(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 477 883 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
18.12.2024 Bulletin 2024/51

(21) Application number: **22926095.5**

(22) Date of filing: **19.12.2022**

(51) International Patent Classification (IPC):
F04B 39/00 *(2006.01)* ***F04B 39/16*** *(2006.01)*
F04C 23/00 *(2006.01)* ***F04C 29/00*** *(2006.01)*
F04C 29/04 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04B 39/00; F04B 39/16; F04C 23/00; F04C 29/00; F04C 29/04

(86) International application number:
PCT/JP2022/046606

(87) International publication number:
WO 2023/153081 (17.08.2023 Gazette 2023/33)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **09.02.2022 JP 2022019133**

(71) Applicant: **Hitachi Industrial Equipment Systems Co., Ltd.**
Tokyo 101-0021 (JP)

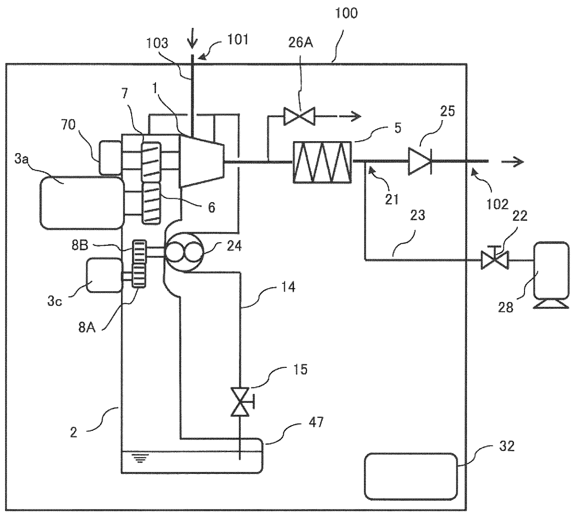
(72) Inventors:
- **ISHIZUKA, Yuki**
  Tokyo 101-0021 (JP)
- **ITOU, Yuuji**
  Tokyo 101-0021 (JP)

(74) Representative: **MERH-IP Matias Erny Reichl Hoffmann**
Patentanwälte PartG mbB
Paul-Heyse-Straße 29
80336 München (DE)

(54) OIL-FREE AIR COMPRESSOR

(57) There is provided an oil-free air compressor that prevents oil from entering a compressor body by preventing a reverse rotation of the compressor body when the compressor is in shutdown, while improving the rust prevention effect, and that has improved reliability. An oil-free air compressor 100 includes an oil-free compressor body 1 that compresses air, and that outputs the compressed air; a cooler 5 that is connected to the compressor body, and that cools the compressed high-temperature air; a dry air supply mechanism for supplying dry air to an output side of the compressor body; and a mechanism for preventing a reverse rotation of the compressor body during a shutdown of the compressor.

FIG.1



EP 4 477 883 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to an oil-free air compressor such as an oil-free screw compressor.

BACKGROUND ART

[0002] There are oil-free (oil-less) and oil-lubricated air compressors. An oil-free screw compressor does not use lubricating oil or has a structure in which the lubricating oil does not enter a compression chamber, and provides clean compressed air that does not contain oil, and rotors rotate without being in contact with each other, so that the oil-free screw compressor has the advantage of having good durability and requiring little maintenance.

[0003] In addition, in the air compressor, rust occurs due to moisture contained in compressed air during shutdown, which is a risk, and it is necessary to prevent rust from occurring.

[0004] To address this problem, Patent Document 1 discloses a "rust prevention method for a compressor during shutdown in which when the compressor is in shutdown, dry gas containing no moisture or only a small amount of moisture is suctioned into the compressor, gas containing moisture remaining in the compressor is replaced with the dry gas, and the dry gas is sealed therein" as a "rust prevention method for a compressor during shutdown" (refer to claim 1).

CITATION LIST

PATENT DOCUMENT

[0005] Patent Document 1: JP H5-141350 A

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] Patent Document 1 discloses a technique in which dry gas is suctioned into the compressor during shutdown, gas containing moisture remaining in the compressor is replaced with the dry gas, and the dry gas is sealed therein, as the rust prevention method for a compressor during shutdown.

[0007] It is desirable that a position where the dry gas is supplied is on a discharge side of a compressor body and on a downstream side of a cooler. The reason is that air compressed by the compressor body becomes moist air when cooled by the cooler and it is very effective to directly replace the moist air with the dry gas.

