston 13. The variable Vi valve 9 stops at a position where the Vi piston 13 comes into contact with the wall of the cylinder chamber 14b. Therefore, the variable Vi valve 9 is accurately positioned for the high Vi value.

(2) Operation with Low Vi Value

[0060] Fig. 6 is a schematic diagram illustrating the driving device and the pressure-switching mechanism included in the screw compressor according to Embodiment 2 of the present invention that operate at a low internal volume ratio.

[0061] When the Vi value is low, the driving device 11 causes the variable Vi valve 9 to move rightward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is advanced.

[0062] Specifically, the solenoid valve 27 is closed. Accordingly, the inside of the cylinder chamber 14a is under suction pressure. On the other hand, the cylinder chamber 14b is coupled to the suction chamber 16, and suction pressure is constantly introduced into the cylinder chamber 14b. Hence, there is no pressure difference in the cylinder 12.

[0063] Regarding the variable Vi valve 9 coupled to the Vi piston 13, the suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out.

[0064] Since there is no pressure difference in the cylinder 12, the variable Vi valve 9 moves rightward in the drawing because of the difference between the discharge pressure acting on the driving-device-side end 9h and the suction pressure acting on the suction-side end 9g. The variable Vi valve 9 stops at a position where the suction-side end 9g comes into contact with the wall of the casing 2. Therefore, the variable Vi valve 9 is accurately positioned for the low Vi value.

[0065] Embodiment 2 is different from Embodiment 1 in that the pressure-switching mechanism 21 is connected to the cylinder chamber 14a instead of the cylinder chamber 14b, and can produces the same advantageous effects as Embodiment 1.

Embodiment 3

[0066] While Embodiment 1 and Embodiment 2 concern a case where the Vi value is variable between two levels of high and low, Embodiment 3 concerns a case where the Vi value is variable among three levels of high, moderate, and low.

[0067] Fig. 7 is a schematic diagram illustrating a driving device and pressure-switching mechanisms included in a screw compressor according to Embodiment 3. Elements that are common to those illustrated in Fig. 2 are denoted by corresponding ones of the reference numerals, and description of such elements is omitted.

[0068] The screw compressor according to Embodiment 3 includes a pressure-switching mechanism 31, in addition to the elements according to Embodiment 1. Furthermore, the cylinder chamber 14b of the driving device 11 is provided with a Vi piston 39, an interlocked piston 40, a coupling portion 41, and a positioning wall 42, in addition to the elements according to Embodiment 1. The cylinder chamber 14b is divided by the Vi piston 39 into two cylinder chambers.

Specifically, the cylinder chamber 14b includes a cylinder chamber 14c provided between the Vi piston 39 and the Vi piston 13, and a cylinder chamber 14d provided opposite to the cylinder chamber 14c. The Vi piston 39 corresponds to the second Vi piston according to the present invention.

[0069] In Embodiment 1, the pressure-switching mechanism 21 switches the pressure to be introduced into the cylinder chamber 14b. In Embodiment 3, the pressure to be introduced into the cylinder chamber 14c included in the cylinder chamber 14b is switched. The cylinder chamber 14a corresponds to the first cylinder chamber according to the present invention. The cylinder chamber 14c corresponds to the second cylinder chamber according to the present invention. The cylinder chamber 14d corresponds to the third cylinder chamber according to the present invention.

[0070] The Vi piston 39 is coupled to the interlocked piston 40 through the coupling portion 41. The positioning wall 42 extending in a direction orthogonal to the direction of movement of the Vi piston 39 is provided between the Vi piston 39 and the interlocked piston 40. The positioning wall 42 has a hole 42a. The coupling portion 41 movably extends through the hole 42a. Therefore, the Vi piston 39 is movable together with the interlocked piston 40 in the cylinder chamber 14b.

[0071] The Vi piston 39 is positioned when the Vi piston 39 is stopped by coming into contact with the positioning wall 42 or when the Vi piston 39 moving away from the positioning wall 42 is stopped because the interlocked piston 40 comes into contact with the positioning wall 42. The Vi piston 13 and the Vi piston 39 are movable independently of each other in the cylinder 12.

[0072] The cylinder 12 has a pressure-introducing hole 114e and a pressure-releasing hole 114f on the side of the cylinder chamber 14d. The cylinder chamber 14d is connected to the pressure-switching mechanism 31 through the pressure-introducing hole 114e and a passage 15d. The pressure-switching mechanism 31 switches whether to enable or disable the introduction of discharge pressure. The cylinder chamber 14d communicates with the suction chamber 16 through the pressure-releasing hole 114f, a passage 15f, an expansion mechanism 15fa, and the passage 15c. The cylinder chamber 14c communicates with the suction chamber 16 through the pressure-releasing hole 114c, a passage 15e, an expansion mechanism 15ea, and the passage 15c.

[0073] The pressure-switching mechanism 31 has the same configuration as the pressure-switching mechanism 21. If the first figure "2" in each of the reference numerals given to the respective elements of the pressure-switching mechanism 21 is changed to "3", a reference numeral denoting a corresponding one of the elements of the pressure-switching mechanism 31 is obtained. The pressure-switching mechanism 31 switches whether to enable or disable the introduction of discharge pressure into the cylinder chamber 14d.

[0074] Table 1 below summarizes the open/closed states of the solenoid valve 27 and a solenoid valve 37 for Vi values at individual levels of high, moderate, and low in Embodiment 3. The table is to be referred to in the following description of relevant operations.

[Table 1]

	Solenoid valve 27	Solenoid valve 37
High Vi value	Closed	Closed
Moderate Vii value	Closed	Open
Low Vi value	Open	Closed

(1) Operation with High Vi Value

[0075] Fig. 8 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a high internal volume ratio.

[0076] When the Vi value is high, as summarized in Table 1, the solenoid valve 27 is closed, and the solenoid valve 37 is closed. Since the solenoid valve 27 is closed, suction pressure is introduced from the pressure-switching mechanism 21 into the cylinder chamber 14c. Furthermore, since the solenoid valve 37 is closed, suction pressure is introduced into the cylinder chamber 14d. That is, the cylinder chamber 14c and the cylinder chamber 14d are both under suction pressure. That is, the cylinder chamber 14b is under suction pressure. Furthermore, discharge pressure is constantly introduced into the cylinder chamber 14a.

[0077] As described above, with respect to the Vi piston 13 as a partition, discharge pressure is introduced into the cylinder chamber 14a, whereas suction pressure is introduced into the cylinder chamber 14b. Therefore, the operation with a high Vi value according to Embodiment 1 also applies here. Specifically, the variable Vi valve 9 moves leftward as indicated by the arrow illustrated in the drawing. That is, the driving device 11 causes the variable Vi valve 9 to move leftward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is slowed.

(2) Operation with Moderate Vi Value

[0078] Fig. 9 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a moderate internal volume ratio.
[0079] When the Vi value is moderate, the solenoid valve 27 is closed, whereas the solenoid valve 37 is open. Since the solenoid valve 27 is closed, suction pressure is introduced into the cylinder chamber 14c. Furthermore, since the solenoid valve 37 is open, discharge pressure is introduced into the cylinder chamber 14d. Furthermore, discharge pressure is constantly introduced into the cylinder chamber 14a. Consequently, the cylinder chamber 14a and the cylinder chamber 14d are under discharge pressures of the same level, whereas the cylinder chamber 14c is under suction pressure.
[0080] Note that the cylinder chamber 14d is under suction pressure both in the case of a high Vi value and in a case of a low Vi value to be described below. Therefore, when the Vi value is switched from the high or low level to the moderate level, the pressure in the cylinder chamber 14d changes from suction pressure to discharge pressure because the state of the solenoid valve 37 is switched from closed to open.
[0081] More specifically, when the Vi value is switched from the high level to the moderate level, the pressure in the cylinder chamber 14d in which the Vi piston 39 is positioned as illustrated in Fig. 8 is raised from suction pressure to discharge pressure. Accordingly, the Vi piston 39 moves rightward together with the interlocked piston 40. With the rightward movement of the Vi piston 39, the variable Vi valve 9 is pushed by the interlocked piston 40 to move rightward. Then, when the Vi piston 39 stops moving by coming into contact with the positioning wall 42, the Vi piston 13 and the variable Vi valve 9 stop moving correspondingly and are positioned as illustrated in Fig. 9.
[0082] When the Vi value is switched from the low level to the moderate level, the pressure in the cylinder chamber 14d in which the Vi piston 39 is positioned as illustrated in Fig. 10 to be referred to below is raised from suction pressure to discharge pressure. Meanwhile, since the solenoid valve 27 is closed, the cylinder chamber 14c comes to receive suction pressure. Such a pressure difference between the cylinder chamber 14d and the cylinder chamber 14c causes the Vi piston 39 to move rightward and stop moving by coming into contact with the positioning wall 42.
[0083] When the Vi value is low as to be described below, the cylinder chamber 14a and the cylinder chamber 14c are under discharge pressure. When the Vi value is switched to a moderate level and the solenoid valve 27 is therefore closed, the pressure in the cylinder chamber 14c changes from discharge pressure to suction pressure. Such a pressure difference between the cylinder chamber 14a and the cylinder chamber 14c causes the Vi piston 13 to move leftward from the position illustrated in Fig. 10 and stop moving by coming into contact with the interlocked piston 40. Thus, the Vi piston 13 is positioned as illustrated in Fig. 9.
[0084] As described above, when the Vi value is moderate, the Vi piston 13 is stopped by coming into contact with the interlocked piston 40, with the Vi piston 39 being in contact with the positioning wall 42. In this state, the variable Vi valve 9 is positioned more rightward than in the case of a high Vi value illustrated in Fig. 8. Consequently, the timing of opening the discharge port 8 is advanced from the timing in the case of a high Vi value.

(3) Operation with Low Vi Value

[0085] Fig. 10 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 3 that operate at a low internal volume ratio.
[0086] When the Vi value is low, the solenoid valve 27 is open. Therefore, discharge pressure is introduced from the pressure-switching mechanism 21 into the cylinder chamber 14c. Whereas, the solenoid valve 37 is closed. Therefore, suction pressure is introduced into the cylinder chamber 14d. Furthermore, discharge pressure is constantly introduced into the cylinder chamber 14a. Consequently, the cylinder chamber 14a and the cylinder chamber 14c are under discharge pressure, whereas the cylinder chamber 14d is under suction pressure. Hence, there is no pressure difference between the front and rear surfaces of the Vi piston 13 that are defined in the moving direction in the cylinder 12.
[0087] Regarding two ends, defined in the moving direction, of the variable Vi valve 9 coupled to the Vi piston 13, the suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure, as with the case of Embodiment 1. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out. Consequently, the variable Vi valve 9 moves rightward in the drawing because of the difference between the pressures acting on the driving-device-side end 9h and the suction-side end 9g. The variable Vi valve 9 stops at a position where the suction-side end 9g thereof comes into contact with the wall of the casing 2. Therefore, the variable Vi valve 9 is accurately positioned for the low Vi value. Thus, the timing of opening the discharge port 8 is advanced from the timing in the case of a moderate Vi value.
[0088] According to Embodiment 3, the Vi value is controllable among three levels with two pressure-switching mech-

anisms each including a single solenoid valve. Consequently, a screw compressor that is inexpensive and has a simple configuration can be obtained.

