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(71) Applicant: **DAIKIN INDUSTRIES, LTD.**
Osaka-shi, Osaka 530-0001 (JP)

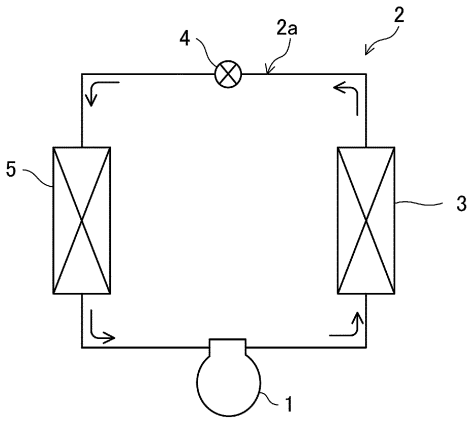
(72) Inventors:
- **IMAMURA, Yoshiyuki**
  Osaka-shi
  Osaka
  5300001 (JP)
- **INOUE, Takashi**
  Osaka-shi
  Osaka
  5300001 (JP)

(74) Representative: **Goddar, Heinz J.**
Boehmert & Boehmert
Anwaltspartnerschaft mbB
Pettenkoferstrasse 22
80336 München (DE)

(54) **SCREW COMPRESSOR AND REFRIGERATION DEVICE**

(57) A screw compressor includes: a screw rotor (40); a plurality of gate rotors (50, 60); a casing (10) having a cylindrical wall (15); and an adjustment mechanism. A plurality of compression chambers are formed inside the cylindrical wall (15) by the screw rotor (40) and the gates (51, 61). The plurality of compression chambers include a first compression chamber (21) and a second compression chamber (22) to which a fluid compressed in the first compression chamber (21) is sent via an intermediate pressure space (S). The adjustment mechanism is configured to adjust, in a two-stage operation, an intermediate pressure, which is a pressure of the fluid in the intermediate pressure space (S).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a screw compressor and a refrigeration apparatus.

BACKGROUND ART

[0002] Patent Document 1 discloses a screw compressor. The screw compressor of Patent Document 1 switches operation between two-stage operation and single-stage operation by moving a high-stage-side slide valve in the two-stage screw compressor in the direction of an axis. A high-stage-side compression chamber has two outlets. When the slide valve is located on a power source side, a first fluid outlet is closed, and the refrigerant is delivered to the outside of the compressor via a second fluid outlet. On the other hand, when the high-stage-side slide valve is located on the opposite side to the power source side, the first fluid outlet is opened, and the refrigerant is delivered to the outside of the compressor via the first fluid outlet. That is, two-stage compression is performed when the slide valve is located on the power source side, and when the slide valve is located on the opposite side to the power source side, the refrigerant is not compressed in the high-stage-side compression chamber, and therefore, the single-stage operation can be performed.

CITATION LIST

PATENT DOCUMENT

[0003] PATENT DOCUMENT 1: Chinese Patent Publication No. 109667760

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0004] However, in the two-stage operation requiring a high compression ratio, a suction pressure (intermediate pressure) into the high-stage-side compression chamber (second compression chamber) is determined according to a volume ratio between the compression chamber on the low stage side and the compression chamber on the high stage side. In the screw compressor described in Patent Document 1, the screw compressor has high performance when the intermediate pressure of the compressor itself and an ideal intermediate pressure coincide with each other, but the performance of the screw compressor is degraded when an operating state deviates from a designed internal volume ratio. The screw compressor described in Patent Document 1 cannot adjust the intermediate pressure, and therefore, it is difficult to reduce degradation of the performance of the screw compressor when the intermediate pressure of the compressor is different from the ideal intermediate pressure.

[0005] It is an object of the present disclosure to provide a screw compressor that can reduce performance degradation.

SOLUTION TO THE PROBLEM

[0006] A screw compressor of a first aspect includes: a screw rotor (40); a plurality of gate rotors (50, 60) having gates (51, 61) that mesh with the screw rotor (40); a casing (10) into which the screw rotor (40) is rotatably inserted, the casing (10) having a cylindrical wall (15) through which the gates (51, 61) penetrate; and an adjustment mechanism configured to adjust a pressure of a fluid in the casing (10), wherein a plurality of compression chambers are formed inside the cylindrical wall (15) by the screw rotor (40) and the gates (51, 61), the plurality of compression chambers include: a first compression chamber (21) in which the fluid introduced into the casing (10) with a suction pressure is compressed to a pressure higher than the suction pressure; and a second compression chamber (22) to which the fluid compressed in the first compression chamber (21) is sent via an intermediate pressure space (S), and the adjustment mechanism is configured to adjust an intermediate pressure, which is a pressure of the fluid in the intermediate pressure space (S), in a two-stage operation in which the fluid is compressed in the first compression chamber (21) and the second compression chamber (22).

[0007] According to the first aspect, it is possible to reduce degradation of the performance of the screw compressor.

[0008] A second aspect is an embodiment of the first aspect. In the second aspect, the adjustment mechanism includes a valve (80) movable to an opposing region indicating a rotor space surrounded by the gate rotors (50, 60) and the screw rotor (40), and the valve (80) changes timing at which the second compression chamber (22) is fully closed, by changing a position of the valve (80) in the opposing region (V).

[0009] According to the second aspect, when the valve (80) is located in the opposing region (V), the formation of the second compression chamber (22) makes it possible to compress the fluid in the second compression chamber (22). It is possible to adjust the intermediate pressure to a desired value (ideal value) by changing, by the valve (80), the timing at which the second compression chamber (22) is fully closed.

[0010] A third aspect is an embodiment of the second aspect. In the third aspect, the valve (80) changes a volume of the second compression chamber (22) at start of a compression phase for the fluid in the second compression chamber (22) by changing the timing at which the second compression chamber (22) is fully closed.

[0011] According to the third aspect, the volume of the second compression chamber (22) is changed, and the amount of fluid to be sent to the second compression

chamber (22) from the intermediate pressure space (S) is thereby limited to an amount corresponding to the volume of the second compression chamber (22) immediately after the second compression chamber (22) has been fully closed. It is thus possible to adjust the intermediate pressure effectively.

[0012] A fourth aspect is an embodiment of the second or third aspect. In the fourth aspect, the valve (80) switches between a single-stage operation in which the fluid is compressed in the first compression chamber (21) out of the first compression chamber (21) and the second compression chamber (22) and the two-stage operation.

[0013] According to the fourth aspect, the valve (80) can switch between the single-stage operation and the two-stage operation.

[0014] A fifth aspect is an embodiment of the fourth aspect. In the fifth aspect, the valve (80) is movable to a separation position (W) apart from the rotor space, and when located at the separation position (W), the valve (80) maintains a state in which the intermediate pressure space (S) communicates with an outside of the screw compressor.

[0015] According to the fifth aspect, when the valve (80) is located at the separation position (W), the second compression chamber (22) is kept communicating with the outside of the compressor; therefore, the refrigerant compressed in the first compression chamber (21) can be discharged to the outside of the compressor without being further compressed.

[0016] A sixth aspect is an embodiment of the fifth aspect. In the sixth aspect, the screw compressor further includes, inside the casing (10), a first passage (91) and a second passage (92) which communicate with the intermediate pressure space (S), wherein the valve (80) when located in the opposing region (V), allows the fluid to be sent from the intermediate pressure space (S) to the second compression chamber (22) via the first passage (91), and allows the fluid which has not entered the second compression chamber (22) because the second compression chamber (22) is fully closed to be sent to the intermediate pressure space (S) via the second passage (92), and when located at the separation position (W), allows the fluid in the intermediate pressure space (S) to be sent to the outside of the screw compressor via the first passage (91), and allows the fluid in the intermediate pressure space (S) to be sent to the outside of the screw compressor via the second passage (92).

[0017] According to the sixth aspect, when the valve (80) is located in the opposing region (V), the fluid is returned to the intermediate pressure space (S) via the first passage (91) and the second passage (92). It is thus possible to limit the amount of fluid compressed in the second compression chamber (22) and adjust the intermediate pressure. When the valve (80) is located at the separation position (W), the fluid can be smoothly sent to the outside of the compressor through the plurality of passages (the first passage (91) and the second passage (92)). It is thus possible to reduce the pressure loss of the fluid.

[0018] A seventh aspect is an embodiment of the fifth or sixth aspect. In the seventh aspect, the two-stage operation is performed when the valve (80) is located in the opposing region (V), the intermediate pressure is adjusted by changing the position of the valve (80) in the opposing region (V), and the single-stage operation is performed when the valve (80) is located at the separation position (W).

[0019] According to the seventh aspect, it is possible, by moving the valve (80), to switch between the single-stage operation and the two-stage operation and further possible to adjust the intermediate pressure in the two-stage operation. Thus, the operation of the screw compressor can be easily switched, and the intermediate pressure can be adjusted easily.

[0020] An eighth aspect is an embodiment of any one of the second to seventh aspects. In the eighth aspect, the position of the valve (80) is continuously changeable, and the timing at which the second compression chamber (22) is fully closed is thus continuously adjustable.

[0021] According to the eighth aspect, the intermediate pressure can be adjusted with high accuracy.

[0022] A ninth aspect is an embodiment of the sixth aspect. In the ninth aspect, the first passage (91) and the second passage (92) are located on one side (J1) in a movement direction (J) of the valve (80) with respect to the separation position (W), and the one side (J1) in the movement direction (J) indicates a direction toward the opposing region (V) in the movement direction (J) of the valve (80) from the separation position (W).

[0023] According to the ninth aspect, it is possible to arrange the first passage (91) and the second passage (92) so as to be spaced apart from the separation position (W) of the valve (80) in the movement direction (J) of the valve (80).

[0024] A tenth aspect is an embodiment of the sixth or ninth aspect. In the tenth aspect, the valve (80) includes an end surface (82) toward the one side (J1) in the movement direction (J) of the valve (80), and the second passage (92) is disposed so as to face the end surface (82), and the one side (J1) in the movement direction (J) indicates a direction toward the opposing region (V) in the movement direction (J) of the valve (80) from the separation position (W).

[0025] According to the tenth aspect, the valve (80) is moved to approach or to be spaced from the second passage (92), thereby making it possible to change the position of the valve (80) to a position within the opposing region (V) or the separation position (W).

[0026] An eleventh aspect is an embodiment of any one of the sixth, ninth, and tenth aspects. In the eleventh aspect, the first passage (91) includes a first opening (91a) communicating with the second compression chamber (22), the second passage (92) includes a second opening (92a) communicating with the second compression chamber (22), and the second opening (92a) is located at a position lower than the first opening (91a).

[0027] According to the eleventh aspect, it is possible to reduce accumulation of oil inside the compressor.

[0028] A twelfth aspect is an embodiment of any one of the sixth and ninth to eleventh aspects. In the twelfth aspect, the second passage (92) extends along an axis (N) of the valve (80).

[0029] According to the twelfth aspect, the valve (80) and the second passage (92) can be arranged in line.

[0030] A thirteenth aspect is directed to a refrigeration apparatus includes the screw compressor of any one of the first to twelfth aspects.