[0008] In the compressor body, an internal gap is maintained at several tens of μm to prevent leakage of the air during compression. When male and female rotors are not in rotation, air has to pass through the very small gap to flow from an intake port to a discharge port of the compressor body. For that reason, even when the dry gas is supplied to a suction side, it is difficult for the dry gas to flow to a discharge side, and this approach is not suitable for the purpose of replacing the moist air with the dry gas.

[0009] On the other hand, when air is introduced into the discharge side of the compressor body from the outside, if a large amount of the dry air is introduced to greatly improve the rust prevention effect, a force acts to rotate the compressor body in a reverse direction. When the compressor body rotates in the reverse direction, a force acts to draw lubricating oil from bearings in the direction of a working chamber. If the lubricating oil is mixed into the working chamber, the advantage of the oil-free compressor, such as providing clean compressed air that does not contain oil, is impaired.

[0010] An object of the present invention is to provide an oil-free air compressor that prevents oil from entering a compressor body by preventing a reverse rotation of the compressor body when the compressor is in shutdown, while improving the rust prevention effect, and that has improved reliability.

SOLUTIONS TO PROBLEMS

[0011] In order to solve the above-described problems, one example of an "oil-free air compressor" of the present invention is an oil-free air compressor including: an oil-free compressor body that compresses air, and that outputs the compressed air; a cooler that is connected to the compressor body, and that cools the compressed high-temperature air; a dry air supply mechanism for supplying dry air to an output side of the compressor body; and a mechanism for preventing a reverse rotation of the compressor body during a shutdown of the compressor.

[0012] In addition, another example of the "oil-free air compressor" of the present invention is an oil-free air compressor including: an oil-free low-pressure stage compressor body and an oil-free high-pressure stage compressor body that compress air, and that output the compressed air; an intermediate-stage pipe connecting the low-pressure stage compressor body and the high-pressure stage compressor body; an intercooler that is provided in an intermediate stage, and that cools the compressed high-temperature air; an aftercooler provided on an output side of the high-pressure stage compressor body; a dry air supply mechanism for supplying dry air to the intermediate-stage pipe; and a mechanism for preventing a reverse rotation of the low-pressure stage compressor body during a shutdown of the compressor.

EFFECTS OF THE INVENTION

[0013] According to the present invention, it is possible to provide the oil-free air compressor that prevents the oil from entering the compressor body by preventing the reverse rotation of the compressor when the compressor is in shutdown, while improving the rust prevention effect, and that has improved reliability.

[0014] Problems, configurations, and effects other than those described above will be apparent from the description of the following embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a diagram showing an oil-free screw compressor according to a first embodiment of the present invention.
Fig. 2 is a diagram showing an oil-free screw compressor according to a second embodiment of the present invention.
Fig. 3 is a diagram showing an oil-free screw compressor according to a third embodiment of the present invention.
Fig. 4A is a schematic internal structure view showing a state of a trochoid pump when in operation.
Fig. 4B is a schematic internal structure view showing a state of the trochoid pump when closed.
Fig. 5 is a diagram showing an oil-free screw compressor according to a fourth embodiment of the present invention.
Fig. 6 is a diagram showing an oil-free screw compressor according to a fifth embodiment of the present invention.
Fig. 7 is a diagram showing an oil-free screw compressor according to a sixth embodiment of the present invention.
Fig. 8A is a cross-sectional plan view showing an internal structure of a compressor body of an oil-free screw compressor.
Fig. 8B is a cross-sectional front view showing an internal structure of the compressor body of the oil-free screw compressor.

MODE FOR CARRYING OUT THE INVENTION

[0016] Before embodiments of the present invention will be described, an oil-free screw compressor that is one example of an oil-free air compressor will be described.

[0017] Figs. 8A and 8B show cross-sectional views of a compressor body 1 of an oil-free screw compressor. Fig. 8A is a cross-sectional plan view, and Fig. 8B is a cross-sectional front view. The compressor body 1 is a capacity control air compressor that generates compressed air by allowing teeth of a pair of screw rotors, namely, a male rotor 50A and a female rotor 50B to mesh with each other in a state where a predetermined gap therebetween is maintained and allowing the screw rotors to rotate at high speed.