Embodiment 4

[0089] Embodiment 4 is different from Embodiment 3 in that the pressure-switching mechanism 21 is connected to the cylinder chamber 14a instead of the cylinder chamber 14c. More specifically, the pressure-switching mechanism 21 is connected to the pressure-introducing hole 114a, and the pressure-introducing hole 114b is made to communicate with the suction chamber 16.

[0090] Now, an operation of the variable Vi valve 9 according to Embodiment 4 will be described. As with the case of Embodiment 3, the Vi value is settable among three levels of high, moderate, and low.

[0091] Table 2 below summarizes the open/closed states of the solenoid valve 27 and the solenoid valve 37 for the Vi values at individual levels of high, moderate, and low in Embodiment 4. The table is to be referred to in the following description of relevant operations.

[Table 2]

	Solenoid valve 27	Solenoid valve 37
High Vi value	Open	Closed
Moderate Vii value	Open	Open
Low Vi value	Closed	Closed

(1) Operation with High Vi Value

[0092] Fig. 11 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 4 that operate at a high internal volume ratio.

[0093] When the Vi value is high, the solenoid valve 27 is open, whereas the solenoid valve 37 is closed. Since the solenoid valve 27 is open, discharge pressure is introduced from the pressure-switching mechanism 21 into the cylinder chamber 14a. Furthermore, since the solenoid valve 37 is closed, suction pressure is introduced into the cylinder chamber 14d. Furthermore, suction pressure is constantly introduced into the cylinder chamber 14c.

[0094] As described above, with respect to the Vi piston 13 as a partition, discharge pressure is introduced into the cylinder chamber 14a, whereas suction pressure is introduced into the cylinder chamber 14b. Therefore, the operation with a high Vi value according to Embodiment 1 also applies here. Specifically, the variable Vi valve 9 moves leftward as indicated by the arrow illustrated in the drawing. That is, the driving device 11 causes the variable Vi valve 9 to move leftward as indicated by the arrow illustrated in the drawing. Thus, the timing of opening the discharge port 8 is slowed.

(2) Operation with Moderate Vi Value

[0095] Fig. 12 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 4 that operate at a moderate internal volume ratio.

[0096] When the Vi value is moderate, the solenoid valve 27 is open, and the solenoid valve 37 is open. Since the solenoid valve 27 is open, discharge pressure is introduced into the cylinder chamber 14a. Furthermore, since the solenoid valve 37 is open, discharge pressure is introduced into the cylinder chamber 14d. Furthermore, suction pressure is constantly introduced into the cylinder chamber 14c.
Consequently, the cylinder chamber 14a and the cylinder chamber 14d are under discharge pressures of the same level, whereas the cylinder chamber 14c is under suction pressure.

[0097] When the Vi value is switched from the high level to the moderate level, the pressure in the cylinder chamber 14d in which the Vi piston 39 is positioned illustrated in Fig. 11 is raised from suction pressure to discharge pressure. Accordingly, the Vi piston 39 moves rightward together with the interlocked piston 40. With the rightward movement of the Vi piston 39, the variable Vi valve 9 is pushed by the interlocked piston 40 to move rightward. Then, when the Vi piston 39 stops moving by coming into contact with the positioning wall 42, the Vi piston 13 and the variable Vi valve 9 stop moving correspondingly and are positioned as illustrated in Fig. 12.

[0098] When the Vi value is switched from the low level to the moderate level, the pressure in the cylinder chamber 14d in which the Vi piston 39 is positioned as illustrated in Fig. 13 to be referred to below is raised from suction pressure to discharge pressure. Meanwhile, the cylinder chamber 14c is constantly under suction pressure. Such a pressure difference between the cylinder chamber 14d and the cylinder chamber 14c causes the Vi piston 39 to move rightward and stop moving by coming into contact with the positioning wall 42. In addition, when the Vi value is low as to be described below, the cylinder chamber 14a and the cylinder chamber 14c are both under suction pressure. However, when the Vi value is switched to the moderate level, the solenoid valve 27 is opened. Consequently, the pressure in the cylinder chamber 14a changes from suction pressure to discharge pressure. Such a pressure difference between the cylinder chamber 14a and the cylinder chamber 14c causes the Vi piston 13 to move leftward from the position illustrated in Fig. 13 and stop moving by coming into contact with the interlocked piston 40. Thus, the Vi piston 13 is positioned as illustrated in Fig. 12.

[0099] As described above, when the Vi value is moderate, the Vi piston 13 stops by coming into contact with the interlocked piston 40, with the Vi piston 39 being in contact with the positioning wall 42. In this state, the variable Vi valve 9 is positioned more rightward than in the case of a high Vi value illustrated in Fig. 11. Consequently, the timing of opening the discharge port 8 is advanced from the timing in the case of a high Vi value.

(3) Operation with Low Vi Value

[0100] Fig. 13 is a schematic diagram illustrating the driving device and the pressure-switching mechanisms included in the screw compressor according to Embodiment 4 that operate at a low internal volume ratio.

[0101] When the Vi value is low, the solenoid valve 27 is closed. Therefore, suction pressure is introduced from the pressure-switching mechanism 21 into the cylinder chamber 14a. Furthermore, the solenoid valve 37 is closed. Therefore, suction pressure is introduced into the cylinder chamber 14d. Furthermore, suction pressure is constantly introduced into the cylinder chamber 14c. That is, the cylinder chamber 14a, the cylinder chamber 14c, and the cylinder chamber 14d are under suction pressure. Hence, there is no pressure difference between the front and rear surfaces of the Vi piston 13 that are defined in the moving direction in the cylinder 12.

[0102] Regarding two ends, defined in the moving direction, of the variable Vi valve 9 coupled to the Vi piston 13, the suction-side end 9g of the valve body 9a is under suction pressure, and the driving-device-side end 9h of the guide portion 9b is under discharge pressure, as with the case of Embodiment 1. Furthermore, the discharge-port-side end 9d of the valve body 9a is under discharge pressure obtained immediately after the discharge, and the discharge-port-side end 9e of the guide portion 9b is under discharge pressure that is equal to but acts in the opposite direction to the pressure acting on the discharge-port-side end 9d. Hence, loads applied to the discharge-port-side end 9d and the discharge-port-side end 9e cancel each other out. Consequently, the variable Vi valve 9 moves rightward in the drawing because of the difference between the pressures acting on the driving-device-side end 9h and the suction-side end 9g. The variable Vi valve 9 stops at a position where the suction-side end 9g thereof comes into contact with the wall of the casing 2. Therefore, the variable Vi valve 9 is accurately positioned for the low Vi value. Thus, the timing of opening the discharge port 8 is advanced from the timing in the case of a moderate Vi value.

[0103] Embodiment 4 is different from Embodiment 3 in that the pressure-switching mechanism 21 is connected to the cylinder chamber 14a instead of the cylinder chamber 14c, and can produce the same advantageous effects as Embodiment 3.

Embodiment 5

[0104] Embodiment 5 of the present invention concerns a pressure-switching mechanism having a simpler configuration.

[0105] Fig. 14 is a schematic diagram of a screw compressor according to Embodiment 5 of the present invention.

[0106] A screw compressor 1 according to Embodiment 5 includes a pressure-switching mechanism 21A instead of the pressure-switching mechanism 21 employed in Embodiment 1. The pressure-switching mechanism 21A includes a solenoid valve 27 that switches whether to enable or disable the introduction of discharge pressure from the discharge chamber 7 into the cylinder chamber 14b by opening or closing the passage 30 through which the discharge chamber 7 and the cylinder chamber 14b communicate with each other. In other words, the pressure-switching mechanism 21A is obtained by removing the switching piston 23, the rod 24, and the spring 25 from the pressure-switching mechanism 21 according to Embodiment 1. The pressure-switching mechanism 21A corresponds to the second mechanism according to the present invention.

[0107] When the Vi value is high, the solenoid valve 27 is closed. Accordingly, discharge pressure is not introduced into the cylinder chamber 14b. Moreover, the pressure in the cylinder chamber 14b is released from the pressure-releasing hole 114c and is eventually reduced to suction pressure. Thus, the same pressure state as illustrated in Fig. 3 is established in the cylinder 12, and the same operation as illustrated in Fig. 3 is realized.

[0108] When the Vi value is low, the solenoid valve 27 is open. Accordingly, discharge pressure is introduced into the cylinder chamber 14b. Thus, the same pressure state as illustrated in Fig. 4 is established, and the same operation as illustrated in Fig. 4 is realized.

[0109] According to Embodiment 5 described above, a much simpler configuration is realized by removing the switching piston 23, the rod 24, and the spring 25 from the mechanism according to Embodiment 1. Consequently, a screw compressor that is inexpensive and has a simple configuration can be obtained.

Embodiment 6

[0110] Embodiment 6 is obtained by simplifying Embodiment 2 and is also regarded as a combination of Embodiment 2 and Embodiment 5.

[0111] Fig. 15 is a schematic diagram of a screw compressor according to Embodiment 6.

[0112] Embodiment 6 is obtained by applying the pressure-switching mechanism 21 according to Embodiment 2 illustrated in Fig. 7 to the pressure-switching mechanism 21A according to Embodiment 5 illustrated in Fig. 14.

[0113] Such a configuration is much simpler than the configuration according to Embodiment 2. Consequently, a screw compressor that is inexpensive and has a simple configuration can be obtained.

[0114] The mechanism of opening and closing each of the solenoid valves 27 and 37 is the same as in Embodiment 2.

[0115] While Embodiment 6 concerns a configuration in which the pressure-switching mechanism 21 is simplified, a configuration in which the pressure-switching mechanism 31 is simplified or a configuration in which both the pressure-switching mechanism 21 and the pressure-switching mechanism 31 are simplified is also acceptable.

[0116] While Embodiments 1 to 6 each concern a case where one variable Vi valve 9 is provided for one driving device 11, two variable Vi valves 9 may alternatively be provided. That is, the number of variable Vi valves 9 is not limited. Moreover, the pressures to be introduced into the cylinder chambers 14a, 14b, 26a, and 26b are not limited to discharge pressure and suction pressure. For example, intermediate pressure may also be introduced. Intermediate pressure is a pressure that is lower than the discharge pressure but higher than the suction pressure.

[0117] Furthermore, the refrigerant to be used in the screw compressor 1 is not limited to a particular refrigerant and may be, for example, selected from any of those having low GWPs, standing for global warming potentials, with consideration for factors affecting the environment. Examples of the refrigerant having a low GWP include R32, HFO-1123, HFO-1234yf, or a mixed refrigerant containing at least one of the foregoing refrigerants. The refrigerant to be used in the screw compressor 1 may alternatively be a natural refrigerant such as carbon dioxide.