[0031] According to the thirteenth aspect, it is possible to reduce degradation of the performance of the screw compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

FIG. 1 is a refrigerant circuit diagram illustrating a configuration of a refrigeration apparatus.
FIG. 2 is a cross-sectional view of a configuration of a screw compressor as viewed from the back side.
FIG. 3 is a sectional side view of the configuration of the screw compressor.
FIG. 4 is a perspective view of a configuration of a compression mechanism.
FIG. 5 is a plan view of helical grooves on low stage side.
FIG. 6 is a plan view of helical grooves on high stage side.
FIG. 7 is a plan view illustrating a suction phase of the screw compressor.
FIG. 8 is a plan view illustrating a compression phase of the screw compressor.
FIG. 9 is a plan view illustrating a discharge phase of the screw compressor.
FIG. 10 is a perspective cross-sectional view of the screw compressor.
FIG. 11 is a perspective cross-sectional view of the screw compressor.
FIG. 12 is a plan view of an intermediate pressure space.
FIG. 13 is a perspective view illustrating a second slide valve.
FIG. 14 is a perspective cross-sectional view of the second slide valve located in an opposing region.
FIG. 15 is a perspective cross-sectional view of the second slide valve located in the opposing region.
FIG. 16 is a perspective cross-sectional view of the second slide valve located at a separation position.

DESCRIPTION OF EMBODIMENTS

[0033] Embodiments of the present disclosure will be described in detail below with reference to the drawings. The present disclosure is not limited to the embodiments shown below, and various changes can be made within the scope without departing from the technical concept of the present disclosure. Since each of the drawings is intended to illustrate the present disclosure conceptually, dimensions, ratios, or numbers may be exaggerated or simplified as necessary for ease of understanding. The same reference characters denote the same or equivalent components in each embodiment, each variation, and the drawings, and the detailed description thereof, the description of advantages associated therewith, and other descriptions will not be repeated.

-Refrigeration Apparatus-

[0034] As illustrated in FIG. 1, a refrigeration apparatus (2) has a refrigerant circuit (2a) filled with refrigerant. The refrigerant circuit (2a) has a screw compressor (1), a radiator (3), a decompression mechanism (4), and an evaporator (5). The decompression mechanism (4) is, for example, an expansion valve. The refrigerant circuit (2a) performs a vapor compression refrigeration cycle. In the refrigeration cycle, the refrigerant compressed by the screw compressor (1) dissipates heat to the air in the radiator (3). The refrigerant which has dissipated heat is decompressed by the decompression mechanism (4) and evaporates in the evaporator (5). The evaporated refrigerant is sucked into the screw compressor (1). The refrigerant contains lubricant that lubricates a sliding portion of the screw compressor (1). The refrigerant is an example of a fluid.

[0035] The refrigeration apparatus (2) is an air conditioner. The air conditioner may be a cooling-only apparatus, a heating-only apparatus, or an air conditioner switchable between cooling and heating. In this case, the air conditioner has a switching mechanism (e.g., a four-way switching valve) configured to switch the direction of circulation of the refrigerant. The refrigeration apparatus (2) may be a water heater, a chiller unit, or a cooling apparatus configured to cool air in an internal space. The cooling apparatus cools the air in an internal space of a refrigerator, a freezer, a container, or the like.

-Screw Compressor-

[0036] As illustrated in FIGS. 2 and 3, the screw compressor (1) includes a casing (10) and a compression mechanism (20). The casing (10) houses the compression mechanism (20). The compression mechanism (20) is coupled to an electric motor (not illustrated) via a drive shaft (25).

[0037] The compression mechanism (20) has a cylindrical wall (15) provided in the casing (10), one screw rotor (40), a first rotor (31), and a second rotor (32).

[0038] The screw rotor (40) is a metal member having a generally cylindrical shape. The outer diameter of the screw rotor (40) is set to be slightly smaller than the inner diameter of the cylindrical wall (15). The outer peripheral surface of the screw rotor (40) is close to the inner peripheral surface of the cylindrical wall (15). The screw

rotor (40) is rotatably inserted into the casing (10).

[0039] As illustrated in FIGS. 3 to 6, the outer periphery of the screw rotor (40) has a plurality of helical grooves (41) extending helically. The helical groove (41) extends from one side (J1) to the other side (J2) in the axial direction (J) of the screw rotor (40). The axial direction (J) is a direction in which the axis of the screw rotor (40) extends. A first end portion (42) and a second end portion (43) are provided at respective ends of the screw rotor (40) in the axial direction (J). Each of the first end portion (42) and the second end portion (43) has a smooth cylindrical outer peripheral surface without any helical grooves (41). The helical grooves (41) of the screw rotor (40) are formed between the first end portion (42) and the second end portion (43) of the screw rotor (40). The drive shaft (25) is coupled to the screw rotor (40). The drive shaft (25) and the screw rotor (40) rotate together. The axial direction (J) is an example of a movement direction of a valve (80).

[0040] As illustrated in FIGS. 2 and 5, the first rotor (31) is configured as a first gate rotor (50). The first gate rotor (50) has first gates (51) which are a plurality of teeth arranged radially. The first gates (51) mesh with the helical grooves (41) of the screw rotor (40). The first gate rotor (50) is housed in a first gate rotor chamber (17). The first gate rotor chamber (17) is defined in the casing (10), and is adjacent to the cylindrical wall (15). The gates (51, 61) penetrate the cylindrical wall (15).

[0041] As illustrated in FIGS. 2 and 6, the second rotor (32) is configured as a second gate rotor (60). The second gate rotor (60) has second gates (61) which are a plurality of teeth arranged radially. The second gates (61) mesh with the helical grooves (41) of the screw rotor (40). The second gate rotor (60) is housed in a second gate rotor chamber (18). The second gate rotor chamber (18) is defined in the casing (10), and is adjacent to the cylindrical wall (15).

[0042] As illustrated in FIGS. 2 and 3, a plurality of compression chambers is formed inside the cylindrical wall (15) by the screw rotor (40) and the gates (51, 61). In this embodiment, a first compression chamber (21) and a second compression chamber (22) are formed inside the cylindrical wall (15). The first compression chamber (21) is a space surrounded by the helical groove (41) of the screw rotor (40) and the first gate (51) of the first gate rotor (50). The second compression chamber (22) is a space surrounded by the helical groove (41) of the screw rotor (40) and the second gate (61) of the second gate rotor (60).

[0043] A first discharge pipe (7) communicates with the discharge side of the first compression chamber (21). An intermediate pressure space (S) is formed inside the casing (10). The intermediate pressure space (S) is a space in which the electric motor that rotationally drives the screw rotor (40) is disposed. A suction pipe (8) communicates with the suction side of the intermediate pressure space (S). The first discharge pipe (7) and the suction pipe (8) communicate with each other via, e.g., a connection pipe (not illustrated). The intermediate pressure space (S) communicates with the second compression chamber (22) via a plurality of passages (first passage (91) and second passage (92)) described later. A second discharge pipe (9) communicates with the discharge side of the second compression chamber (22). The second discharge pipe (9) communicates with the outside of the compressor (outside of the screw compressor (1)). A wall (19) is provided in the casing (10) to partition the intermediate pressure space (S) from a space in which the screw rotor (40) is installed.

[0044] As illustrated in FIG. 3, the screw compressor (1) is provided with a first slide valve (70) and a second slide valve (80). The first slide valve (70) and the second slide valve (80) are housed in respective valve storing portions (16a, 16b), which are portions formed at two locations in the circumferential direction of the cylindrical wall (15) and bulged outward in the radial direction of the screw rotor (40) (see FIG. 2). The second slide valve (80) is an example of an adjustment mechanism.

[0045] Each of the first slide valve (70) and the second slide valve (80) is slidable along the axial direction (J). Each of the first slide valve (70) and the second slide valve (80), while inserted in the valve storing portion (16), faces the outer peripheral surface of the screw rotor (40). The screw compressor (1) is provided with a drive mechanism (28) to drive the first slide valve (70) and the second slide valve (80) slidably.

[0046] The drive mechanism (28) includes a first electric motor that slides (moves) the first slide valve (70), and a second electric motor that slides the second slide valve (80). Rotational motion of the first electric motor is converted into linear motion by a gear, whereby the first slide valve (70) moves along the axial direction (J). The first electric motor includes, for example, a stepper motor, and the number of rotations can be changed steplessly. The fact that the number of rotations of the first electric motor can be changed steplessly means that the number of rotations (rotational angle) of the first electric motor can be changed continuously (can be changed at minute intervals). Rotational motion of the second electric motor is converted into linear motion by a gear, whereby the second slide valve (80) moves along the axial direction (J). The second electric motor includes, for example, a stepper motor, and the number of rotations can be changed steplessly. The fact that the number of rotations of the second electric motor can be changed steplessly means that the number of rotations (rotational angle) of the second electric motor can be changed continuously (can be changed at minute intervals).

[0047] Each of the first slide valve (70) and the second slide valve (80) is a valve, the position of which is adjustable in the axial direction. The first slide valve (70) can be used as an unloading mechanism that returns the refrigerant being compressed in the first compression chamber (21) toward the suction side to change an operating capacity. The first slide valve (70) can also be used as a compression ratio regulation mechanism that

adjusts the timing at which the refrigerant is discharged from the first compression chamber (21), thereby regulating the compression ratio (internal volume ratio) of the first compression chamber (21). The second slide valve (80) can be used as an unloading mechanism that returns the refrigerant being compressed in the second compression chamber (22) toward the suction side to change the operating capacity. The second slide valve (80) can also be used as a compression ratio regulation mechanism that adjusts the timing at which the refrigerant is discharged from the second compression chamber (22), thereby regulating the compression ratio (internal volume ratio) of the second compression chamber (22).

[0048] The screw compressor (1) includes a storage unit and a control unit. The storage unit includes a memory such as a read only memory (ROM) or a random access memory (RAM), and stores various computer programs executable by the control unit. The control unit includes a processor such as a CPU or an MPU. The control unit executes the computer program stored in the storage unit to control each component (e.g., the above-described electric motor, first electric motor, and second electric motor) of the screw compressor (1).

-First Compression Chamber and Second Compression Chamber-

[0049] The first compression chamber (21) is a compression chamber on a low stage side in two-stage compression, and compresses the refrigerant introduced into the casing (10) hand having a suction pressure to a pressure higher than the suction pressure. The second compression chamber (22) is a compression chamber on a high stage side in two-stage compression, and compresses the refrigerant that has been compressed in the first compression chamber (21) to a discharge pressure even higher.

[0050] As illustrated in FIGS. 2 and 3, a low-pressure pipe (6) through which a low-pressure refrigerant (a fluid with the suction pressure) flows is connected to the first gate rotor chamber (17). The first gate rotor chamber (17) is configured to supply the low-pressure refrigerant to the suction opening of the first compression chamber (21).

[0051] The low-pressure refrigerant is compressed in the first compression chamber (21). The refrigerant compressed in the first compression chamber (21) is supplied to the intermediate pressure space (S) via the first discharge pipe (7) and the suction pipe (8), and then, is supplied to the second compression chamber (22) from the second gate rotor chamber (18).

[0052] The high-pressure refrigerant compressed in the second compression chamber (22) is sent to the outside of the compressor via the second discharge pipe (9). The refrigerant sent to the outside of the compressor via the second discharge pipe (9) circulates in the refrigerant circuit (2a). As described above, the low-pressure space (S 1), the first compression chamber (21), the intermediate pressure space (S), and the second compression chamber (22) are connected in this order from the low fluid pressure side to the high fluid pressure side.

-Operation-

<Phases of Suction, Compression, and Discharge>

[0053] When the screw rotor (40) rotates, the first gate rotor (50) and the second gate rotor (60) meshing with the helical grooves (41) rotate. Thus, in the compression mechanism (20), a suction phase, a compression phase, and a discharge phase are continuously repeated in the first compression chamber (21).