[0018] The male rotor 50A is integrated with or directly coupled to a rotor shaft 48A, and the female rotor 50B is integrated with or directly coupled to a rotor shaft 48B. In the rotor shafts of the male rotor 50A and the female rotor 50B, bearings 11A and 11B and bearings 12A and 12B are disposed in the direction of an air suction-side end portion and the direction of a discharge-side end portion, respectively, and rotatably support the rotor shafts. In addition, timing gears 9A and 9B are disposed at end portions of the rotor shafts 48A and 48B, respectively, the end portions being located further outside than the bearings 12A and 12B, and as the male rotor 50A connected to the rotor shaft 48A rotates, the male and female rotors rotate relative to each other due to meshing between the timing gears 9A and 9B. As the male and female rotors rotate, air suctioned from an intake port 41 is compressed in a working chamber 60, and then is supplied to a user side from a discharge port 42 through a predetermined compressed air path.

[0019] On a suction side of the rotor shafts 48A and 48B, a shaft seal portion 17 (17A and 17B) and a shaft seal portion 18 (18A and 18B) are disposed between the male and female rotors 50A and 50B and the bearings 11A and 11B. The shaft seal portion 18 is an air seal, and is an annular member that reduces leakage of the air compressed in the working chamber 60 to a bearing 11A side and the like. The shaft seal portion 18 is in non-contact with the rotor shaft 48A and the like, and a gap therebetween is very small, approximately several tens of μm. The air seals 18A (male side) and 18B (female side) are disposed on the rotor shafts 48 of the male and female rotors 50A and 50B, respectively.

[0020] The shaft seal portion 17 is a screw seal, and serves to prevent lubricating oil from entering the working chamber 60, the lubricating oil being supplied to the bearings 11A and 11B via a path 34. Spiral angle grooves are applied to inner surfaces of the screw seals 17A and 17B, and the screw seals 17A and 17B are assembled in non-contact with the rotor shaft 48A and the like so as to maintain a very small gap therebetween. The rotation of the rotor shaft 48A and the like generates seal pressure in the groove portions of inner-diameter portions, so that the screw seals 17A and 17B act to push the lubricating oil back to the sides of the bearings 11A and 11B.

[0021] In addition, a groove is formed in a circumferential direction on the rotor shaft 48A and the like between the shaft seal portions 17 and 18, and a hole portion 43 communicating with the outside air from a compressor body casing is formed at a position facing the groove in the circumferential direction. The hole portion 43 functions as a gas vent hole or the like for allowing air leaking from the working chamber 60 to escape to the outside of the compressor body 1.

[0022] In addition, an oil drain port 45 that collects the lubricating oil which has lubricated the bearings 11A and 11B and returns the lubricating oil to an oil reservoir 47 of a gear casing 2 is formed between the screw seals 17A and 17B and the bearings 11A and 11B.

[0023] Similarly to the configuration on the suction side of the rotor shafts 48A and 48B, a shaft seal portion 20 (air seal) and a shaft seal portion 19 (screw seal) are also disposed on a discharge side of the rotor shafts 48A and

48B. The shaft seal portion 19 and the shaft seal portion 20 are disposed between the rotors 50A and 50B and the bearings 12A and 12B. In addition, a hole portion 44 communicating with the outside air and functioning as a gas vent for compressed air leaking from the working chamber 60 is formed between the shaft seal portion 19 and the shaft seal portion 20 of the compressor body casing.

[0024] Three bearings 12A and three bearings 12B are disposed on each of the male and female rotor shafts. Furthermore, in the compressor body casing, a path 33 for supplying the lubricating oil from above is formed at a position between these three bearings 12. In addition, a discharge port 46 that collects the lubricating oil from a position between the bearings 12A and 12B and the screw seals 19A and 19B is formed in the compressor body casing. The lubricating oil supplied from the path 33 lubricates the bearings 12A and 12B, and then is collected from the oil drain port 46.

[0025] A path 35 for supplying the lubricating oil to above the timing gears 9A and 9B is formed in the compressor body casing, and the lubricating oil lubricates the timing gears 9A and 9B, and then is collected in the oil reservoir 47 from the oil drain port 45 formed at a lower portion. Incidentally, the path 35 is formed to branch off from the path 33 midway on the compressor casing, and the oil drain port 46 is formed to merge with the oil drain port 45 midway.

[0026] When the compressor body rotates in a forward direction, the shaft seal portion 17 (screw seal) acts to push the lubricating oil back to the sides of the bearings 11A and 11B; however, when the compressor body rotates in a reverse direction, the shaft seal portion 17 acts to draw the lubricating oil from the bearings in the direction of the working chamber, so that it is not preferable that compressor body rotates in the reverse direction.

[0027] According to the present invention, in such an oil-free air compressor, the oil is prevented from entering the compressor body by preventing reverse rotation of the compressor body when the compressor is in shutdown, while improving the rust prevention effect, and reliability is improved.