Reference Signs List

[0118] 1 screw compressor 2 casing 3 motor 3a stator 3b motor rotor 4 screw shaft 5 screw rotor 5a screw groove 6 compression chamber 7 discharge chamber 8 discharge port 9 variable Vi valve 9a valve body 9b guide portion 9c coupling portion 9d discharge-port-side end 9e discharge-port-side end 9f discharge air gap 9g suction-side end 9h driving-device-side end 10 rod 11 driving device 12 cylinder 13 Vi piston 14a cylinder chamber 14b cylinder chamber 14c cylinder chamber 14d cylinder chamber 15a passage 15b passage 15c passage 15ca expansion mechanism 15d passage 15f passage 15fa expansion mechanism 15e passage 15ea expansion mechanism 16 suction chamber 21 pressure-switching mechanism 21A pressure-switching mechanism 22 cylinder 23 switching piston 24 rod 25 spring 26a cylinder chamber 26b cylinder chamber 27 solenoid valve 28a passage 28b passage 28ba expansion mechanism 28c passage 28d passage 30 passage 31 pressure-switching mechanism 37 solenoid valve 39 Vi piston 40 interlocked piston 41 coupling portion 42 positioning wall 42a hole 50 controller 114a pressure-introducing hole 114b pressure-introducing hole 114c pressure-releasing hole 114e pressure-introducing hole 114f pressure-releasing hole 214a pressure-introducing hole 214b pressure-releasing hole 214c pressure-releasing hole 214d pressure-introducing hole

Claims

1. A screw compressor (1) comprising:

a casing (2) in which a discharge chamber (7) and a suction chamber (16) are provided;
a screw rotor (5), on an outer peripheral surface of which a plurality of grooves forming a compression chamber (6) are provided, the screw rotor (5) being rotatable in the casing (2);
a variable Vi valve (9) movable in an axial direction of the screw rotor (5) and whose stopping position is shifted to change an internal volume ratio that is a ratio between a volume of the compression chamber (6) at completion of suction and a volume of the compression chamber (6) at completion of discharge;
a driving device (11) including a Vi piston (13) coupled to the variable Vi valve (9), and a driving cylinder (12) that houses the Vi piston (13) movably in the driving cylinder (12) and inside of which is divided by the Vi piston (13) into two cylinder chambers;
a pressure-switching mechanism (21) that switches pressure to be introduced into the driving device (11), wherein the pressure-switching mechanism (21) includes a solenoid valve (27) configured to open to form a

first passage (30) through which the discharge chamber (7) and a pressure-introducing hole (114b) provided at the one cylinder chamber communicate with each other, and close to block the first passage (30), the solenoid valve (27) being switched to open to enable introduction of discharge pressure from the discharge chamber (7) into the one cylinder chamber or close to disable introduction of discharge pressure from the discharge chamber (7) into the one cylinder chamber, and wherein the pressure in the one cylinder chamber changes with opening or closing of the solenoid valve (27);
characterized by
an expansion mechanism (15ca) provided at a passage communicating between a pressure-releasing hole (114c) and the suction chamber (16), the pressure-releasing hole (114c) being provided at one of the two cylinder chambers;
wherein the driving device (11) moves the Vi piston (13) by changing pressure in the one cylinder chamber to control a position of the variable Vi valve (9).

2. The screw compressor (1) of claim 1,

wherein the two cylinder chambers are a first cylinder chamber (14a) and a second cylinder chamber (14b) in order of arrangement from a side nearer to the variable Vi valve (9),
wherein discharge pressure is constantly introduced into the first cylinder chamber (14a), and
wherein the second cylinder chamber (14b) corresponds to the one cylinder chamber and communicates with the suction chamber (16) through the expansion mechanism (15ca), and the pressure in the second cylinder chamber (14b) is switched between discharge pressure and suction pressure depending on whether the solenoid valve (27) is opened or closed.

3. The screw compressor (1) of claim 1,

wherein the two cylinder chambers are a first cylinder chamber (14a) and a second cylinder chamber (14b) in order of arrangement from a side nearer to the variable Vi valve (9),
wherein the first cylinder chamber (14a) corresponds to the one cylinder chamber and communicates with the suction chamber (16) through the expansion mechanism (15ca), and the pressure in the first cylinder chamber (14a) is switched between discharge pressure and suction pressure depending on whether the solenoid valve (27) is opened or closed, and
wherein suction pressure is constantly introduced into the second cylinder chamber (14b).

4. The screw compressor (1) according to any of claims 1 to 3,

wherein the pressure-switching mechanism (21) further includes a switching cylinder (22) communicating with the first passage (30) extending between the solenoid valve (27) and the one cylinder chamber; a switching piston (23) movably housed in the switching cylinder (22); and a spring (25) that is compressed with a movement of the switching piston (23),
wherein an inside of the switching cylinder (22) is divided by the switching piston (23) into a first switching cylinder chamber (26a) into which suction pressure is constantly introduced and in which the spring (25) is provided, and a second switching cylinder chamber (26b) that communicates with the first passage (30),
wherein a second passage (28b) through which the first switching cylinder chamber (26a) and the one cylinder chamber communicate with each other is opened or closed depending on a position of the switching piston (23) that receives a spring (25) force exerted by the spring (25), and
wherein the pressure in the one cylinder chamber changes when the first passage (30) is opened or closed with opening or closing of the solenoid valve (27) while the second passage (28b) is opened or closed with the movement of the switching piston (23).

5. The screw compressor (1) of claim 4, wherein the second passage (28b) is provided with a first expansion mechanism (28ba).

Patentansprüche

1. Schraubenverdichter (1), umfassend:

ein Gehäuse (2), in dem eine Auslasskammer (7) und eine Ansaugkammer (16) vorgesehen sind;

einen Schraubenrotor (5), auf dessen äußerer Umfangsfläche eine Vielzahl von Nuten vorgesehen sind, die eine Verdichtungskammer (6) bilden, wobei der Schraubenrotor (5) in dem Gehäuse (2) drehbar ist;
ein variables Vi-Ventil (9), das in einer axialen Richtung des Schraubenrotors (5) beweglich ist und dessen Stopp-Position verschoben wird, um ein internes Volumenverhältnis zu ändern, das ein Verhältnis zwischen einem Volumen der Verdichtungskammer (6) bei Beendigung des Ansaugens und einem Volumen der Verdichtungskammer (6) bei Beendigung des Auslassens ist;
eine Antriebseinrichtung (11) mit einem mit dem variablen Vi-Ventil (9) gekoppelten Vi-Kolben (13) und einem Antriebszylinder (12), der den Vi-Kolben (13) beweglich in dem Antriebszylinder (12) aufnimmt und in dessen Inneren durch den Vi-Kolben (13) in zwei Zylinderkammern unterteilt ist;
einen Druckschaltmechanismus (21), der den in die Antriebseinrichtung (11) einzuleitenden Druck schaltet,
wobei der Druckschaltmechanismus (21) ein Magnetventil (27) aufweist, das eingerichtet ist, sich zu öffnen, um einen ersten Durchgang (30) zu bilden, durch den die Auslasskammer (7) und ein an einer Zylinderkammer vorgesehenes Druckeinleitungsloch (114b) miteinander in Verbindung stehen, und sich zu schließen, um den ersten Durchgang (30) zu blockieren, wobei das Magnetventil (27) so umgeschaltet wird, dass es sich öffnet, um die Einleitung von Auslassdruck aus der Auslasskammer (7) in die eine Zylinderkammer zu ermöglichen, oder sich zu schließen, um die Einleitung von Auslassdruck aus der Auslasskammer (7) in die eine Zylinderkammer zu verhindern, und wobei sich der Druck in der einen Zylinderkammer mit dem Öffnen oder Schließen des Magnetventils (27) ändert;
gekennzeichnet durch
einen Expansionsmechanismus (15ca), der an einem Durchgang vorgesehen ist, der ein Druckentlastungsloch (114c) mit der Saugkammer (16) verbindet, wobei das Druckentlastungsloch (114c) an einer der zwei Zylinderkammern vorgesehen ist;
wobei die Antriebseinrichtung (11) den Vi-Kolben (13) durch Änderung des Drucks in der einen Zylinderkammer bewegt, um eine Position des variablen Vi-Ventils (9) zu steuern.

2. Schraubenverdichter (1) nach Anspruch 1,

wobei es sich bei den zwei Zylinderkammern um eine erste Zylinderkammer (14a) und eine zweite Zylinderkammer (14b) handelt, in der Reihenfolge der Anordnung von einer dem variablen Vi-Ventil (9) näheren Seite aus,
wobei in die erste Zylinderkammer (14a) ständig Auslassdruck eingeleitet wird, und
wobei die zweite Zylinderkammer (14b) der einen Zylinderkammer entspricht und über den Expansionsmechanismus (15ca) mit der Saugkammer (16) in Verbindung steht und der Druck in der zweiten Zylinderkammer (14b) zwischen Auslassdruck und Saugdruck umgeschaltet wird, je nachdem, ob das Magnetventil (27) geöffnet oder geschlossen ist.

3. Schraubenverdichter (1) nach Anspruch 1,

wobei es sich bei den zwei Zylinderkammern um eine erste Zylinderkammer (14a) und eine zweite Zylinderkammer (14b) handelt, in der Reihenfolge der Anordnung von einer dem variablen Vi-Ventil (9) näheren Seite aus,
wobei die erste Zylinderkammer (14a) der einen Zylinderkammer entspricht und über den Expansionsmechanismus (15ca) mit der Saugkammer (16) in Verbindung steht und der Druck in der ersten Zylinderkammer (14a) zwischen Auslassdruck und Saugdruck umgeschaltet wird, je nachdem, ob das Magnetventil (27) geöffnet oder geschlossen ist, und
wobei in die zweite Zylinderkammer (14b) ständig Saugdruck eingeleitet wird.

4. Schraubenverdichter (1) nach einem der Ansprüche 1 bis 3,

wobei der Druckschaltmechanismus (21) ferner einen Schaltzylinder (22) aufweist, der mit dem ersten Durchgang (30) in Verbindung steht, der sich zwischen dem Magnetventil (27) und der einen Zylinderkammer erstreckt; einen Schaltkolben (23), der beweglich in dem Schaltzylinder (22) untergebracht ist; und eine Feder (25), die bei einer Bewegung des Schaltkolbens (23) zusammengedrückt wird,
wobei ein Innenraum des Schaltzylinders (22) durch den Schaltkolben (23) in eine erste Schaltzylinderkammer (26a), in die ständig Saugdruck eingeleitet wird und in der die Feder (25) vorgesehen ist, und eine zweite Schaltzylinderkammer (26b), die mit dem ersten Durchgang (30) in Verbindung steht, unterteilt ist,
wobei ein zweiter Durchgang (28b), über den die erste Schaltzylinderkammer (26a) und die eine Zylinderkammer miteinander in Verbindung stehen, in Abhängigkeit von einer Position des Schaltkolbens (23) geöffnet oder geschlossen wird, der eine von der Feder (25) ausgeübte Kraft der Feder (25) empfängt, und
wobei sich der Druck in der einen Zylinderkammer ändert, wenn der erste Durchgang (30) mit dem Öffnen oder

Schließen des Magnetventils (27) geöffnet oder geschlossen wird, während der zweite Durchgang (28b) mit der Bewegung des Schaltkolbens (23) geöffnet oder geschlossen wird.