[0054] In the suction phase illustrated in FIG. 7, the shaded first compression chamber (21) communicates with the space on the suction side. The helical groove (41) corresponding to the first compression chamber (21) meshes with the first gate (51) of the first gate rotor (50). When the screw rotor (40) rotates, the first gate (51) relatively moves toward the terminal end of the helical groove (41), causing the volume of the first compression chamber (21) to increase. As a result, the refrigerant is sucked into the first compression chamber (21).

[0055] When the screw rotor (40) further rotates, the compression phase illustrated in FIG. 8 is performed. In the compression phase, the shaded first compression chamber (21) is fully closed. That is, the helical groove (41) corresponding to the first compression chamber (21) is partitioned, by the first gate (51), from the space on the suction side. When the position of the first slide valve (70) in the axial direction (J) is changed, the timing at which the first compression chamber (21) is fully closed is changed. As the first gate (51) approaches the terminal end of the helical groove (41) in accordance with the rotation of the screw rotor (40), the volume of the first compression chamber (21) gradually decreases. As a result, the refrigerant in the first compression chamber (21) is compressed.

[0056] When the screw rotor (40) further rotates, the discharge phase illustrated in FIG. 9 is performed. In the discharge phase, the shaded first compression chamber (21) communicates with the first discharge pipe (7) via the end portion on the discharge side (right end portion in the figure). As the first gate (51) approaches the terminal end of the helical groove (41) in accordance with the rotation of the screw rotor (40), the compressed refrigerant is pushed out from the first compression chamber (21) via the first discharge pipe (7). The refrigerant that has been pushed out is sent to the intermediate pressure space (S) via the suction pipe (8).

[0057] The suction phase, the compression phase, and the discharge phase in the second compression chamber (22) on the high stage side will be described later.

-Configurations of Second Slide Valve and its Periphery -

[0058] FIGS. 11 and 12 are partially cutaway sectional

views of the screw compressor (1). In FIGS. 11 and 12, the screw rotor (40), the second gate rotor (60), the second slide valve (80), etc. are not illustrated. As illustrated in FIGS. 11 and 12, the valve storing portion (16b) is provided in the outer peripheral portion of the cylindrical wall (15), and extends along the axial direction (J). The inner peripheral surface of the valve storing portion (16b) has an arc shape along the outer peripheral surface of the second slide valve (80). The valve storing portion (16b) is provided from a position facing the second compression chamber (22) to a position not facing the second compression chamber (22) (position apart from the second compression chamber (22)). Specifically, the expression "facing the second compression chamber (22)" means facing the second compression chamber (22) from the outside in the radial direction of the screw rotor (40). The radial direction of the screw rotor (40) is a direction passing through the axis (the center of rotation) of the screw rotor (40) and perpendicular to the axial direction (J). The outside in the radial direction is a direction away from the axis of the screw rotor (40) in the radial direction. The second discharge pipe (9) has an opening (9a) in the inner peripheral surface of the valve storing portion (16b).

[0059] As illustrated in FIGS. 10 to 12, the first passage (91) and the second passage (92) are provided inside the casing (10). The first passage (91) and the second passage (92) each communicate with the second gate rotor chamber (18) (second compression chamber (22)) and the intermediate pressure space (S). The first passage (91) has an opening (91a) in the inner peripheral surface of the cylindrical wall (15). The opening (91a) of the first passage (91) is located at a position facing the second compression chamber (22). The second passage (92) has an opening (92a) in the end surface of the valve storing portion (16b) on the one side (J1) in the axial direction (J). The opening (92a) of the second passage (92) is located at a position lower than the opening (91a) of the first passage (91). The lower position indicates the lower side in the vertical direction. It is thus possible to reduce accumulation of oil inside the screw compressor (1).

[0060] As illustrated in FIG. 14, the first passage (91) and the second passage (92) are located on the one side (J1) in the axial direction (J) with respect to a separation position (W).

[0061] The second slide valve (80) includes an end surface (82) toward the one side (J1) in the axial direction (J). The second passage (92) is disposed so as to face the end surface (82).

[0062] The second passage (92) is located on the axis (N) of the second slide valve (80). The second passage (92) extends along the axis (N) of the second slide valve (80). The axis (N) of the second slide valve (80) is an imaginary line which passes through the center of the second slide valve (80) and extends along the movement direction of the second slide valve (80) (along the axial direction (J)).

[0063] FIG. 13 is an end view of the intermediate pressure space (S) as viewed from the one side (J1) in the axial direction (J). As illustrated in FIG. 13, the wall (19) is provided with an opening (91b) of the first passage (91) and an opening (92b) of the second passage (92). The first passage (91) is an internal passage of a tubular member formed from the opening (91a) to the opening (91b). The second passage (92) is an internal passage of a tubular member formed from the opening (92a) to the opening (92b).

[0064] FIG. 14 is a perspective view illustrating the second slide valve (80). The second slide valve (80) is provided with a fluid passage (81). The fluid passage (81) is a cutout formed in the second slide valve (80).

[0065] As illustrated in FIG. 10, the second slide valve (80) is movable between an opposing region (V) and the separation position (W).

-Opposing Region-

[0066] FIGS. 14 and 15 illustrate the second slide valve (80) located in the opposing region (V). As illustrated in FIGS. 10, 14, and 15, the opposing region (V) is a region which indicates a rotor space and which can change the timing at which the second compression chamber (22) is fully closed. The rotor space is a space surrounded by the gate rotors (50, 60) and the screw rotor (40). The rotor space is a space surrounded by the gate rotors (50, 60) and the outer surface of the screw rotor (40) on the side on which the second compression chamber (22) is formed. The rotor space is, for example, a space surrounded by the gate rotors (50, 60) along the rotation direction of the screw rotor (40). When the second slide valve (80) is located in the opposing region (V), the fluid passage (81) (see FIG. 13) of the second slide valve (80) faces the opening (9a) of the second discharge pipe (9). When the second slide valve (80) is located in the opposing region (V), the screw compressor (1) performs two-stage operation. The two-stage operation is operation in which the refrigerant is compressed in the first compression chamber (21) and the second compression chamber (22).

-Two-Stage Operation-

[0067] When the second slide valve (80) is located in the opposing region (V), the second compression chamber (22) communicates with the first passage (91) in the suction phase (see FIGS. 6 and 7). The helical groove (41) corresponding to the second compression chamber (22) meshes with the second gate (61) of the second gate rotor (60). When the screw rotor (40) rotates, the second gate (61) relatively moves toward the terminal end of the helical groove (41), causing the volume of the second compression chamber (22) to increase. As a result, the refrigerant in the intermediate pressure space (S) (refrigerant compressed in the first compression chamber (21)) is sucked into the second compression

chamber (22) via the first passage (91).

[0068] When the screw rotor (40) further rotates, the compression phase is performed (see FIGS. 6 and 8). In the compression phase, the second compression chamber (22) is fully closed. That is, the helical groove (41) corresponding to the second compression chamber (22) is partitioned, by the second gate (61), from the space on the suction side. Of the refrigerant sent from the intermediate pressure space (S) to the second compression chamber (22) via the first passage (91) (see the arrow Z1 in FIG. 11), the refrigerant which has not entered the second compression chamber (22) due to the fully closed state of the second compression chamber (22) is sent to the intermediate pressure space (S) via the second passage (92) (see the arrow Z2 in FIGS. 14 and 15). As the second gate (61) approaches the terminal end of the helical groove (41) in accordance with the rotation of the screw rotor (40), the volume of the second compression chamber (22) gradually decreases. As a result, the refrigerant in the second compression chamber (22) is compressed to the refrigerant with the discharge pressure.

[0069] When the screw rotor (40) further rotates, the discharge phase is performed (see FIGS. 6 and 9). In the discharge phase, the second compression chamber (22) faces the fluid passage (81) of the second slide valve (80) via the end portion on the discharge side, and therefore communicates with the second discharge pipe (9) via the fluid passage (81) and the opening (9a). As the second gate (61) approaches the terminal end of the helical groove (41) in accordance with the rotation of the screw rotor (40), the compressed refrigerant (refrigerant with the discharge pressure) is pushed out from the second compression chamber (22) to the outside of the compressor via the fluid passage (81) and the second discharge pipe (9) (see the arrow Z3 in FIGS. 14 and 15).

[0070] When the second slide valve (80) is located in the opposing region (V), the above-described suction phase, compression phase, and discharge phase are continuously repeated in the second compression chamber (22) in the compression mechanism (20).

[0071] As described above, when the second slide valve (80) is located in the opposing region (V), the refrigerant compressed in the first passage (91) and further compressed in the second compression chamber (22) is discharged from the screw compressor (1); therefore, two-stage operation is performed.

-Timing of Fully Closing Second Compression Chamber in Two-Stage Operation-

[0072] Hereinafter, the pressure of the refrigerant in the intermediate pressure space (S) may be referred to as an intermediate pressure.

[0073] As illustrated in FIGS. 10, 14, and 15, the timing at which the second compression chamber (22) is fully closed is changed in the compression phase by changing the position of the second slide valve (80) in the opposing region (V). In this embodiment, the closer to the one side (J1) in the axial direction (J) the second slide valve (80) is in the opposing region (V), the earlier the timing at which the second compression chamber (22) is fully closed. When the second compression chamber (22) is fully closed at earlier timing, the volume of the second compression chamber (22) at the start of the compression phase for the fluid in the second compression chamber (22) increases. As the volume of the second compression chamber (22) at the start of the compression phase for the fluid in the second compression chamber (22) increases, the amount of refrigerant returned to the intermediate pressure space (S) via the second passage (92) out of the refrigerant sent from the intermediate pressure space (S) to the second compression chamber (22) via the first passage (91) (see the arrow Z1 in FIG. 11) decreases (see the arrow Z2 in FIGS. 14 and 15).

[0074] As described above, the timing at which the second compression chamber (22) is fully closed is changed by changing the position of the second slide valve (80) in the opposing region (V), which changes the volume of the second compression chamber (22) at the start of the compression phase (immediately after the second compression chamber (22) is fully closed). If the volume of the second compression chamber (22) at the start of the compression phase is reduced, the refrigerant is less smoothly discharged via the intermediate pressure space (S), the second compression chamber (22), and the second discharge pipe (9), resulting an increase in the intermediate pressure. In contrast, if the volume of the second compression chamber (22) at the start of the compression phase is increased, the refrigerant is smoothly discharged via the intermediate pressure space (S), the second compression chamber (22), and the second discharge pipe (9), reducing an increase in the intermediate pressure. As a result, the intermediate pressure is adjusted by changing the position of the second slide valve (80) in the opposing region (V).

[0075] As described above, the number of rotations of the second electric motor can be changed steplessly. Since the second slide valve (80) can continuously change its position in the axial direction (J) (can change its position at minute intervals), it is possible to continuously adjust (finely adjust) the timing at which the second compression chamber (22) is fully closed.

-Separation Position-

[0076] FIG. 16 illustrates the second slide valve (80) at the separation position (W). The separation position (W) is a position at which the second slide valve (80) is apart from the above-described rotor space. As illustrated in FIGS. 10 and 16, when the second slide valve (80) is located at the separation position (W), the screw compressor (1) performs single-stage operation. The single-stage operation is operation in which the refrigerant is compressed only in the first compression chamber (21) out of the first compression chamber (21) and the second

compression chamber (22).