[0028] Hereinafter, embodiments of the present invention will be described with reference to the drawings. However, the present invention should not be interpreted as being limited to contents of the embodiments shown below. Those skilled in the art would easily understand that specific configurations of the present invention can be changed without departing from the concept or scope of the present invention.

[0029] In addition, in configurations of the invention to be described below, the same reference signs are used for the same portions or portions having the same functions in common between different drawings, and duplicate descriptions will be omitted.

FIRST EMBODIMENT

[0030] Fig. 1 shows an oil-free screw compressor according to a first embodiment of the present invention. Incidentally, Fig. 1 shows a case where the minimum necessary devices are installed, and other devices may be installed.

[0031] A compressor 100 includes a compressor body 1, a gear casing 2, a motor 3a as a drive source for the compressor body 1, and a motor 3c as a drive source for an oil pump 24. A speed-increasing drive gear 6 is attached to an output shaft of the motor 3a disposed on a side surface of the gear casing 2. The speed-increasing drive gear 6 meshes with a speed-increasing driven gear 7 set to a predetermined gear ratio, and transmits a driving force to a male rotor of the compressor body 1 via a rotor shaft connected to the speed-increasing driven gear 7.

[0032] The oil pump 24 is attached to a side surface of the gear casing 2 through flange fitting, and a driving force is transmitted to the oil pump 24 via an oil pump drive gear 8A being attached to the motor 3c and an oil pump driven gear 8B that meshes with the oil pump drive gear 8A at a predetermined gear ratio.

[0033] The oil pump 24 is a pump that circulates lubricating oil to various drive units of the compressor 100, and pressure-feeds the lubricating oil to various oil paths using the driving force transmitted via an oil pump shaft, the various oil paths being disposed in the compressor 100. The oil pump 24 suctions the lubricating oil from an oil reservoir 47 via an opening-closing valve 15, the oil reservoir 47 being provided at a lower portion of the gear casing 2, and pressure-feeds the lubricating oil to an oil cooler (not shown) via a path 14. The oil cooler is an air-cooled or water-cooled heat exchanger using a fan (not shown), and cools the lubricating oil to a predetermined temperature or less.

[0034] Air compressed to be high temperature by the compressor body 1 becomes moist air when cooled in an aftercooler 5. For that reason, replacing the moist air with dry air is effective in preventing rust.

[0035] In the present embodiment, a dry air supply line 23 including a dry air supply port 21 and a supply valve 22 is provided on a downstream side of the aftercooler 5, and dry air stored in an air tank 28 is supplied to the dry air supply line 23. The supply valve 22 is caused to perform an opening and closing operation at a predetermined timing by a control panel 32.

[0036] When the compressor is in shutdown, if high-pressure dry air is supplied to a discharge side of the compressor body 1, the pressure on the discharge side of the compressor body 1 increases, thereby rotating the compressor body 1 in a reverse direction, which is a risk. Therefore, in the present embodiment, a brake device 70 that operates when the compressor is in shutdown is provided for the compressor body 1.

[0037] The brake device 70 is connected to the male rotor of the compressor body 1, and is controlled by the control panel 32 to prevent the male rotor from rotating during the supply of the dry air. By employing this configuration, the compressor body 1 can be prevented from rotating in the reverse direction during the supply of the dry air.

[0038] The operation of the compressor is as follows.

[0039] When the compressor is in operation, air is suctioned into the compressor body 1 from an air suction port 101 through an air suction pipe 103. The compressed air that is compressed to be high temperature by the compressor body 1 is cooled by the aftercooler 5, and is output from a compressed air discharge port 102 via a check valve 25.

[0040] When the compressor is in shutdown, the motor 3a is stopped and the compressor body 1 is stopped. Then, an air release valve 26A connected between the compressor body 1 and the aftercooler 5 is opened to release pressure inside the compressor. Then, the dry air stored in the air tank 28 is supplied to an output side of the aftercooler 5 from the dry air supply line 23. The dry air supplied from the supply port 21 is released into the atmosphere from the air release valve 26A. At this time, since the pressure on the discharge side of the compressor body 1 increases due to the dry air supplied from the supply port 21, a force acts to rotate the compressor body 1 in the reverse direction; however, since braking is applied to the compressor body 1 by the brake device 70, the compressor body 1 is prevented from rotating in the reverse direction even when high-pressure dry air is supplied.

[0041] The brake device is one example of a mechanism for preventing reverse rotation of the compressor body. Any mechanism may be used as long as the mechanism can prevent reverse rotation of the compressor body, and as another example, a ratchet mechanism or the like may be used.