5. Schraubenverdichter (1) nach Anspruch 4, wobei der zweite Durchgang (28b) mit einem ersten Expansionsmechanismus (28ba) vorgesehen ist.

Revendications

1. Compresseur à vis (1), comprenant :

un boîtier (2) dans lequel sont prévues une chambre de refoulement (7) et une chambre d'aspiration (16) ;
un rotor à vis (5), sur une surface périphérique extérieure duquel sont prévues plusieurs rainures formant une chambre de compression (6), le rotor à vis (5) étant rotatif dans le boîtier (2) ;
une soupape Vi variable (9) mobile dans une direction axiale du rotor à vis (5) et dont la position d'arrêt est déplacée pour modifier un rapport de volume interne qui est un rapport entre un volume de la chambre de compression (6) à la fin de l'aspiration et un volume de la chambre de compression (6) à la fin du refoulement ;
un dispositif d'entraînement (11) comportant un piston Vi (13) couplé à la soupape Vi variable (9), et un cylindre d'entraînement (12) qui loge le piston Vi (13) de manière mobile dans le cylindre d'entraînement (12) et dont l'intérieur est divisé en deux chambres de cylindre par le piston Vi (13) ;
un mécanisme de commutation de pression (21) qui commute la pression à introduire dans le dispositif d'entraînement (11),
dans lequel le mécanisme de commutation de pression (21) comporte une électrovanne (27) configurée pour s'ouvrir afin de former un premier passage (30) à travers lequel la chambre de refoulement (7) et un trou d'introduction de pression (114b) prévu au niveau d'une chambre de cylindre communiquent l'un avec l'autre, et se ferment afin de bloquer le premier passage (30), l'électrovanne (27) étant commutée pour s'ouvrir afin de permettre l'introduction de la pression de refoulement à partir de la chambre de refoulement (7) dans une chambre de cylindre ou pour se fermer afin d'empêcher l'introduction de la pression de refoulement à partir de la chambre de refoulement (7) dans une chambre de cylindre, et dans lequel la pression dans une chambre de cylindre change avec l'ouverture ou la fermeture de l'électrovanne (27) ;
caractérisé par
un mécanisme d'expansion (15ca) prévu au niveau d'un passage communiquant entre un trou de décompression (114c) et la chambre d'aspiration (16), le trou de décompression (114c) étant prévu au niveau d'une des deux chambres de cylindre ;
le dispositif d'entraînement (11) déplace le piston Vi (13) en modifiant la pression dans la chambre d'un cylindre afin de contrôler la position de la soupape Vi variable (9).

2. Compresseur à vis (1) selon la revendication 1,

dans lequel les deux chambres de cylindre sont une première chambre de cylindre (14a) et une deuxième chambre de cylindre (14b) dans l'ordre de disposition à partir d'un côté plus proche de la soupape Vi variable (9), dans lequel la pression de refoulement est constamment introduite dans la première chambre de cylindre (14a), et dans lequel la deuxième chambre de cylindre (14b) correspond à une chambre de cylindre et communique avec la chambre d'aspiration (16) par l'intermédiaire du mécanisme d'expansion (15ca), et la pression dans la deuxième chambre de cylindre (14b) est commutée entre la pression de refoulement et la pression d'aspiration selon que l'électrovanne (27) est ouverte ou fermée.

3. Compresseur à vis (1) selon la revendication 1,

dans lequel les deux chambres de cylindre sont une première chambre de cylindre (14a) et une deuxième chambre de cylindre (14b) dans l'ordre de disposition à partir d'un côté plus proche de la soupape Vi variable (9), dans lequel la première chambre de cylindre (14a) correspond à une chambre de cylindre et communique avec la chambre d'aspiration (16) par l'intermédiaire du mécanisme d'expansion (15ca), et la pression dans la première chambre de cylindre (14a) est commutée entre la pression de refoulement et la pression d'aspiration selon que l'électrovanne (27) est ouverte ou fermée, et
dans lequel une pression d'aspiration est constamment introduite dans la deuxième chambre de cylindre (14b).

4. Compresseur à vis (1) selon l'une quelconque des revendications 1 à 3,

dans lequel le mécanisme de commutation de pression (21) comporte en outre un cylindre de commutation (22) communiquant avec le premier passage (30) s'étendant entre l'électrovanne (27) et la une chambre de cylindre ; un piston de commutation (23) logé de manière mobile dans le cylindre de commutation (22) ; et un ressort (25) qui est comprimé avec un mouvement du piston de commutation (23),
dans lequel l'intérieur du cylindre de commutation (22) est divisé par le piston de commutation (23) en une première chambre de cylindre de commutation (26a) dans laquelle une pression d'aspiration est constamment introduite et dans laquelle le ressort (25) est prévu, et une deuxième chambre de cylindre de commutation (26b) qui communique avec le premier passage (30),
dans lequel un deuxième passage (28b) par lequel la première chambre de cylindre de commutation (26a) et une chambre de cylindre communiquent l'une avec l'autre est ouvert ou fermé en fonction d'une position du piston de commutation (23) qui reçoit une force de ressort (25) exercée par le ressort (25), et
dans lequel la pression dans la une chambre de cylindre change lorsque le premier passage (30) est ouvert ou fermé avec l'ouverture ou la fermeture de l'électrovanne (27) tandis que le deuxième passage (28b) est ouvert ou fermé avec le mouvement du piston de commutation (23).

5. Compresseur à vis (1) selon la revendication 4, dans lequel le deuxième passage (28b) est pourvu d'un premier mécanisme d'expansion (28ba).

FIG. 1

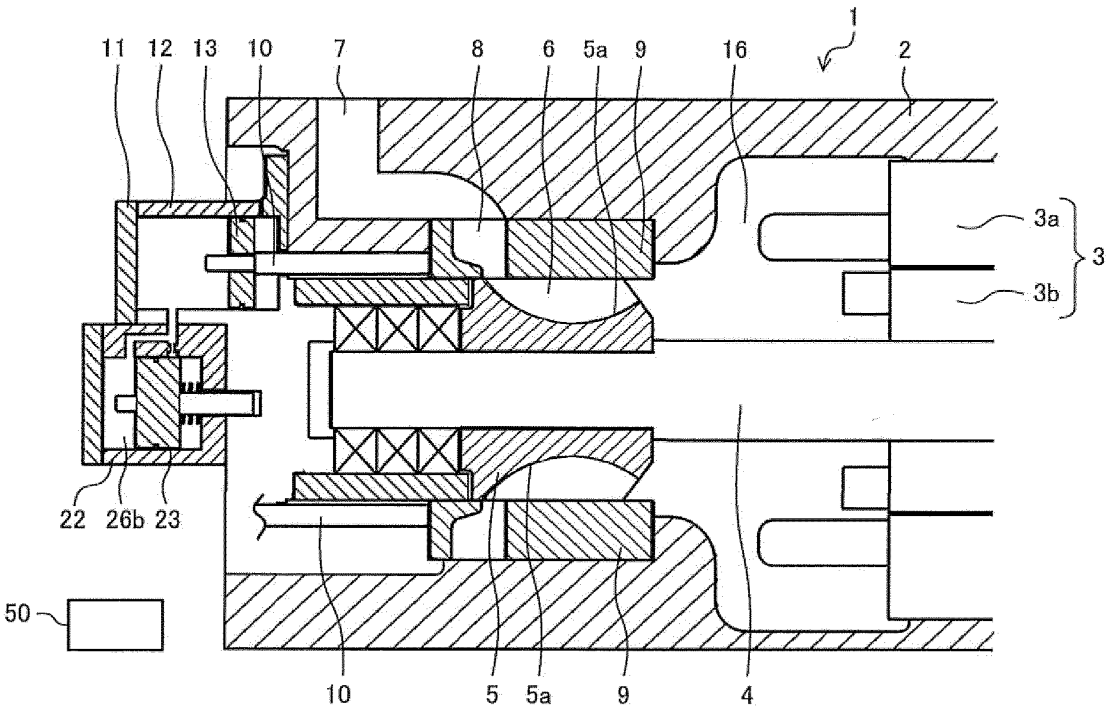

11
12
13
10
7
8
6
5a
9
16
1
2
3a
3
3b
22
26b
23
50
10
5
5a
9
4

FIG. 2

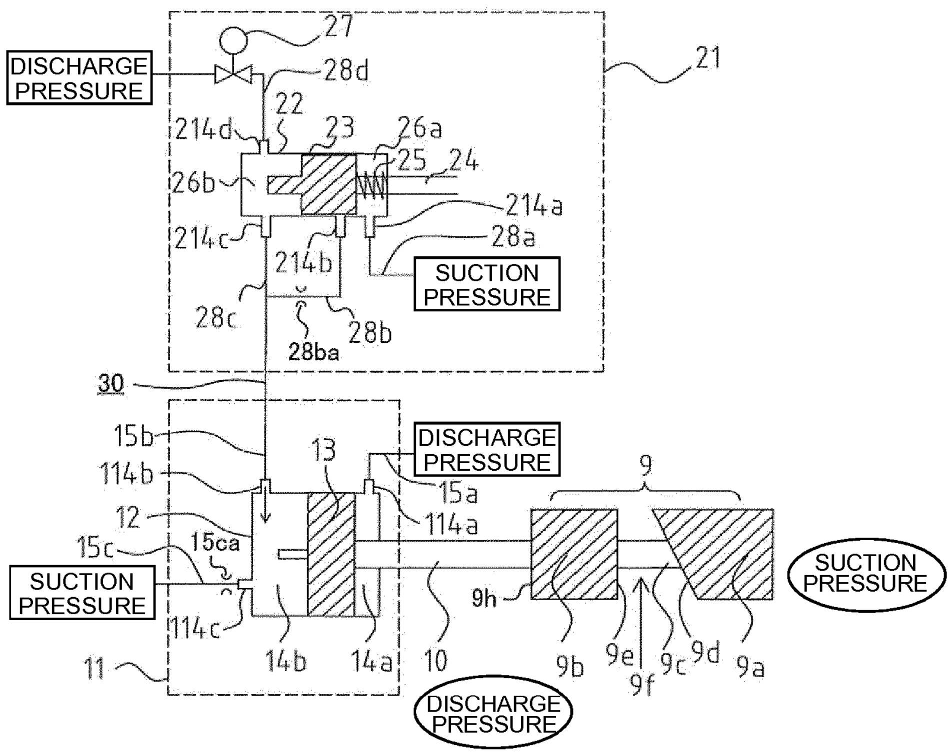

27
DISCHARGE PRESSURE
28d
21
22
214d
23
26a
25
24
26b
214a
214c
28a
214b
SUCTION PRESSURE
28c
28b
28ba
30
15b
13
DISCHARGE PRESSURE
9
114b
15a
12
114a
15c
15ca
SUCTION PRESSURE
SUCTION PRESSURE
9h
114c
14b
14a
10
9b
9e
9c
9d
9a
9f
11
DISCHARGE PRESSURE