-Single-Stage Operation-

[0077] When the second slide valve (80) is located at the separation position (W), the second slide valve (80) is apart from the second compression chamber (22), thereby avoiding fully closing the second compression chamber (22) with the second slide valve (80). Accordingly, compression of the refrigerant in the second compression chamber (22) is avoided.

[0078] When the second slide valve (80) is located at the separation position (W), the intermediate pressure space (S) is kept communicating with the outside of the compressor via the first passage (91) and the second discharge pipe (9), and the intermediate pressure space (S) is also kept communicating with the outside of the compressor via the second passage (92) and the second discharge pipe (9). Thus, the fluid in the intermediate pressure space (S) is sent to the outside of the compressor via the first passage (91) (see the arrow Z1 in FIG. 11 and the arrow Z5 in FIG. 16), and is sent to the outside of the compressor via the second passage (92) (see the arrow Z4 and the arrow Z5 in FIG. 16).

[0079] As described above, when the second slide valve (80) is located at the separation position (W), the refrigerant compressed only in the first passage (91) out of the first passage (91) and the second compression chamber (22) is discharged from the screw compressor (1); therefore, single-stage operation is performed.

-Advantages-

[0080] As described above, the second slide valve (80) adjusts the intermediate pressure, which is the pressure of the fluid in the intermediate pressure space (S), in the two-stage operation in which the fluid is compressed in the first compression chamber (21) and the second compression chamber (22). In this embodiment, the second slide valve (80) adjusts the timing of fully closing the second compression chamber (22) (timing at which the second compression chamber (22) is fully closed), and changes the volume ratio between the first compression chamber (21) and the second compression chamber (22) to adjust the intermediate pressure. It is therefore possible to switch between the single-stage operation and the two-stage operation in accordance with, for example, the usage conditions and state of the screw compressor (1) and further possible to adjust the intermediate pressure in the two-stage operation. The screw compressor (1) can thus be operated efficiently. Further, the intermediate pressure of the compressor can be controlled to approach an ideal intermediate pressure by adjusting the intermediate pressure in the two-stage operation. It is therefore possible to reduce degradation of the performance of the screw compressor.

[0081] Under operating conditions of SCOP, which also include low compression ratio conditions such as general air conditioning conditions, over-compression occurs in the two-stage operation, resulting in a great loss. However, the screw compressor (1) of this embodiment can perform both the single-stage operation and the two-stage operation in which the intermediate pressure is adjustable. Thus, a seasonal efficiency SCOP can be improved.

[0082] In the single-stage operation, the refrigerant is sent to the outside of the compressor using not only the first passage (91) but also the second passage (92). It is therefore possible to reduce the pressure loss of the refrigerant in the passages. As a result, it is possible to reduce degradation of the operating efficiency even in high-speed operation in the single-stage operation.

[0083] The intermediate pressure can be adjusted to an optimum value by adjusting the timing of fully closing the second compression chamber (22). The refrigerant which does not enter the second compression chamber (22) can be returned to the intermediate pressure space (S) via the second passage (92). Since it is possible to control the intermediate pressure and switch to the single-stage operation, the seasonal efficiency of the screw compressor (1) can be improved. In addition, the outlet for the refrigerant after treated in the single-stage operation or the two-stage operation is configured as a single outlet (the outlet of the second discharge pipe (9)). It is therefore possible to simplify the structure of the screw compressor (1) and provide the screw compressor (1) at low cost.

-Variations-

[0084] In this embodiment, the second electric motor slides the second slide valve (80) along the axial direction (J) to change the position of the second slide valve (80). However, the present invention is not limited thereto. For example, the screw compressor (1) may include a hydraulic cylinder, and the hydraulic cylinder may slide the second slide valve (80) along the axial direction (J) to change the position of the second slide valve (80). The hydraulic cylinder includes a cylinder, a piston disposed in the cylinder, and a rod connected to the piston. The inside of the cylinder is partitioned into a first cylinder chamber and a second cylinder chamber by the piston. The tip end of the rod protrudes to the outside of the cylinder. The second slide valve (80) is connected to the tip end of the rod. By adjusting the amount of hydraulic oil in the first cylinder chamber and the amount of hydraulic oil in the second cylinder chamber, the amount of slide of the rod in the axial direction (J) is continuously adjusted, and as a result, the position of the second slide valve (80) in the axial direction (J) is continuously changed. Regarding the first slide valve (70), too, the position of the first slide valve (70) in the axial direction (J) may be changed by making the first slide valve (70) slid along the axial direction (J) using a hydraulic device such as the above-described hydraulic cylinder.

[0085] In this embodiment, the second slide valve (80)

switches between the single-stage operation in which the fluid is compressed only in the first compression chamber (21) out of the first compression chamber (21) and the second compression chamber (22) and the two-stage operation in which the fluid is compressed in the first compression chamber (21) and the second compression chamber (22). However, the present invention is not limited thereto. For example, the screw compressor (1) may include a switching valve different from the second slide valve (80), and the switching valve may switch between the single-stage operation and the two-stage operation. In this case, for example, a refrigerant passage connected to the outlet side of the first compression chamber (21) and the outlet side of the second compression chamber (22) is provided, and the switching valve is provided in the refrigerant passage to open and close the refrigerant passage. When the switching valve is opened, the operation is switched to the single-stage operation. When the switching valve is closed, the operation is switched to the two-stage operation. In this case, the switching valve is used to switch between the single-stage operation and the two-stage operation, and the second slide valve (80) is used in the two-stage operation to adjust the intermediate pressure, which is the pressure of the fluid in the intermediate pressure space (S).

[0086] While the embodiments and variations have been described above, it will be understood that various changes in form and details can be made without departing from the spirit and scope of the claims. The embodiments, the variations thereof, and the other embodiments may be combined and replaced with each other without deteriorating intended functions of the present disclosure.

[0087] The ordinal numbers such as "first," "second," "third," ..., described above are used to distinguish the terms to which these expressions are given, and do not limit the number and order of the terms.

INDUSTRIAL APPLICABILITY

[0088] As described above, the present disclosure is useful for a screw compressor and a refrigeration apparatus.

DESCRIPTION OF REFERENCE CHARACTERS

[0089]

1 Screw Compressor
10 Casing
15 Cylindrical Wall
21 First Compression Chamber
22 Second Compression Chamber
40 Screw Rotor
50 First Gate Rotor
51 First Gate
60 Second Gate Rotor
61 Second Gate
80 Second Slide Valve (Valve)
J Axial Direction (Valve Movement Direction)

Claims

1. A screw compressor comprising:

a screw rotor (40);
a plurality of gate rotors (50, 60) having gates (51, 61) that mesh with the screw rotor (40);
a casing (10) into which the screw rotor (40) is rotatably inserted, the casing (10) having a cylindrical wall (15) through which the gates (51, 61) penetrate; and
an adjustment mechanism configured to adjust a pressure of a fluid in the casing (10),
wherein
a plurality of compression chambers are formed inside the cylindrical wall (15) by the screw rotor (40) and the gates (51, 61),
the plurality of compression chambers include: a first compression chamber (21) in which the fluid introduced into the casing (10) with a suction pressure is compressed to a pressure higher than the suction pressure; and a second compression chamber (22) to which the fluid compressed in the first compression chamber (21) is sent via an intermediate pressure space (S), and
the adjustment mechanism is configured to adjust an intermediate pressure, which is a pressure of the fluid in the intermediate pressure space (S), in a two-stage operation in which the fluid is compressed in the first compression chamber (21) and the second compression chamber (22).

2. The screw compressor of claim 1, wherein

the adjustment mechanism includes a valve (80) movable to an opposing region (V) indicating a rotor space surrounded by the gate rotors (50, 60) and the screw rotor (40), and
the valve (80) changes timing at which the second compression chamber (22) is fully closed, by changing a position of the valve (80) in the opposing region (V).

3. The screw compressor of claim 2, wherein
the valve (80) changes a volume of the second compression chamber (22) at start of a compression phase for the fluid in the second compression chamber (22) by changing the timing at which the second compression chamber (22) is fully closed.

4. The screw compressor of claim 2 or 3, wherein
the valve (80) switches between a single-stage op-

eration in which the fluid is compressed in the first compression chamber (21) out of the first compression chamber (21) and the second compression chamber (22) and the two-stage operation.

5. The screw compressor of claim 4, wherein
the valve (80) is movable to a separation position (W) apart from the rotor space, and when located at the separation position (W), the valve (80) maintains a state in which the intermediate pressure space (S) communicates with an outside of the screw compressor.

6. The screw compressor of claim 5, further comprising:

inside the casing (10), a first passage (91) and a second passage (92) which communicate with the intermediate pressure space (S), wherein
the valve (80)
when located in the opposing region (V), allows the fluid to be sent from the intermediate pressure space (S) to the second compression chamber (22) via the first passage (91), and allows the fluid which has not entered the second compression chamber (22) because the second compression chamber (22) is fully closed to be sent to the intermediate pressure space (S) via the second passage (92), and
when located at the separation position (W), allows the fluid in the intermediate pressure space (S) to be sent to the outside of the screw compressor via the first passage (91), and allows the fluid in the intermediate pressure space (S) to be sent to the outside of the screw compressor via the second passage (92).

7. The screw compressor of claim 5 or 6, wherein

the two-stage operation is performed when the valve (80) is located in the opposing region (V),
the intermediate pressure is adjusted by changing the position of the valve (80) in the opposing region (V), and
the single-stage operation is performed when the valve (80) is located at the separation position (W).

8. The screw compressor of any one of claims 2 to 7, wherein
the position of the valve (80) is continuously changeable, and the timing at which the second compression chamber (22) is fully closed is thus continuously adjustable.

9. The screw compressor of claim 6, wherein

the first passage (91) and the second passage (92) are located on one side (J1) in a movement direction (J) of the valve (80) with respect to the separation position (W), and
the one side (J1) in the movement direction (J) indicates a direction toward the opposing region (V) in the movement direction (J) of the valve (80) from the separation position (W).

10. The screw compressor of claim 6 or 9, wherein

the valve (80) includes an end surface (82) toward the one side (J1) in the movement direction (J) of the valve (80), and the second passage (92) is disposed so as to face the end surface (82), and
the one side (J1) in the movement direction (J) indicates a direction toward the opposing region (V) in the movement direction (J) of the valve (80) from the separation position (W).

11. The screw compressor of any one of claims 6, 9, and 10, wherein

the first passage (91) includes a first opening (91a) communicating with the second compression chamber (22),
the second passage (92) includes a second opening (92a) communicating with the second compression chamber (22), and
the second opening (92a) is located at a position lower than the first opening (91a).

12. The screw compressor of any one of claims 6 and 9 to 11, wherein
the second passage (92) extends along an axis (N) of the valve (80).