[0042] According to the present embodiment, in the single-stage compressor, while the rust prevention effect is improved by supplying high-pressure dry air to the pipe on the output side of the aftercooler when the compressor is in shutdown, and the brake device that operates when the compressor is in shutdown is provided for the compressor body, so that reverse rotation of the compressor body can be prevented. And, it is possible to provide the oil-free air compressor that prevents the oil from entering the compressor body and that has improved reliability.

SECOND EMBODIMENT

[0043] Fig. 2 shows an oil-free screw compressor according to a second embodiment of the present invention. Incidentally, Fig. 2 shows a case where the minimum necessary devices are installed, and other devices may be installed.

[0044] The compressor 100 includes a low-pressure stage compressor body la, a high-pressure stage compressor body 1b, the gear casing 2, and the motors 3a and 3b as drive sources. The low-pressure stage compressor body 1a and the high-pressure stage compressor body 1b are attached to the vicinity of an upper portion of the side surface of the gear casing 2 through flange fitting. Speed-increasing drive gears 6A and 6B are attached to the output shafts of the motors 3a and 3b disposed on the side surface of the gear casing 2. The speed-increasing drive gears 6A and 6B mesh with speed-increasing driven gears 7A and 7B set to a predetermined gear ratio, and transmit driving forces to a male rotor of the low-pressure stage compressor body 1a and a male rotor of the high-pressure stage compressor body 1b via rotor shafts connected to the speed-increasing driven gears 7A and 7B.

[0045] An intercooler 4 is provided on a discharge side of the low-pressure stage compressor body 1a, and cools air that is compressed to be high temperature. An intermediate-stage pipe 13 connecting the intercooler 4 and the high-pressure stage compressor body 1b is provided, and supplies the compressed air cooled by the intercooler 4 to the high-pressure stage compressor body 1b.

[0046] The aftercooler 5 is provided on a discharge side of the high-pressure stage compressor body lb, cools the air that is compressed to be high temperature, and outputs the air via the check valve 25.

[0047] Since the air compressed by the low-pressure stage compressor body 1a becomes moist air when cooled in the intercooler 4, replacing the moist air and dry air when the compressor is in shutdown is effective in preventing rust. For that reason, the intermediate-stage pipe 13 between the intercooler 4 and the high-pressure stage compressor body 1b is provided with the dry air supply line 23 including the dry air supply port 21 and the supply valve 22, and the dry air stored in the air tank 28 is supplied to the dry air supply line 23. The supply valve 22 is caused to perform an opening and closing operation at a predetermined timing by the control panel 32.

[0048] When the compressor is in shutdown, if high-pressure dry air is supplied to the intermediate-stage pipe 13, pressure on the discharge side of the low-pressure stage compressor body 1a increases, thereby rotating the low-pressure stage compressor body 1a in the reverse direction, which is a risk. Therefore, in the present embodiment, the brake device 70 that operates when the compressor is in shutdown is provided for the low-pressure stage compressor body 1a.

[0049] The brake device 70 is connected to the male rotor of the low-pressure stage compressor body la, and is controlled by the control panel 32 to prevent the rotor from rotating during the supply of the dry air. By employing this configuration, the low-pressure stage compressor body can be prevented from rotating in the reverse direction during the supply of the dry air.

[0050] The operation of the compressor is as follows.

[0051] When the compressor is in operation, air is suctioned into the low-pressure stage compressor body 1a from the air suction port 101 through the air suction pipe 103. The compressed air that is compressed to be high temperature by the low-pressure stage compressor body 1a is cooled by the intercooler 4, and is supplied to the high-pressure stage compressor body 1b. The compressed air that is further compressed to be high temperature by the high-pressure stage compressor body 1b is cooled by the aftercooler 5, and is output from the compressed air discharge port 102 via the check valve 25.

[0052] When the compressor is in shutdown, the motors 3a and 3b are stopped and the low-pressure stage compressor body 1a and the high-pressure stage compressor body 1b are stopped. Then, the air release valve 26A connected between the low-pressure stage compressor body 1a and the intercooler 4 and an air release valve 26B connected between the high-pressure stage compressor body 1b and the aftercooler 5 are opened to release pressure inside the compressor. Then, then, the dry air stored in the air tank 28 is supplied to the intermediate-stage pipe 13 from the dry air supply line 23 including the dry air supply port 21 and the supply valve 22. The dry air supplied from the supply port 21 to the intermediate-stage pipe 13 is released into the atmosphere from the air release valves 26A and the air release valve 26B; however, since pressure in the intermediate-stage pipe 13 increases due to the dry air supplied from the supply port 21, a force acts to rotate the low-pressure stage compressor body 1a in the reverse direction. At this time, since braking is applied to the low-pressure stage compressor body 1a by the brake mechanism 70, the low-pressure stage compressor body 1a is prevented from rotating in the reverse direction even when high-pressure dry air is supplied.