FIG. 3

<WHEN Vi VALUE IS HIGH>

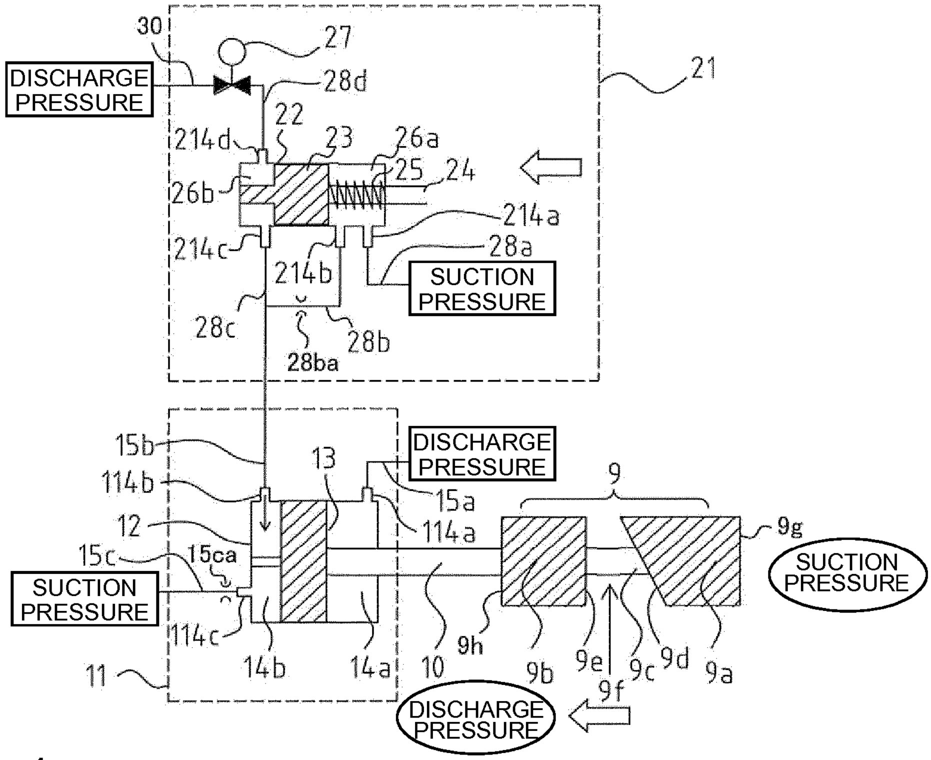


FIG. 4

<WHEN Vi VALUE IS LOW>

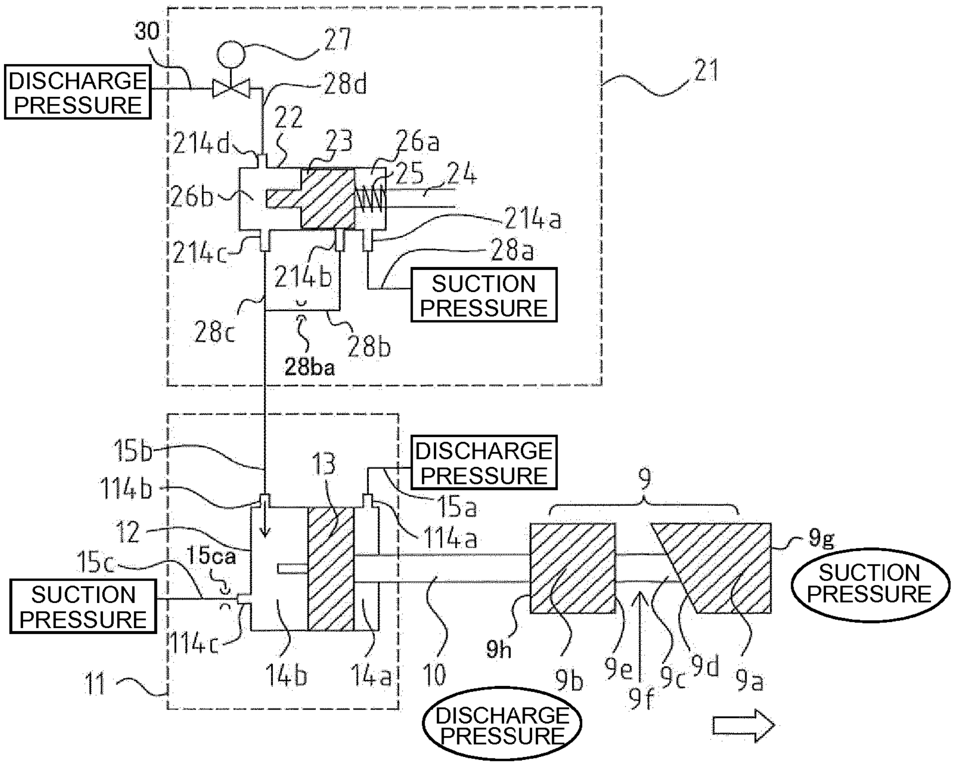


FIG. 5

<WHEN Vi VALUE IS HIGH>

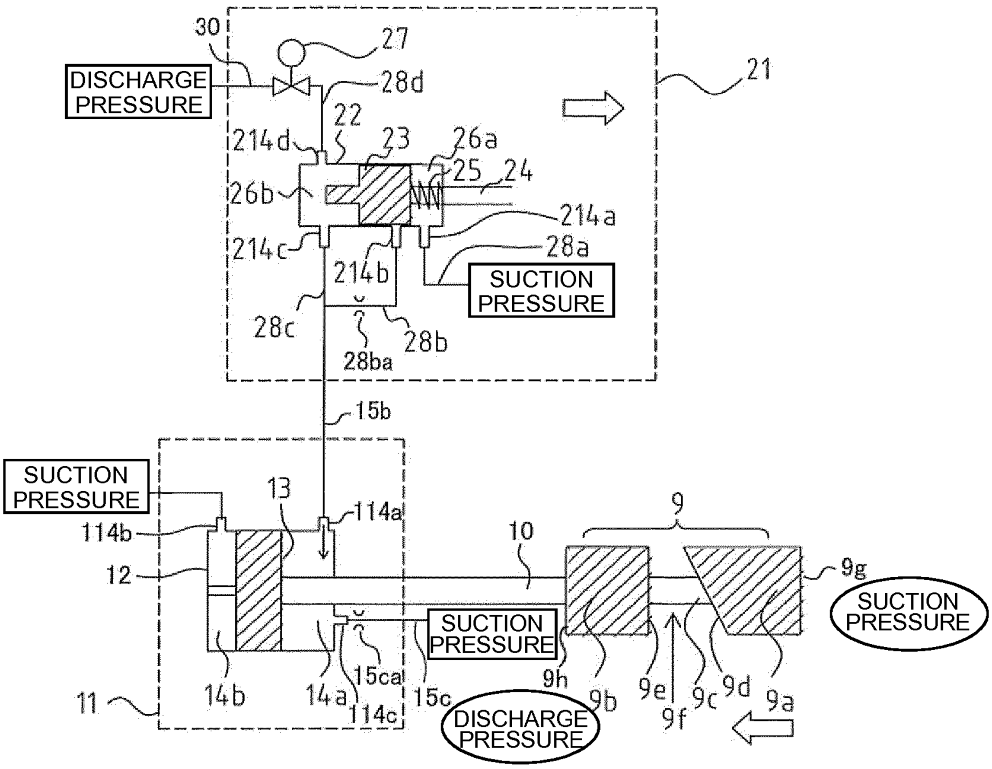


FIG. 6

<WHEN Vi VALUE IS LOW>

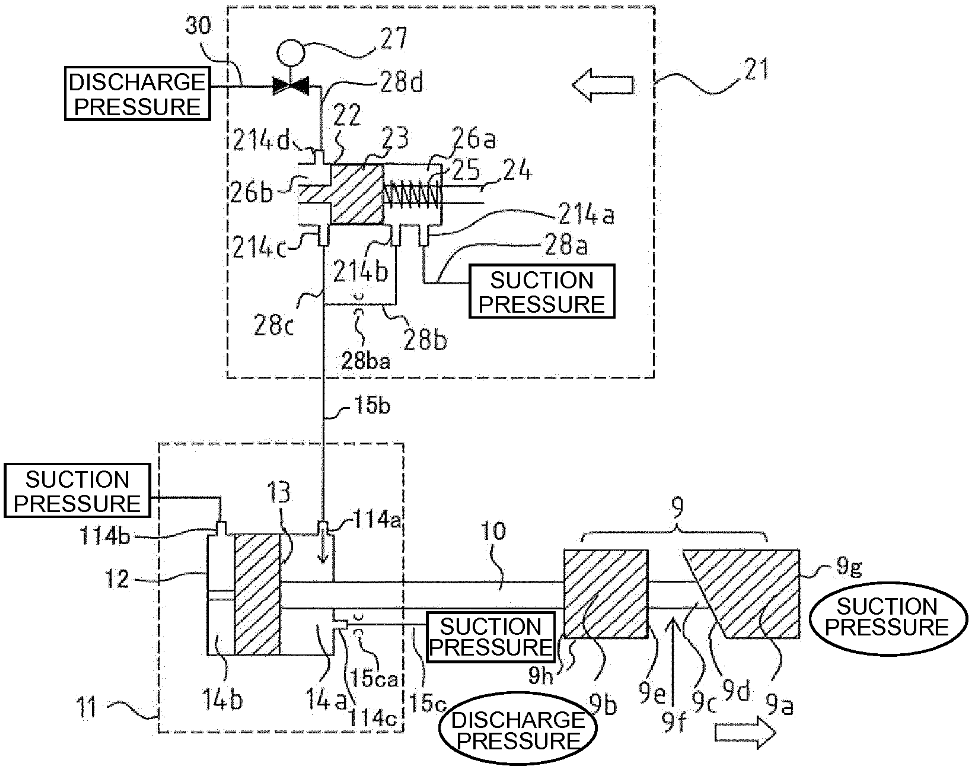


FIG. 7

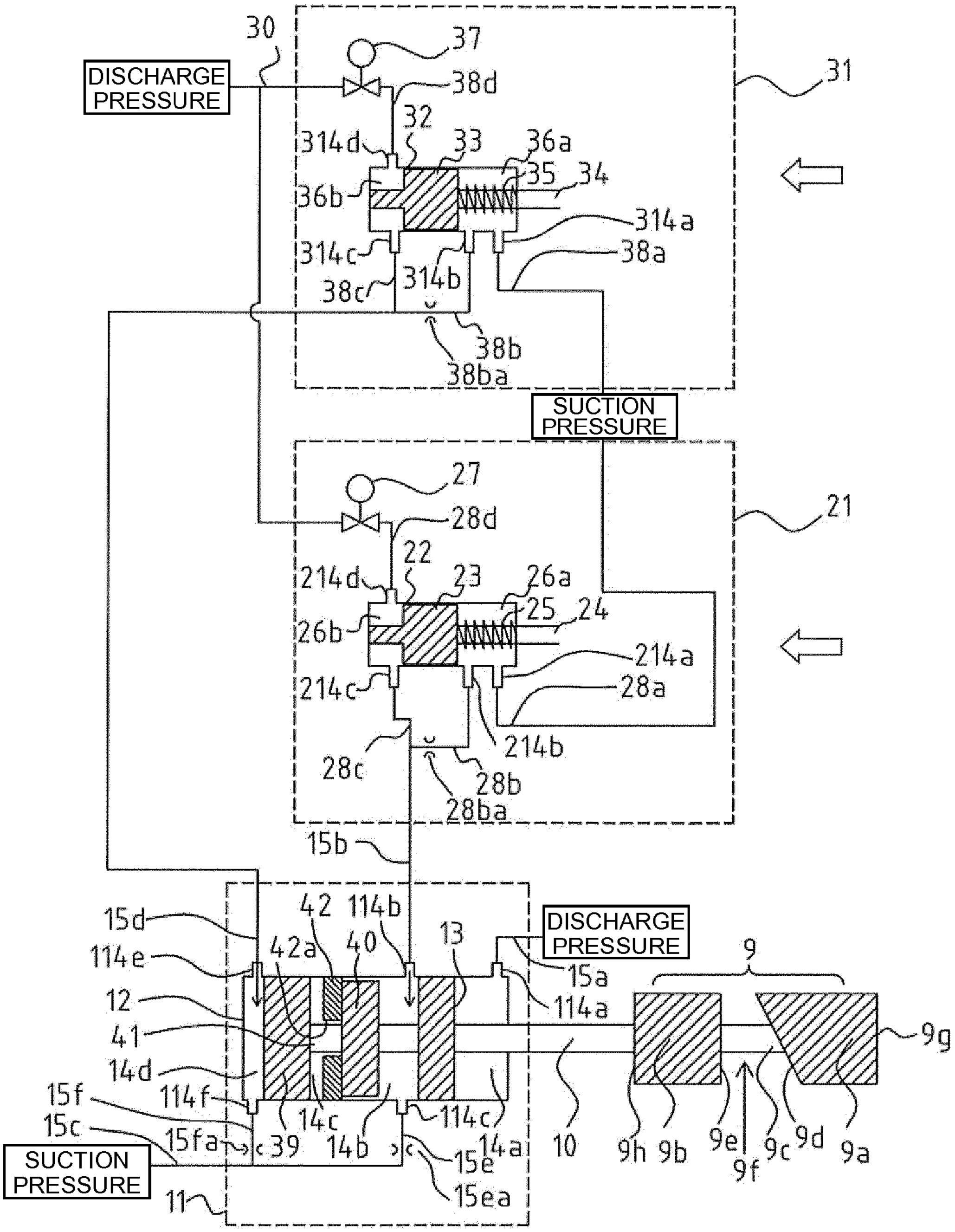

30
37
DISCHARGE PRESSURE
38d
31
32
314d
33
36a
35
34
36b
314a
314c
38a
314b
38c
38b
38ba
SUCTION PRESSURE
27
28d
21
22
214d
23
26a
25
24
26b
214a
214c
28a
214b
28c
28b
28ba
15b
42
114b
15d
42a
40
13
DISCHARGE PRESSURE
114e
15a
9
114a
12
41
9g
14d
15f
114f
14c
114c
15c
15fa
39
14b
15e
14a
10
9h
9b
9e
9c
9d
9a
SUCTION PRESSURE
15ea
9f
11