13. A refrigeration apparatus comprising: the screw compressor of any one of claims 1 to 12.

FIG.1

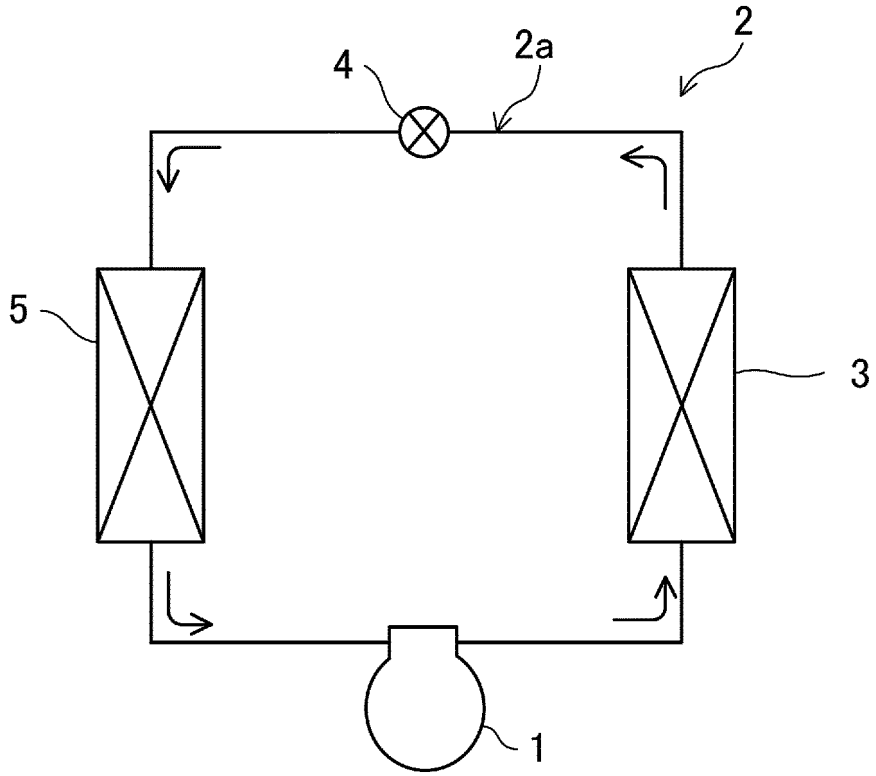


FIG.2

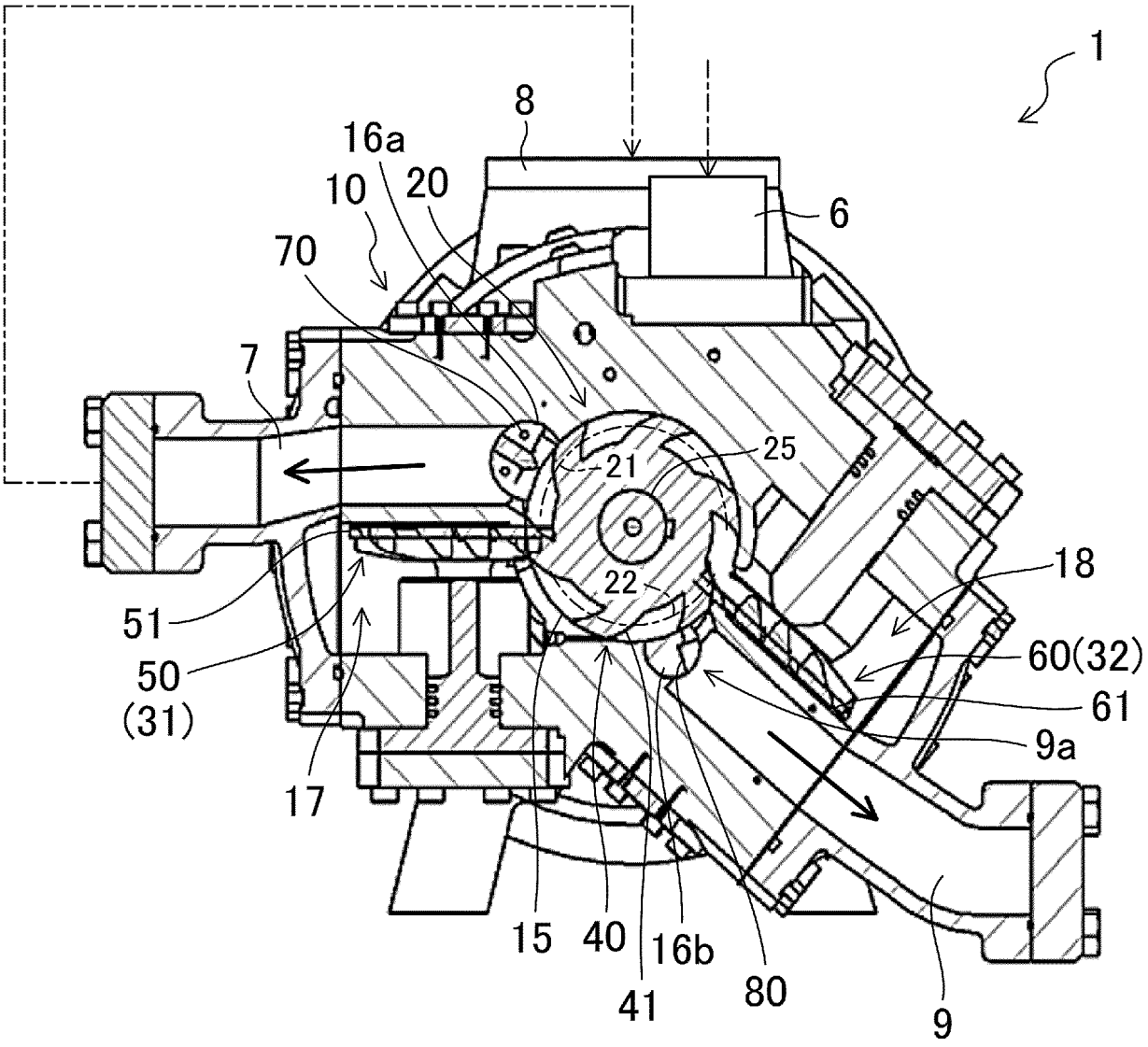


FIG.3

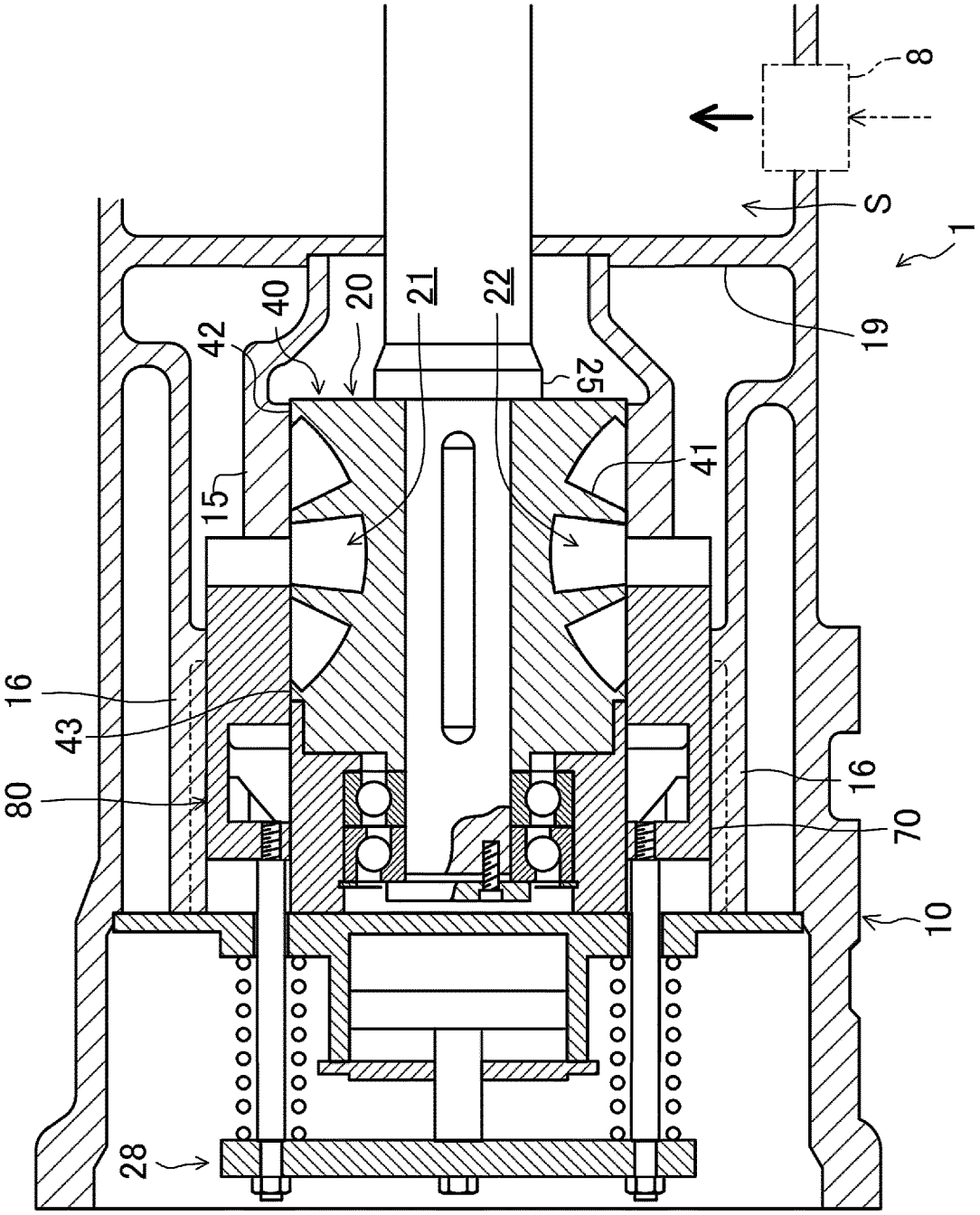


FIG.4

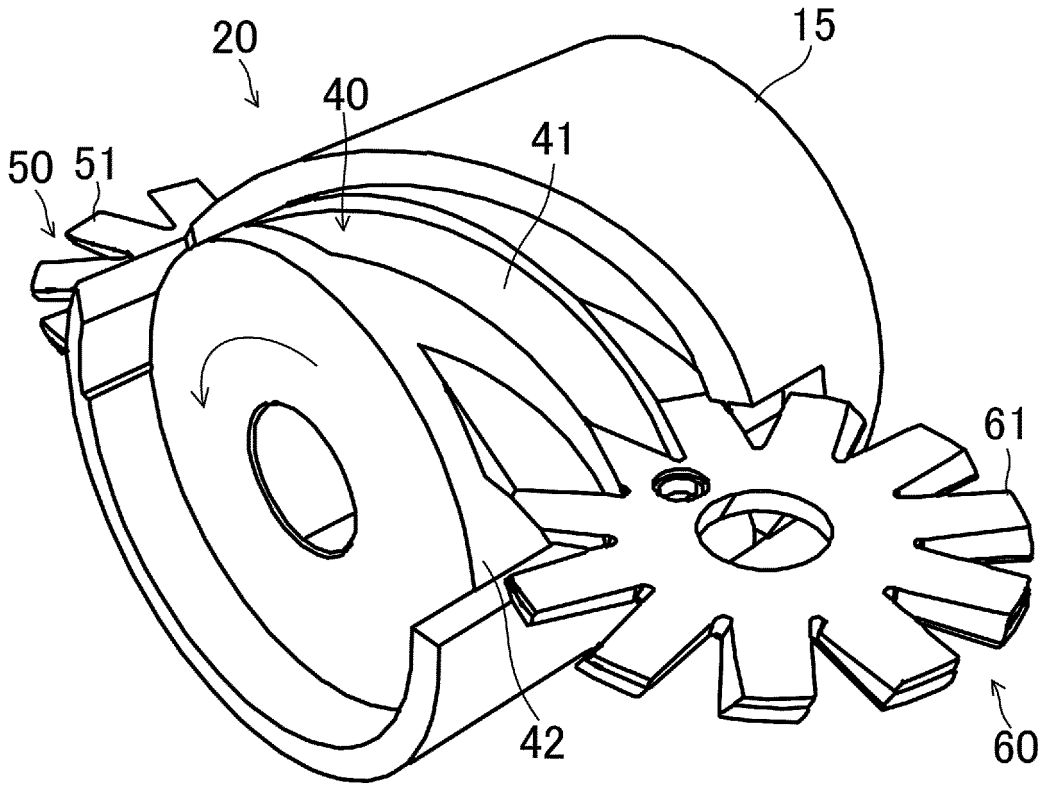


FIG.5

LOW STAGE SIDE

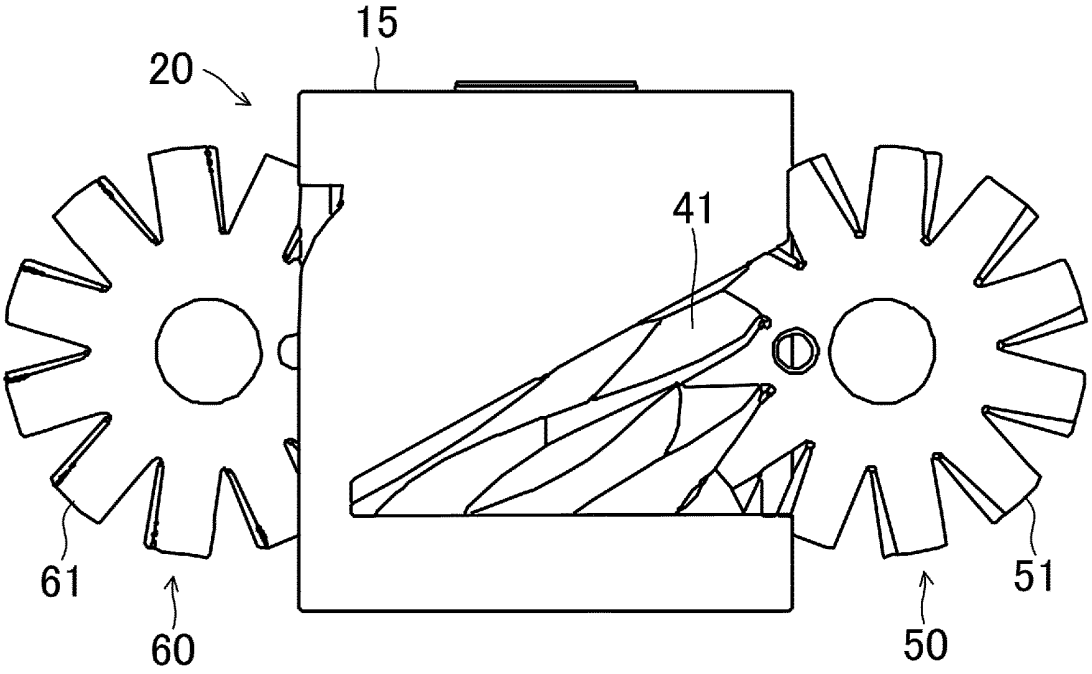