[0053] According to the present embodiment, while the rust prevention effect is improved by supplying high-pressure dry air to the intermediate-stage pipe when the compressor is in shutdown, the brake device that operates when the compressor is in shutdown is provided for the low-pressure stage compressor, so that reverse rotation of the compressor bodies can be prevented. And, it is possible to provide a multi-stage oil-free air compressor that prevents the oil from entering the compressor bodies and that has improved reliability.

THIRD EMBODIMENT

[0054] Fig. 3 shows an oil-free screw compressor according to a third embodiment of the present invention. In the second embodiment, the motor is provided for each of the low-pressure stage compressor body, the high-pressure stage compressor body, and the oil pump that supplies the lubricating oil; however, in the third embodiment, these components are driven by one motor.

[0055] The compressor 100 includes the low-pressure stage compressor body la, the high-pressure stage compressor body lb, the gear casing 2, and one motor 3 as a drive source. The speed-increasing drive gear 6 and the oil pump drive gear 8A are attached to an output shaft of the motor 3 disposed on the side surface of the gear casing 2. The speed-increasing drive gear 6 meshes with the speed-increasing driven gears 7A and 7B set to a predetermined gear ratio, and transmits driving forces to the male rotor of the low-pressure stage compressor body 1a via the rotor shaft connected to the speed-increasing driven gear 7A, and to the male rotor of the high-pressure stage compressor body 1b via the rotor shaft connected to the speed-increasing driven gear 7B.

[0056] In addition, the pump drive gear 8A meshes with the oil pump driven gear 8B set to a predetermined gear ratio. The pump driven gear 8B is connected to the oil pump shaft penetrating to the outside of the gear casing 2, and transmits a driving force to the oil pump 24.

[0057] In the compressor 100 of the present embodiment, the opening-closing valve 15 is provided on a suction side of the oil pump 24, namely, between the oil reservoir 47 and the oil pump 24.

[0058] Figs. 4A and 4B show a trochoid pump used as the oil pump, Fig. 4A shows a state of the trochoid pump when in operation, and Fig. 4B shows a state of the trochoid pump when closed.

[0059] In the trochoid pump, a working chamber formed by an inner rotor 51 and an outer rotor 52 pressure-feeds the lubricating oil from a suction flow path 55 to a discharge flow path 56 by expanding and contracting from a suction port 53 to a discharge port 54.

[0060] Here, when a force is applied to rotate the trochoid pump in the reverse direction, the working chamber expands and contracts from the discharge port 54 to the suction port 53, so that the lubricating oil flows back to the suction port 53 from the discharge port 54. At this time, when the suction flow path 55 is closed, the lubricating oil cannot be fed to the suction side, and a working space cannot contract, so that the pump is locked.

[0061] By controlling the opening-closing valve 15 to open during operation of the compressor 100 and to close during stop, as shown in Fig. 4B, the suction side 55 of the oil pump 24 is filled with the lubricating oil, so that reverse rotation of the oil pump 24 can be prevented. Since the oil pump 24 and the compressor bodies 1a and 1b are connected to each other via the drive gear 6, the compressor bodies 1a and 1b are not rotatable either if the oil pump 24 is not rotatable. Therefore, reverse rotation of the compressor bodies during stop of the compressor can be prevented.

[0062] Incidentally, the trochoid pump has been provided as one example; however, any gear pump can be used as long as the gear pump transfers a fluid through meshing between teeth of gears.

[0063] According to the present embodiment, in the multi-stage compressor, the low-pressure stage compressor body, the high-pressure stage compressor body, and the oil pump are driven by one motor via gears, and the opening-closing valve that opens during operation of the compressor and that closes during shutdown is provided on the suction side of the oil pump, so that reverse rotation of the compressor bodies when the compressor is in shutdown can be prevented. And, it is possible to provide the oil-free air compressor that prevents the oil from entering the compressor bodies and that has improved reliability.

FOURTH EMBODIMENT

[0064] Fig. 5 shows an oil-free screw compressor according to a fourth embodiment of the present invention. The third embodiment is a multi-stage compressor including the low-pressure stage compressor body 1a and the high-pressure stage compressor body 1b; however, the present embodiment is a single-stage compressor including one compressor body.