FIG. 8

<WHEN Vi VALUE IS HIGH>

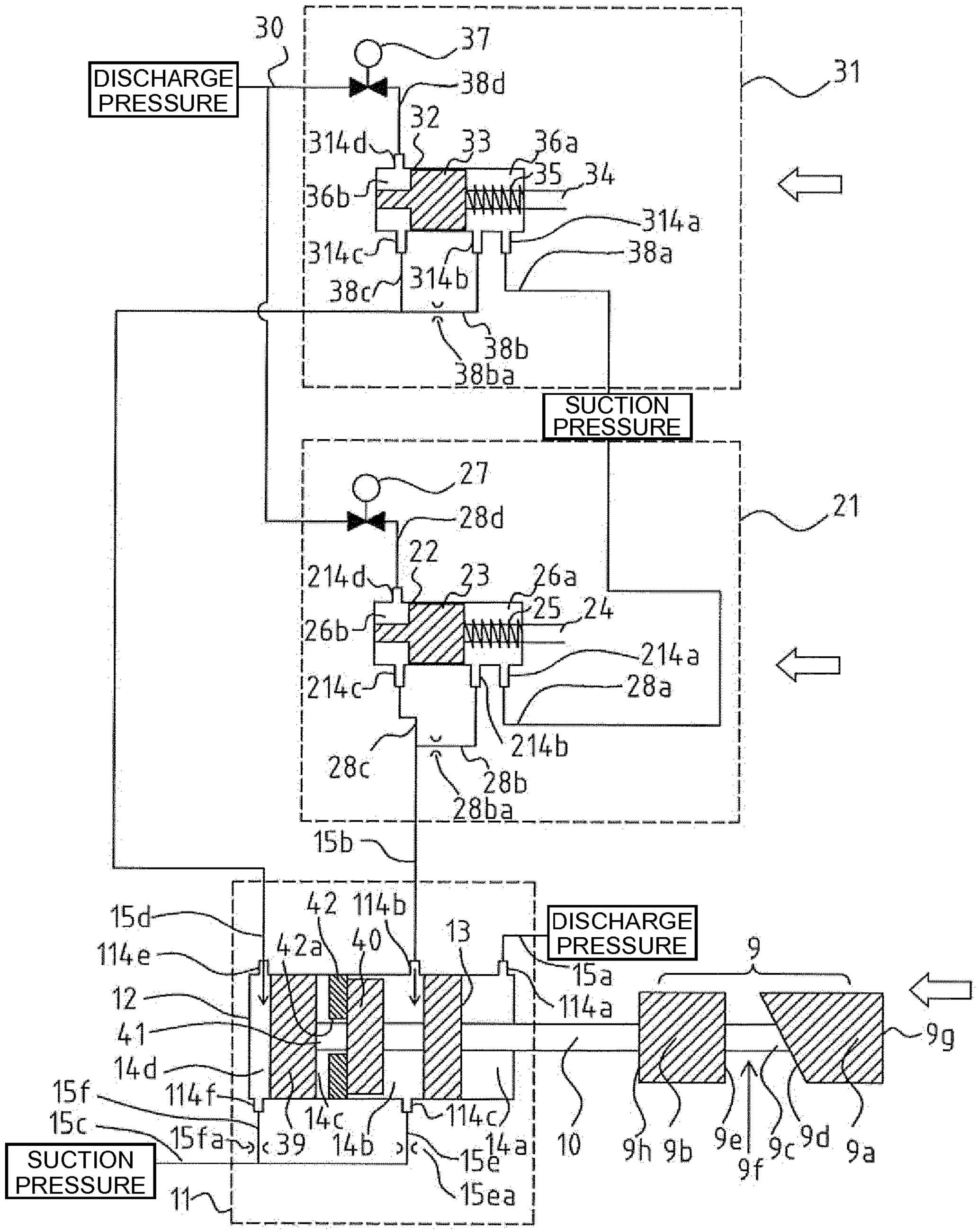


FIG. 9

<WHEN Vi VALUE IS MODERATE>

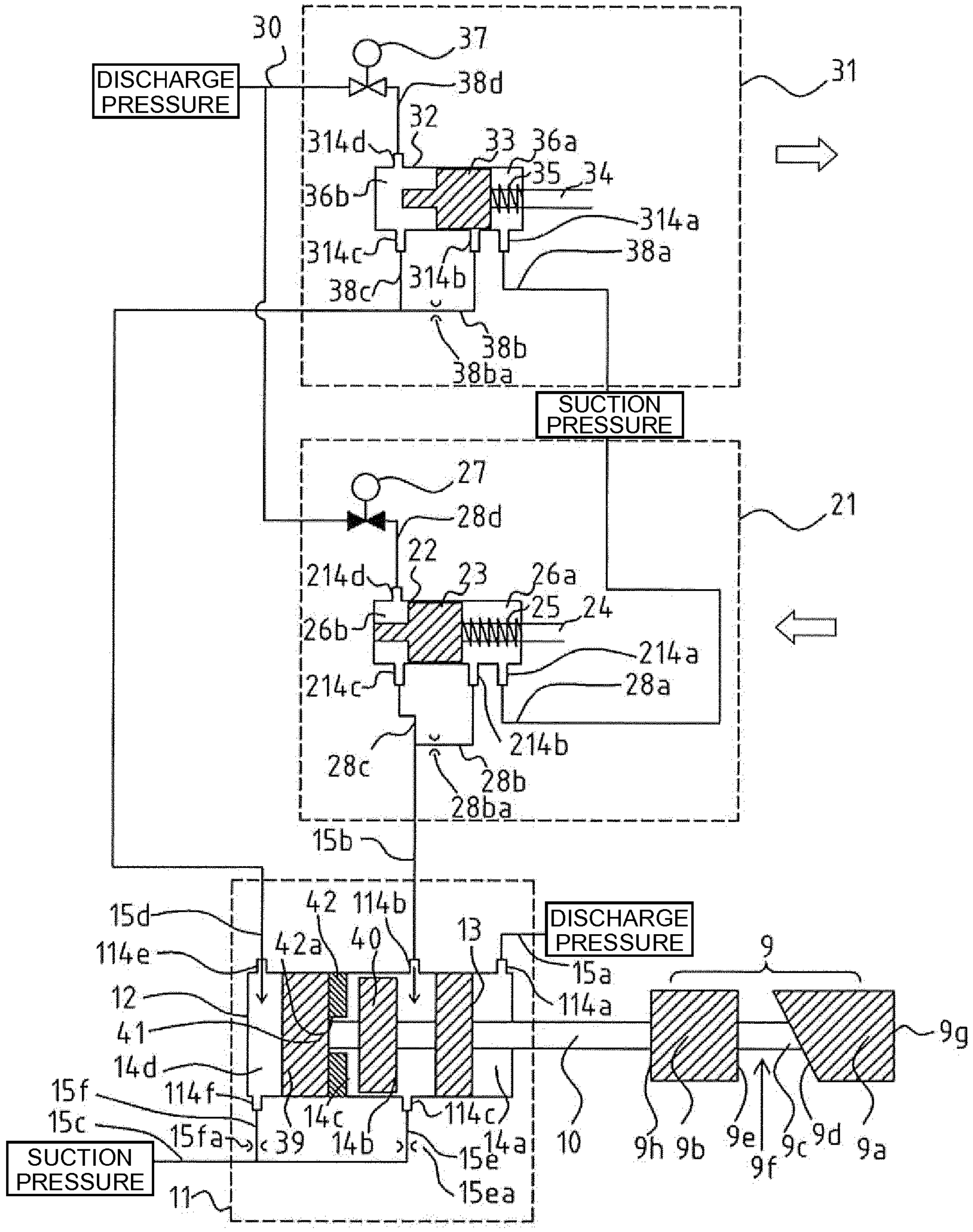


FIG. 10

<WHEN Vi VALUE IS LOW>

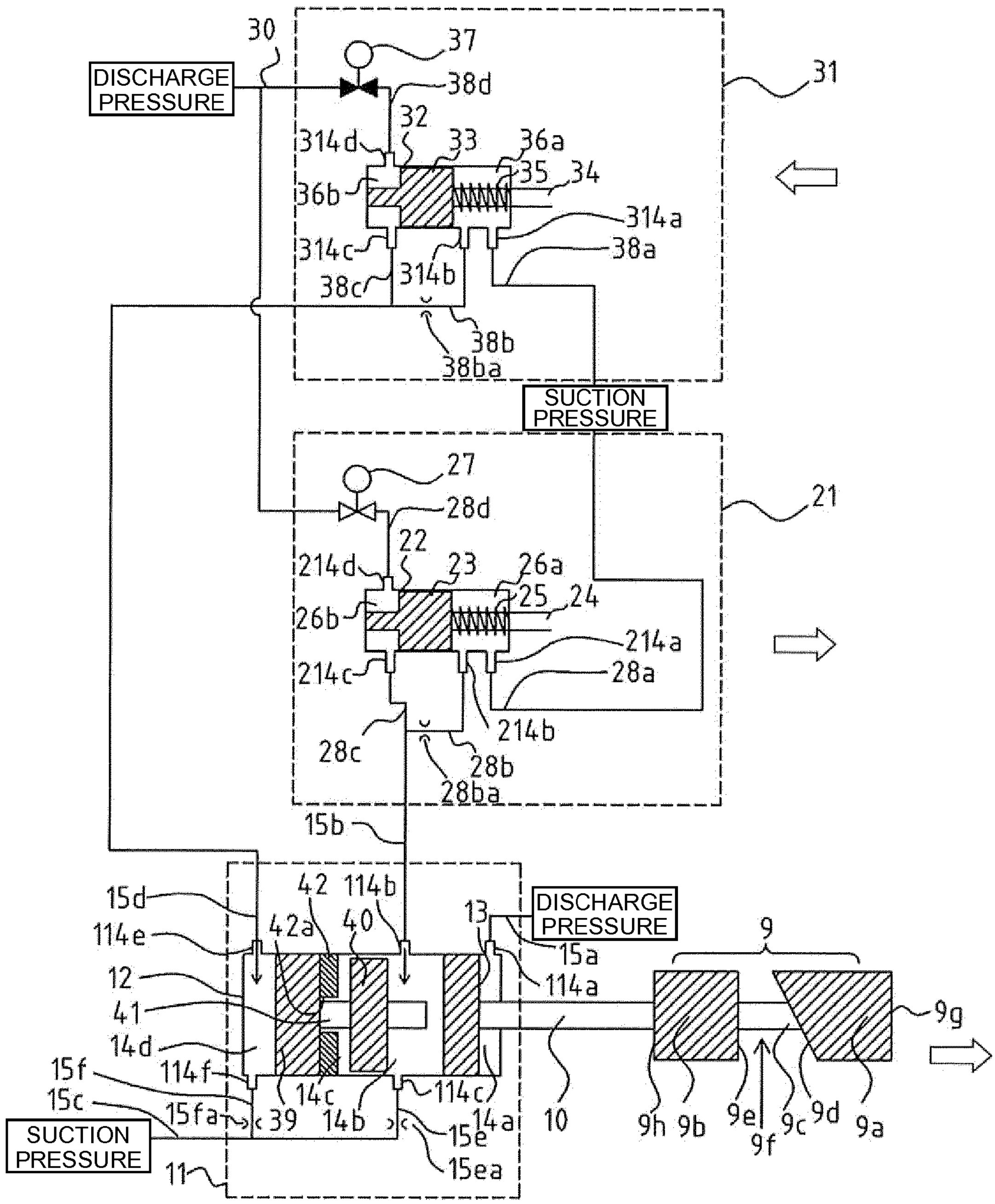


FIG. 11

<WHEN Vi VALUE IS HIGH>

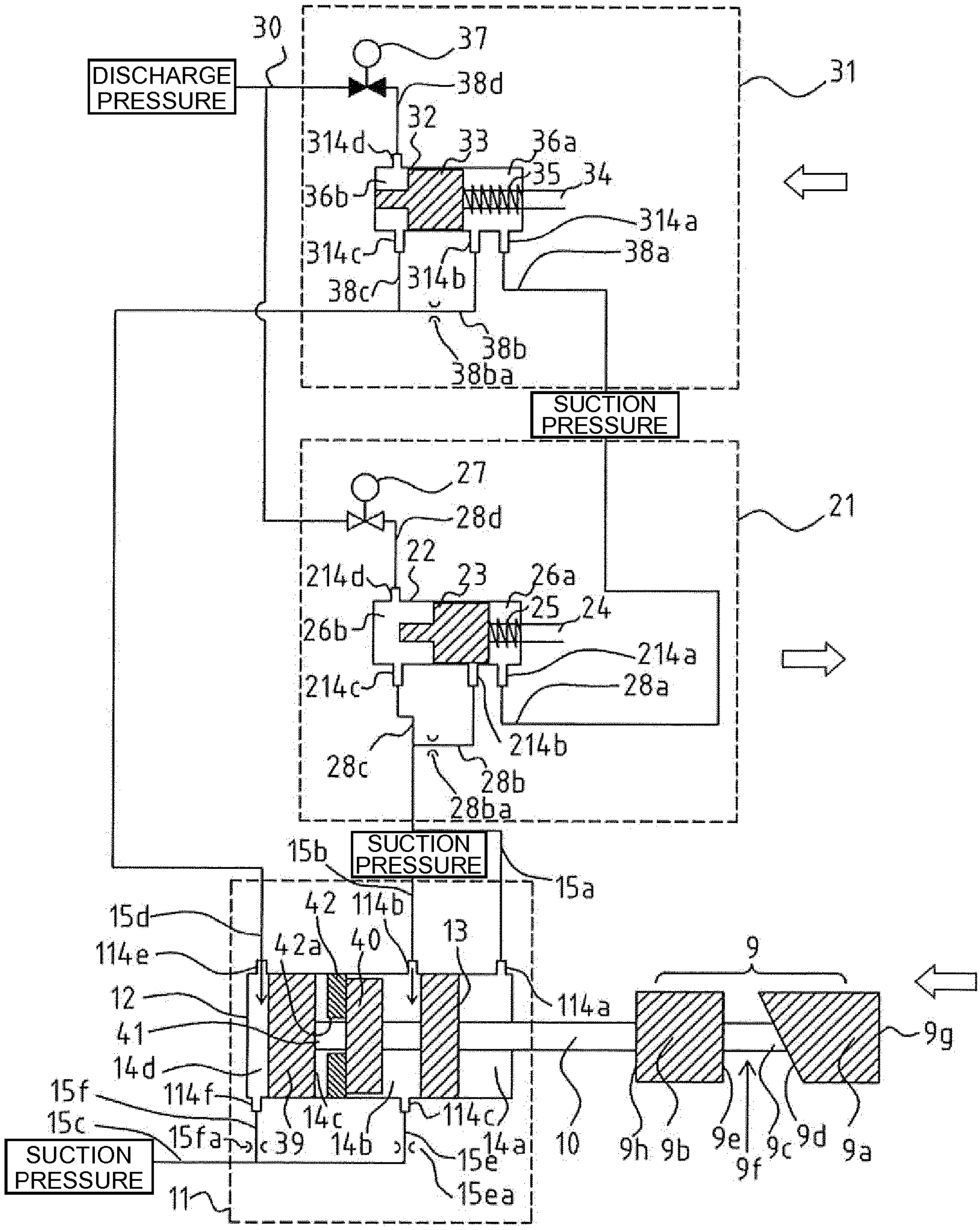


FIG. 12

<WHEN Vi VALUE IS MODERATE>

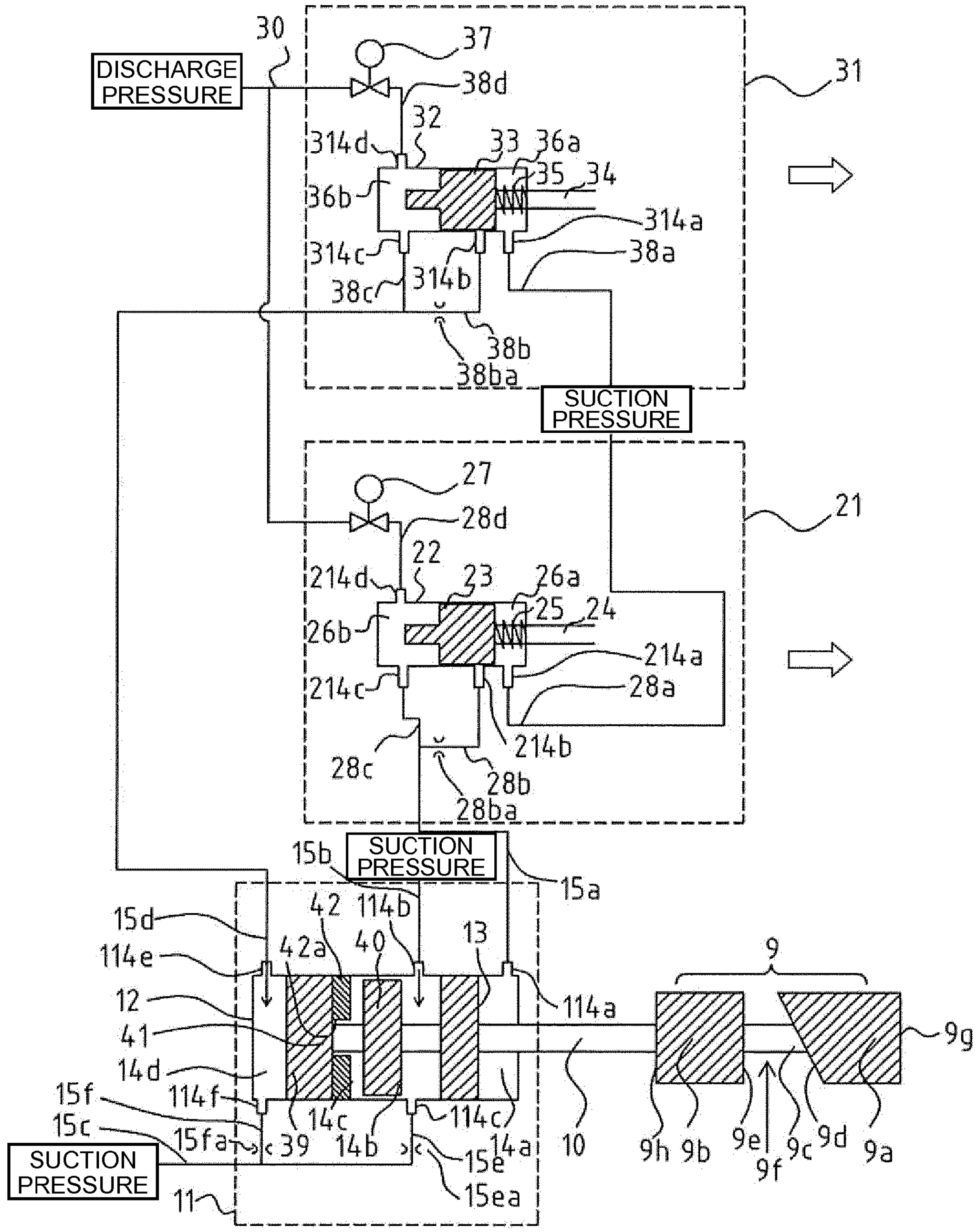


FIG. 13