FIG.6

HIGH STAGE SIDE

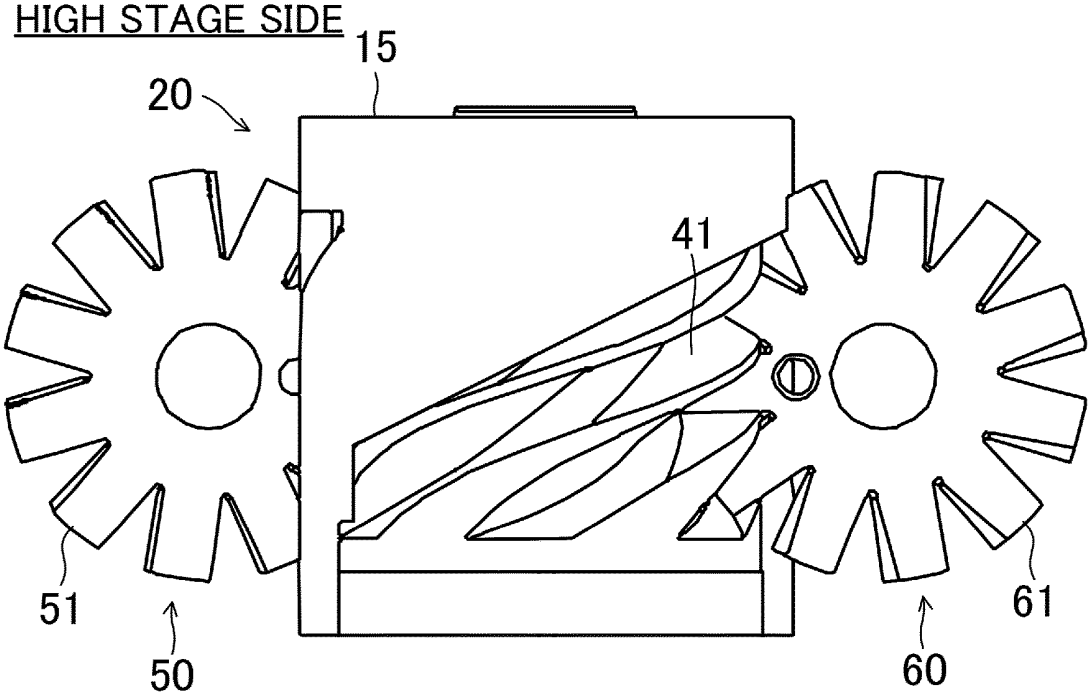


FIG.7

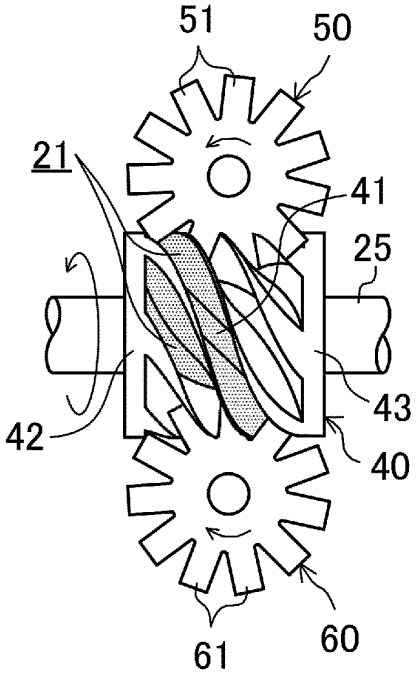

51
50
21
41
25
43
42
40
61
60
SUCTION

FIG.8

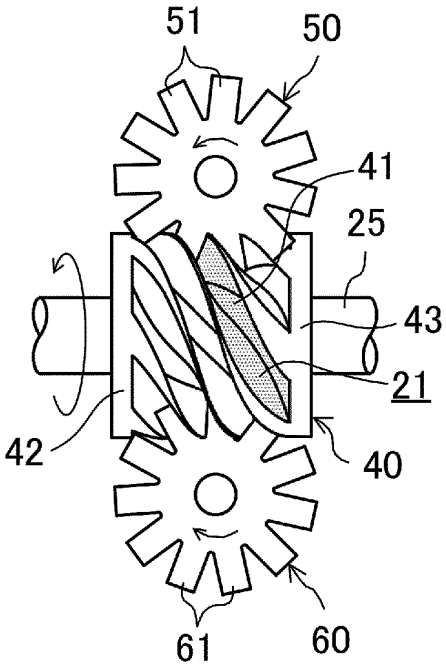

51
50
41
25
43
21
42
40
61
60
COMPRESSION

FIG.9

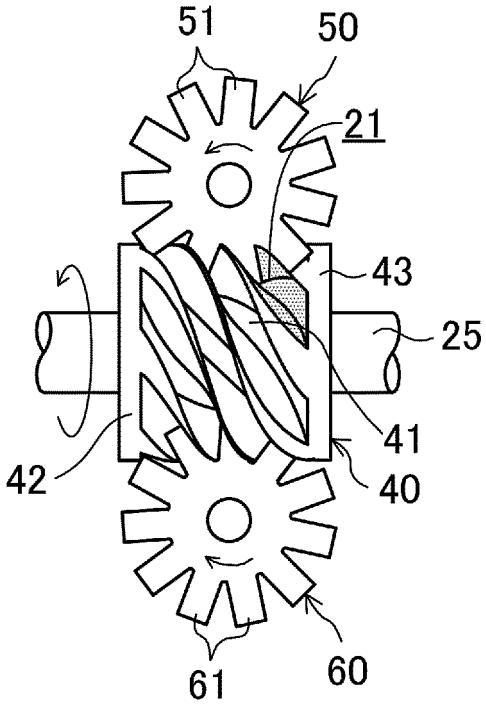
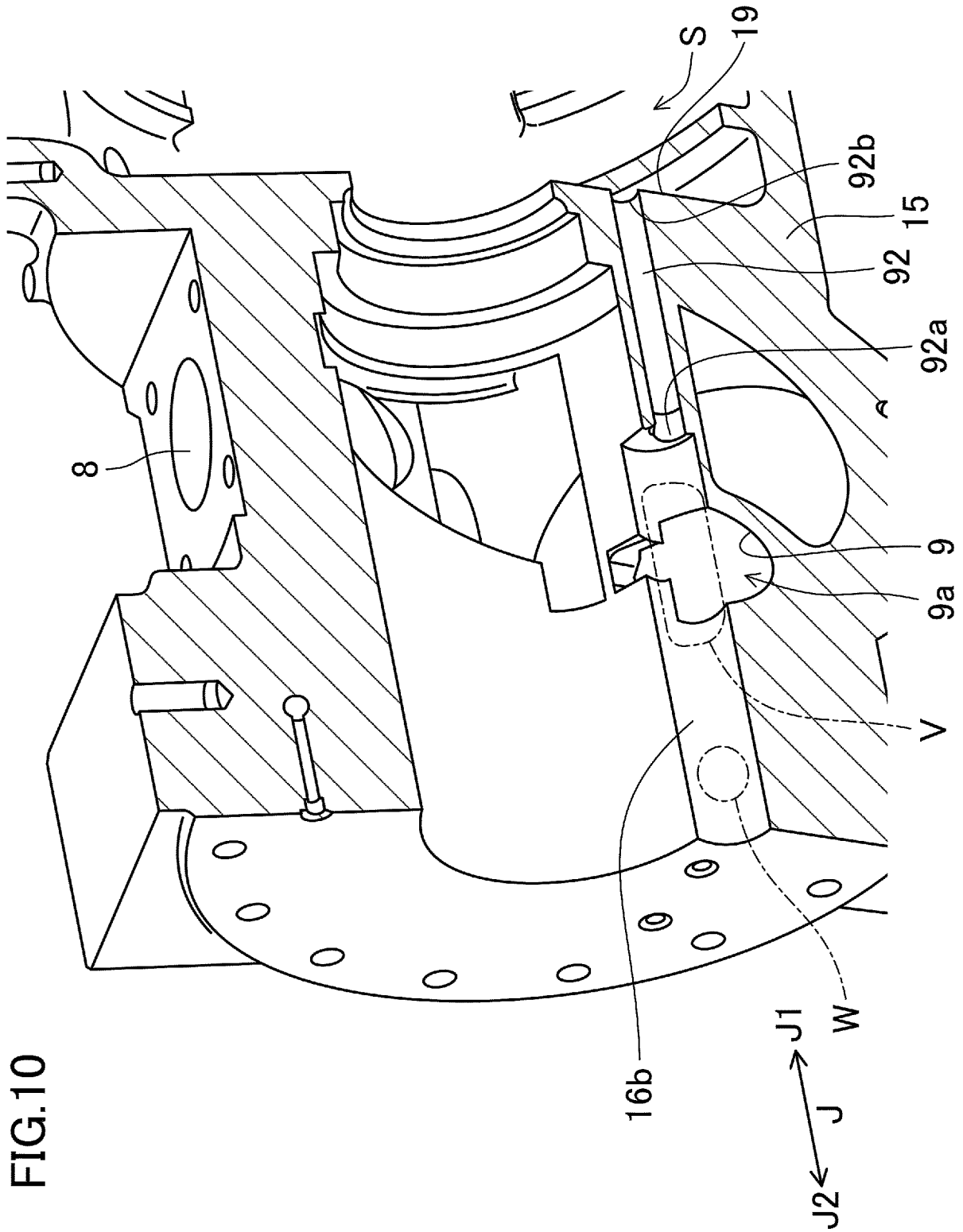