[0065] The compressor 100 includes the compressor body 1, the gear casing 2, and one motor 3 as a drive source. The speed-increasing drive gear 6 and the oil pump drive gear 8A are attached to the output shaft of the motor 3 disposed on the side surface of the gear casing 2. The speed-increasing drive gear 6 meshes with the speed-increasing driven gear 7 set to a predetermined gear ratio, and transmits a driving force to the male rotor of the compressor body 1 via the rotor shaft connected to the speed-increasing driven gear 7. In addition, the pump drive gear 8A meshes with the oil pump driven gear 8B set to a predetermined gear ratio. The pump driven gear 8B is connected to the oil pump shaft penetrating to the outside of the gear casing 2, and transmits a driving force to the oil pump 24. The opening-closing valve 15 is provided on the suction side of the oil pump 24, namely, in the oil pump suction path 14 between the oil reservoir 47 and the oil pump 24.

[0066] As described in the first embodiment, the air compressed to be high temperature by the compressor body 1 becomes moist air when cooled in the aftercooler 5. For that reason, replacing the moist air with dry air is effective in preventing rust.

[0067] In the present embodiment, the supply line 23 including the dry air supply port 21 and the supply valve 22 is provided on the downstream side of the aftercooler 5, and dry air stored in the air tank 28 is supplied to the supply line 23. The supply valve 22 is caused to perform an opening and closing operation at a predetermined timing by the control panel 32.

[0068] Since the check valve 25 in the oil pump suction path 14 is normally closed when the compressor is in shutdown, the supplied dry air passes through the air release valve 26A or the compressor body 1, and exits the compressor from the suction port 101, and at this time, a force acts to rotate the compressor body 1 in the reverse direction.

[0069] In the present embodiment, since the compressor body 1 is connected to the oil pump 24 via the drive gears 6 and 8A, reverse rotation of the compressor body 1 can be prevented by locking the rotation of the oil pump 24 as in the third embodiment.

[0070] According to the present embodiment, in the single-stage compressor, the compressor body and the oil pump are driven by one motor via gears, and the opening-closing valve that opens during operation of the compressor and that closes during shutdown is provided on the suction side of the oil pump, so that reverse rotation of the compressor body when the compressor is in shutdown can be prevented. And, it is possible to provide the oil-free air compressor that prevents the oil from entering the compressor bodies and that has improved reliability.

FIFTH EMBODIMENT

[0071] Fig. 6 shows an oil-free screw compressor according to a fifth embodiment of the present invention. Incidentally, since the basic configuration is the same as that of the third embodiment shown in Fig. 3, differences will be described here. In the present embodiment, a dry air supply port is also provided on a suction side of a low-pressure stage compressor.

[0072] In the present embodiment, the suction pipe 103 is provided with a dry air supply line 23A including a dry air supply port 21A, the supply valve 22, and an orifice 33A. In addition, a dry air supply line 23B including a dry air supply port 21B, the supply valve 22, and an orifice 33B is provided in the intermediate stage.

[0073] The operation will be described.

[0074] When the compressor is in operation, air is suctioned into the low-pressure stage compressor body 1a from the air suction port 101 through the air suction pipe 103. The compressed air that is compressed to be high temperature by the low-pressure stage compressor body 1a is cooled by the intercooler 4, and is supplied to the high-pressure stage compressor body 1b. The compressed air that is compressed to be high temperature by the high-pressure stage compressor body 1b is cooled by the aftercooler 5, and is output from the compressed air discharge port 102 via the check valve 25.

[0075] when the compressor is in shutdown, the air release valve 26A connected between the low-pressure stage compressor body 1a and the inner cooler 4, and the air release valve 26B connected between the high-pressure stage compressor body 1b and the aftercooler 5 are opened to release pressure inside the compressor. Thereafter, by controlling the supply valve 22 to open through the control panel 32, the dry air stored in the air tank 28 is caused to pass through the dry air supply lines 23A and 23B, and is supplied into the compressor. The dry air supplied from the supply port 21B to the intermediate-stage pipe 13 is released into the atmosphere from the air release valve 26A and the air release valve 26B. The dry air supplied from the supply port 21A is released into the atmosphere from the suction port 101.