<WHEN Vi VALUE IS LOW>

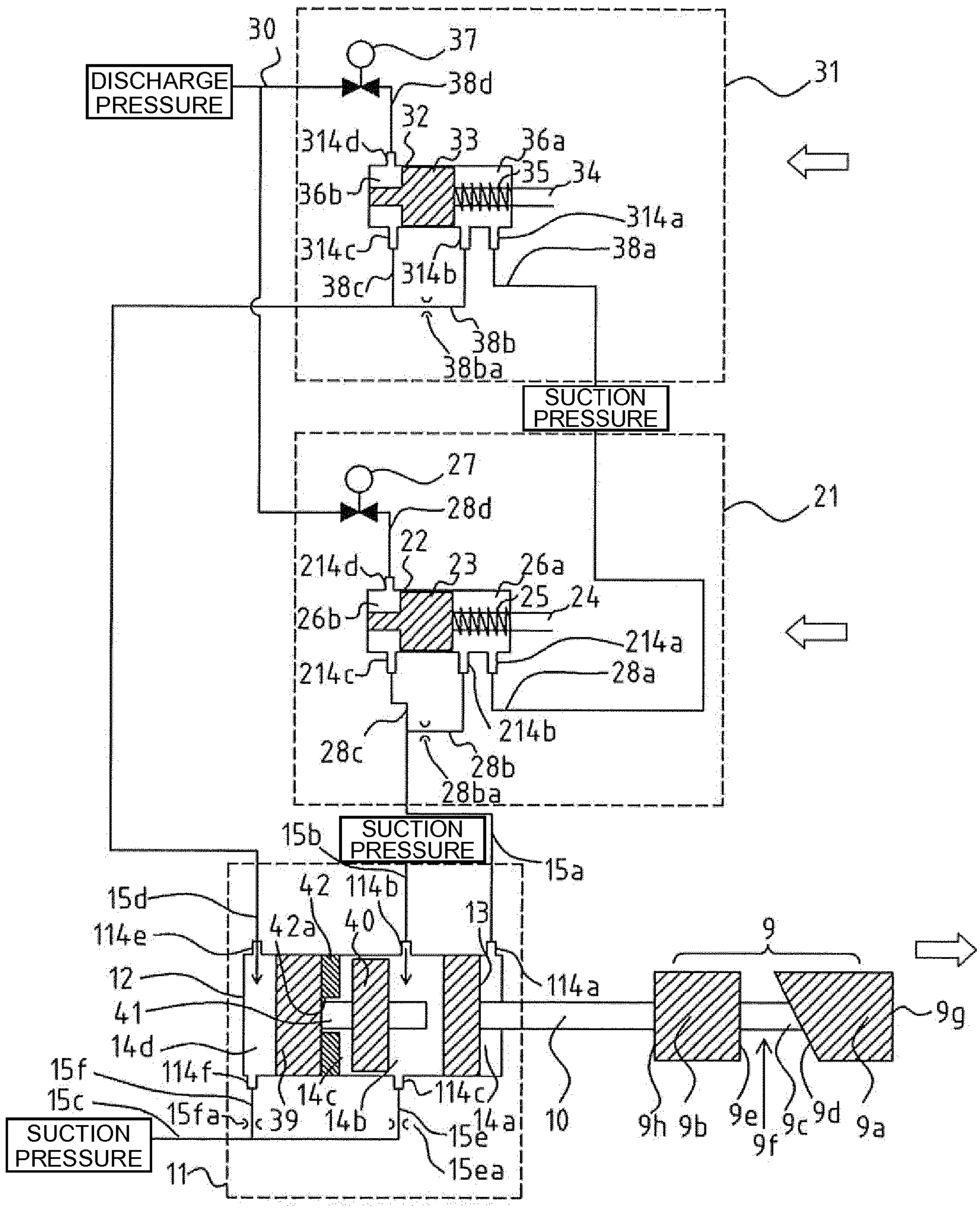


FIG. 14

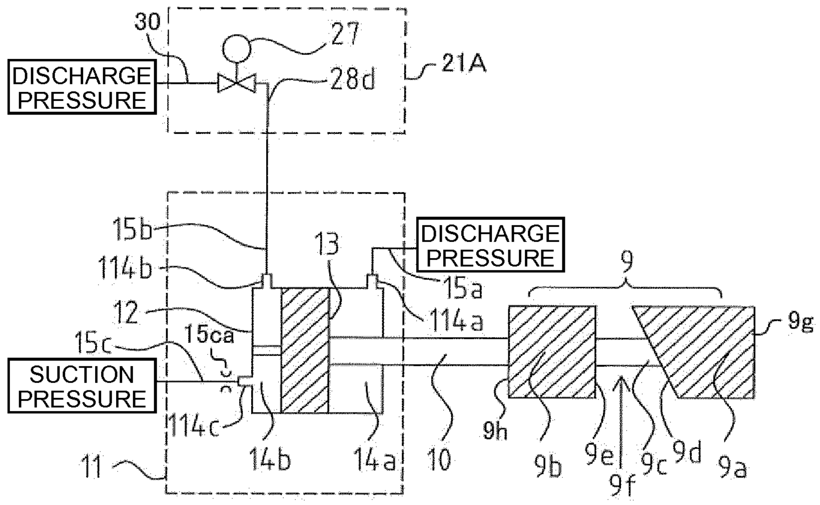
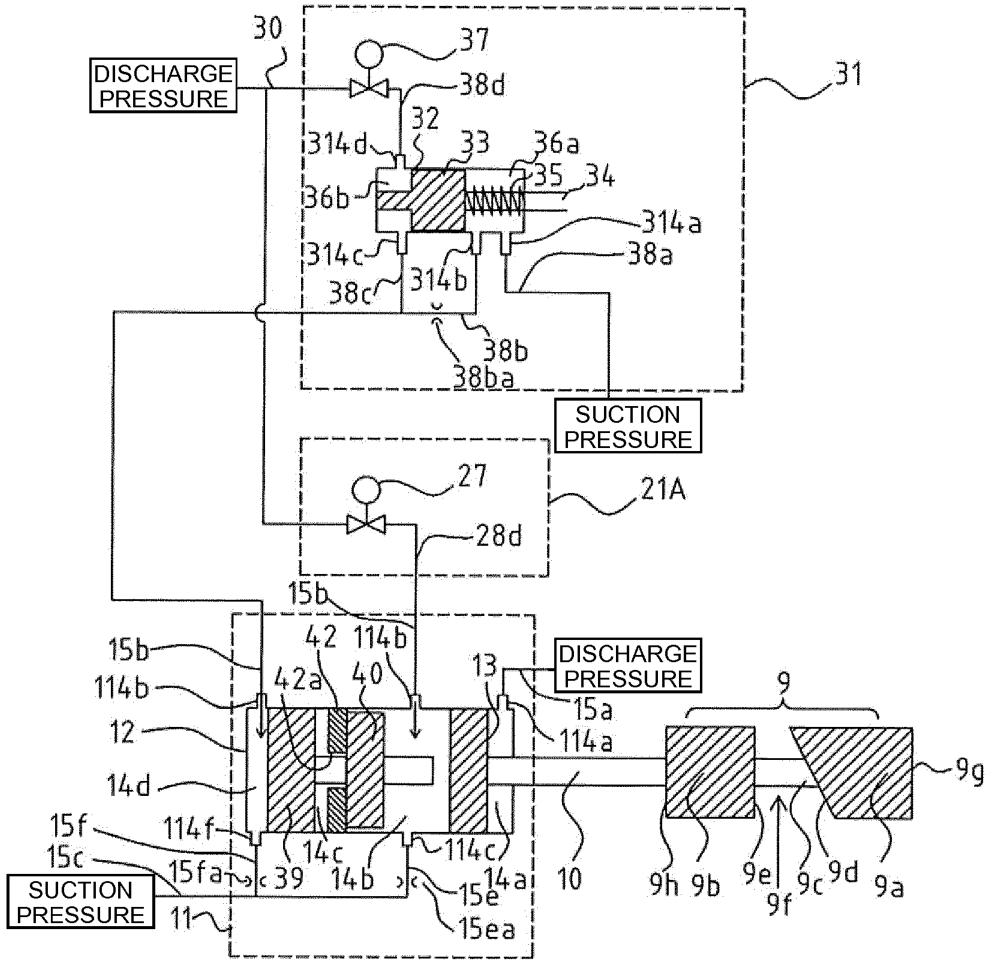

30
27
28d
21A
DISCHARGE PRESSURE
15b
114b
13
DISCHARGE PRESSURE
9
15a
114a
12
15ca
15c
9g
SUCTION PRESSURE
114c
9h
11
14b
14a
10
9b
9e
9f
9c
9d
9a

FIG. 15


30
37
31
DISCHARGE PRESSURE
38d
32
314d
33
36a
35
34
36b
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314c
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38c
314b
38b
38ba
SUCTION PRESSURE
27
21A
28d
15b
15b
42
114b
13
DISCHARGE PRESSURE
9
114b
42a
40
15a
114a
12
9g
14d
15f
114f
14c
114c
15c
15fa
39
14b
14a
10
9h
9b
9e
9c
9d
9a
9f
SUCTION PRESSURE
11
15e
15ea

REFERENCES CITED IN THE DESCRIPTION

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- JP 5881403 B **[0006]**