FIG.10



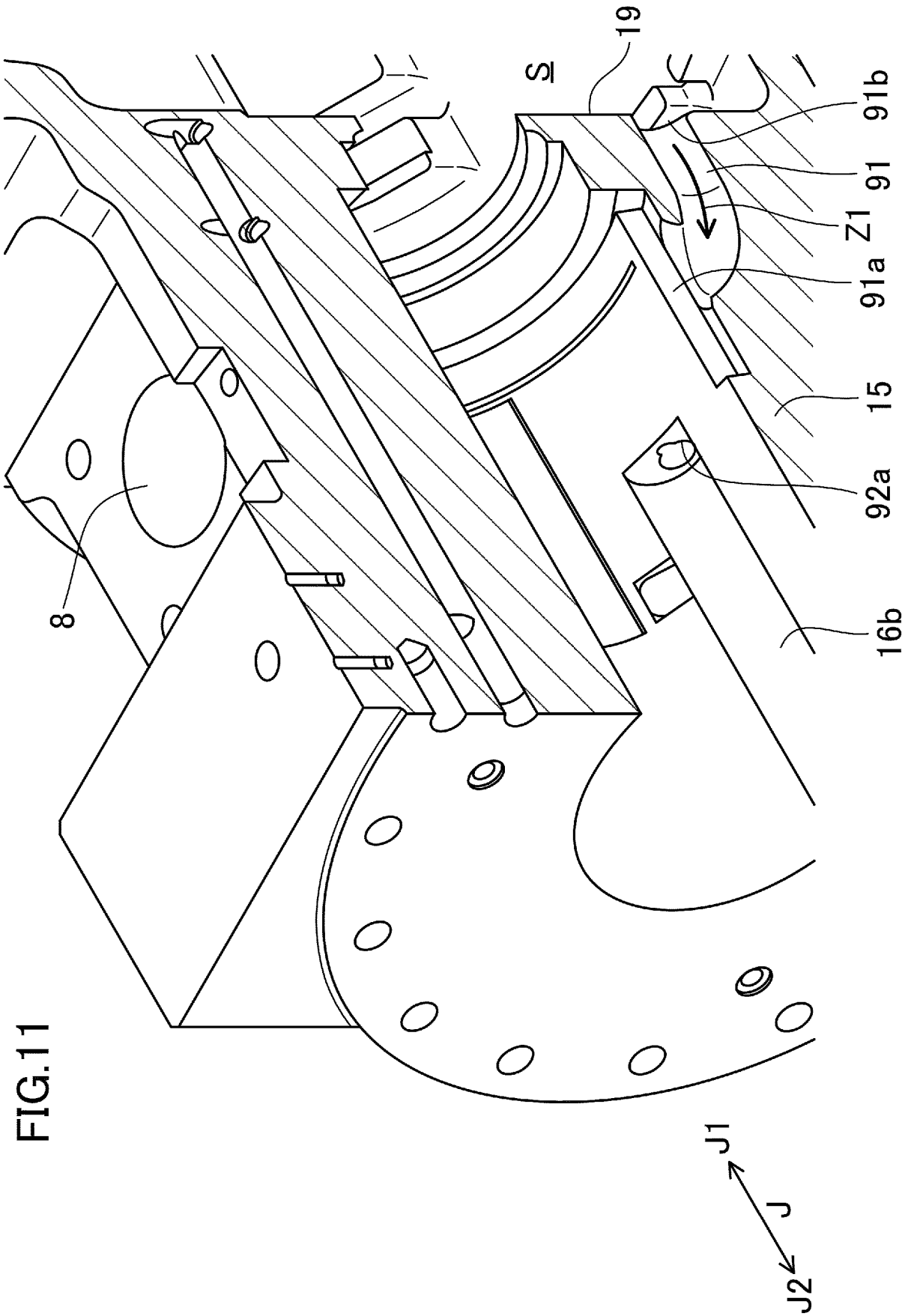


FIG.11

FIG.12

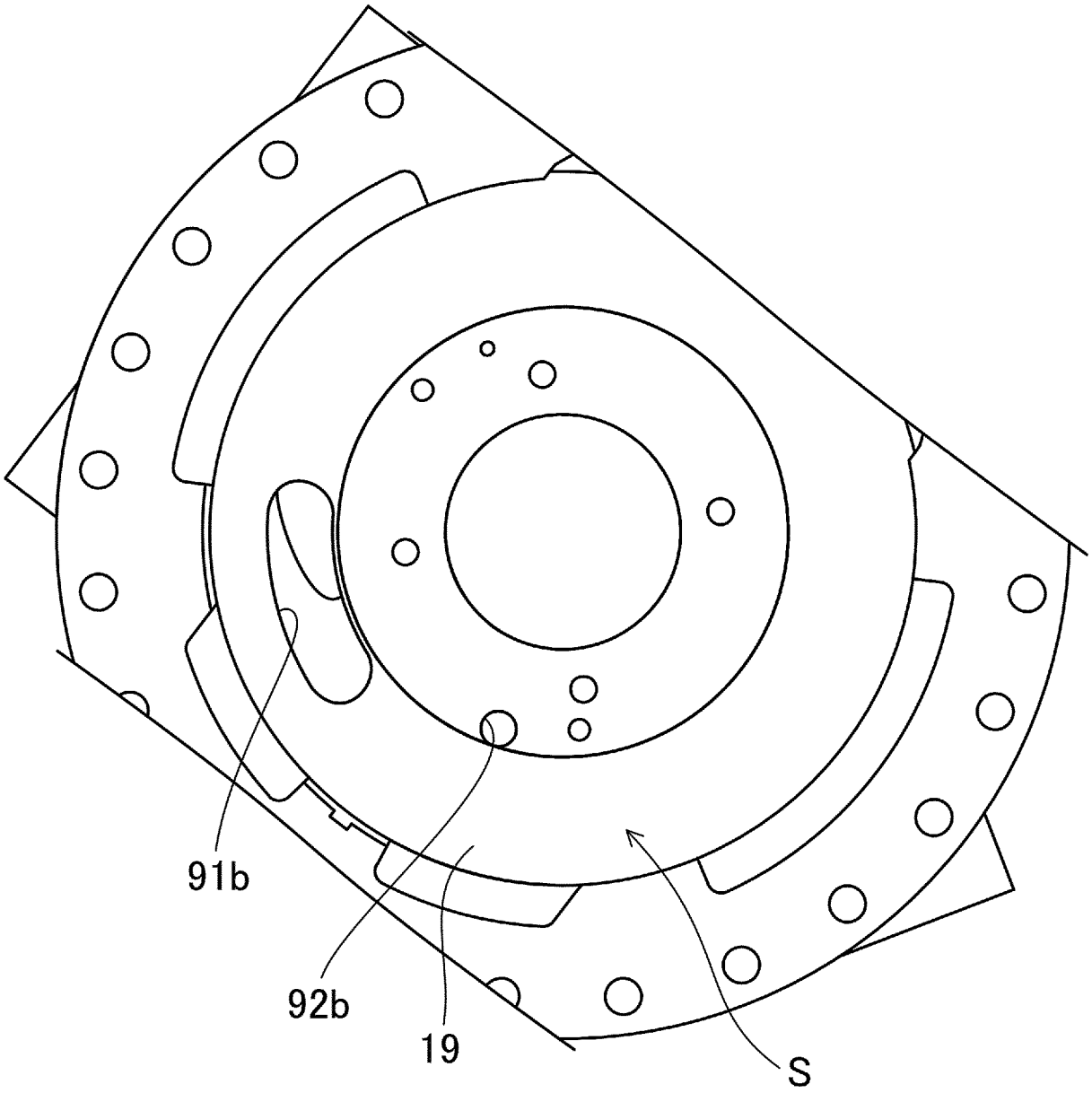


FIG.13

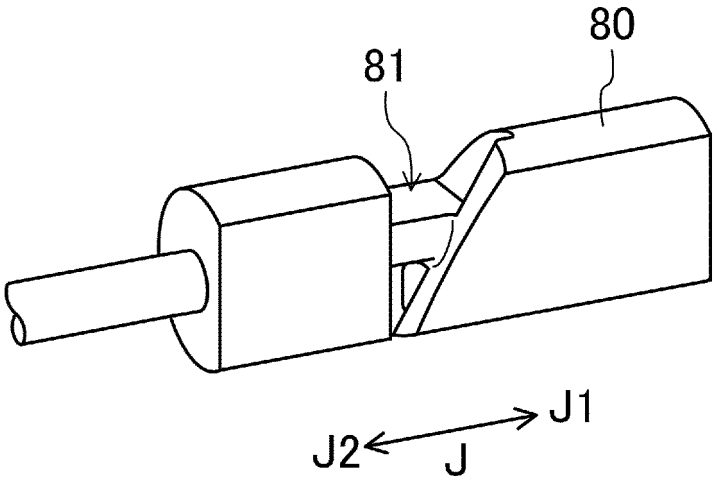


FIG.14

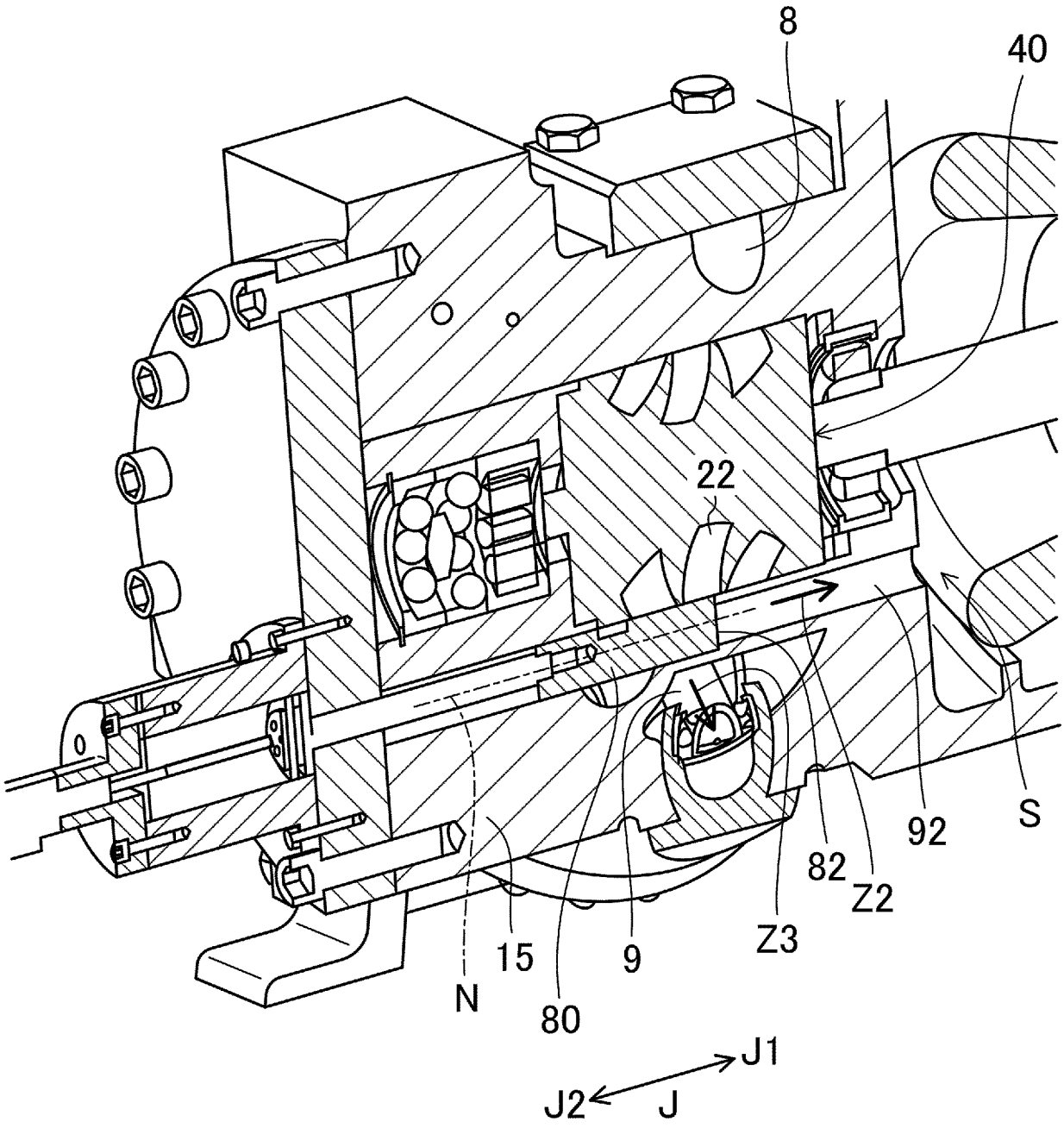


FIG.15

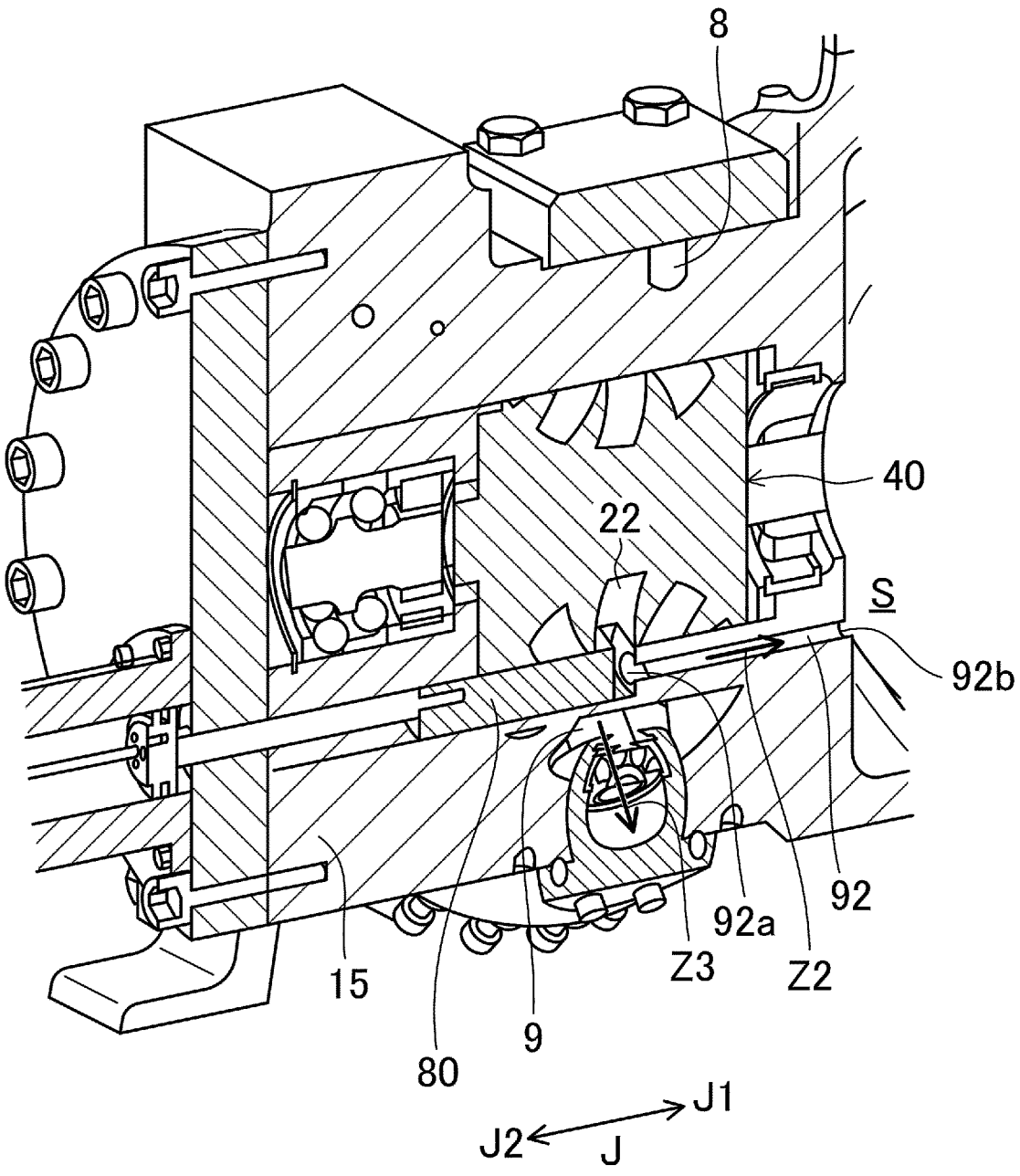
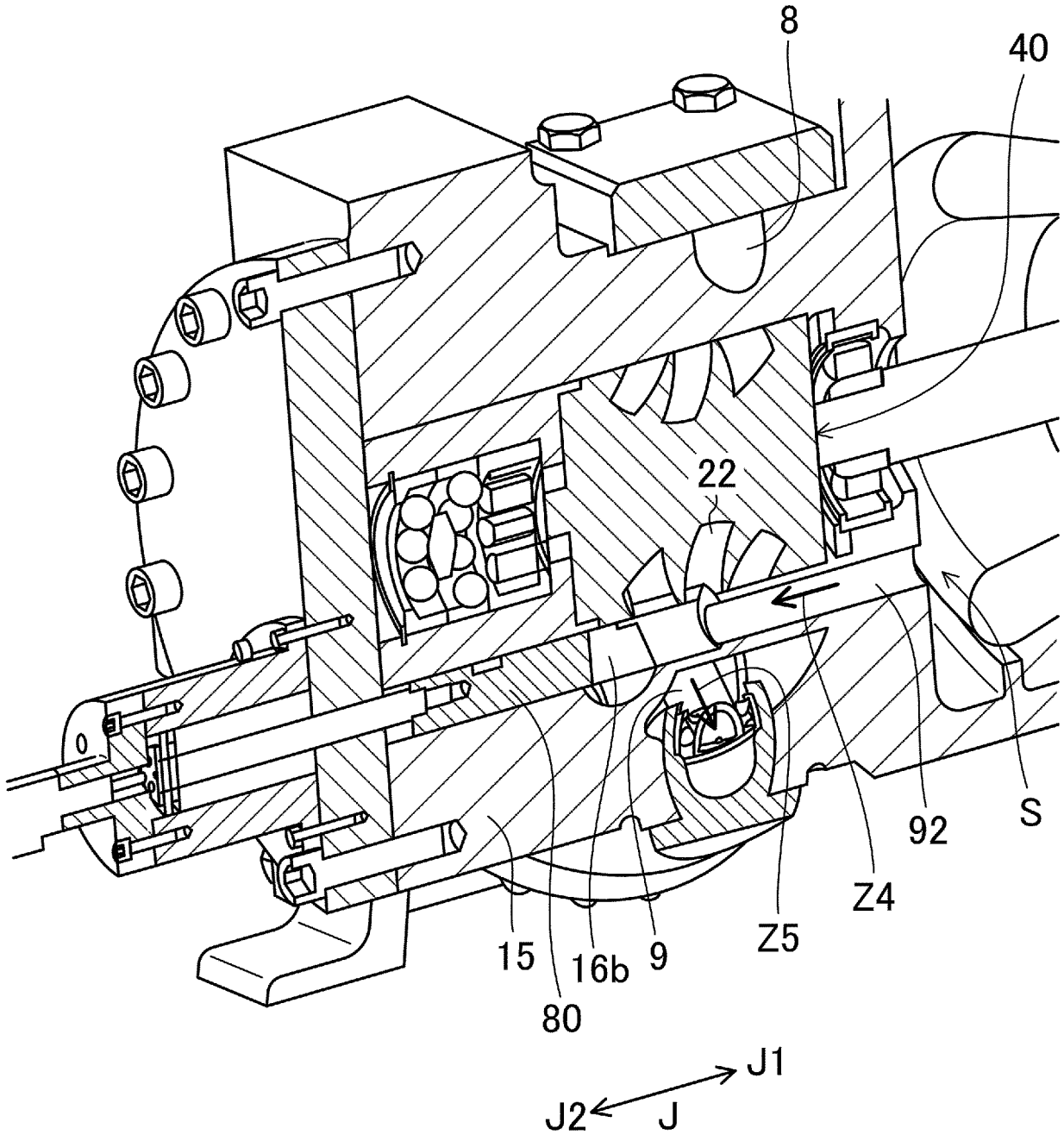


FIG.16



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2024/011792

A. CLASSIFICATION OF SUBJECT MATTER

F04C 18/52(2006.01)i; ***F04C 18/16***(2006.01)i
FI: F04C18/52; F04C18/16 P

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04C18/52; F04C18/16

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2024
Registered utility model specifications of Japan 1996-2024
Published registered utility model applications of Japan 1994-2024

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2021-162021 A (DAIKIN INDUSTRIES, LTD.) 11 October 2021 (2021-10-11) paragraphs [0066]-[0077], fig. 2-4	1-3
Y		4-5, 7-8, 13
A		6, 9-12
Y	JP 2011-132886 A (DAIKIN INDUSTRIES, LTD.) 07 July 2011 (2011-07-07) paragraph [0040], fig. 1	4-5, 7-8, 13

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 2024	**28 May 2024**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2024/011792

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2021-162021 A	11 October 2021	US 2023/0015175 A1 paragraphs [0038]-[0049], fig. 2-4 EP 4105486 A1 CN 115244302 A WO 2021/200858 A1	
JP 2011-132886 A	07 July 2011	(Family: none)	

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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