[0076] At this time, since pressure in the intermediate-stage pipe 13 increases due to the dry air supplied from the supply port 21B, a force acts to rotate the low-pressure stage compressor body 1a in the reverse direction, whereas the dry air supplied from the supply port 21A increases pressure in the suction pipe 103, so that a force is generated to rotate the low-pressure stage compressor body 1a in a forward direction. By setting the diameters of the orifices 33A and 33B in advance such that the force that rotates the low-pressure stage compressor body 1a in the forward direction and the force that rotates the low-pressure stage compressor body 1a in the reverse direction are balanced, the force that rotates the compressor in the forward direction and the force that rotates the compressor in the reverse direction are canceled out, so that reverse rotation of the compressor can be prevented.

[0077] Incidentally, in the present embodiment, the multi-stage compressor has been described as an example; however, the present embodiment can also be used for the single-stage compressor shown in Fig. 1. In that case, the dry air supply port 21 of the dry air supply line 23 may be connected to an outlet side of the aftercooler 5 to supply the dry air, the aftercooler 5 being provided on the discharge side of the compressor body 1, and the dry air supply port may be connected to the suction pipe 103, which is the suction side of the compressor body 1, to supply the dry air.

[0078] According to the present embodiment, when the compressor is in shutdown, the dry air is supplied to the intercooler or the aftercooler provided on the discharge side of the compressor body, and the dry air is also supplied to the suction side of the compressor body, so that reverse rotation of the compressor body can be prevented. And, it is possible to provide the oil-free air compressor that prevents the oil from entering the compressor body and that has improved reliability.

SIXTH EMBODIMENT

[0079] Fig. 7 shows an oil-free screw compressor according to a sixth embodiment of the present invention. In the present embodiment, an unloader 105 is provided between the air suction port 101 and the suction pipe 103 in the low-pressure stage and the dry air supply port 21A is provided between the unloader 105 and the low-pressure stage compressor body 1a. The other configurations are the same as those of the fifth embodiment.

[0080] The unloader 105 is a device that includes a valve thereinside, the valve throttling a path of compressed air, and that reduces power during unload operation of the compressor by controlling the valve to open during load operation and to close during unload operation. Since the compressor is normally stopped when unloading is stopped, the unloader is closed during shutdown.

[0081] The dry air supplied from the dry air supply port 21A during shutdown of the compressor remains between the unloader 105 and the compressor body 1a, so that pressure in the suction pipe 103 increases.

[0082] In the fifth embodiment, an air suction port 101 side of the suction pipe 103 is open to the atmosphere, and in order to increase the pressure in the suction pipe 103, the flow rate of the dry air supplied from the dry air supply port 21A should be set to be larger than that of the dry air supplied from the dry air supply port 21B; however, in the present embodiment, the amount of the dry air supplied from the dry air supply port 21A can be set to be smaller.

[0083] According to the present embodiment, since the unloader is provided between the air suction port and the suction pipe in the low-pressure stage, and the dry air supply port is provided between the unloader and the low-pressure stage compressor body, in addition to the effects of the fifth embodiment, the amount of the dry air supplied from the dry air supply port to the suction side of the low-pressure stage compressor body can be reduced.

[0084] Incidentally, the present invention is not limited to each embodiment described above, and includes various modification examples. For example, the above-described embodiments have been described in detail to facilitate understanding of the present invention, and are not necessarily limited to including all the described configurations. In addition, a part of the configuration of one embodiment can be replaced with the configuration of another embodiment, and the configuration of another embodiment can also be added to the configuration of one embodiment. In addition, it is possible to add, remove, or replace a part of the configuration of each embodiment with other configurations.

REFERENCE SIGNS LIST

[0085]

1 Compressor body
1a Low-pressure stage compressor body
1b High-pressure stage compressor body
2 Gear casing
3, 3a, 3b, 3c Motor
4 Intercooler
5 Aftercooler
6, 6A, 6B Drive gear
7 Driven gear
7A Low-pressure stage driven gear
7B High-pressure stage driven gear
8A Oil pump drive gear
8B Oil pump driven gear
13 Pipe (intermediate stage)
14 Oil pump suction path
15 Opening-closing valve
21, 21A, 21B Dry air supply port
22 Supply valve
23 Dry air supply line
24 Oil pump
25 Check valve
26A, 26B Air release valve
28 Air tank
32 Control panel
33A, 33B Orifice
47 Oil reservoir
70 Brake device
100 Compressor
101 Air suction port

102 Compressed air discharge port
103 Air suction pipe
105 Unloader

Claims

1. An oil-free air compressor comprising:

   an oil-free compressor body that compresses air, and that outputs the compressed air;
   a cooler that is connected to the compressor body, and that cools the compressed high-temperature air;
   a dry air supply mechanism for supplying dry air to an output side of the compressor body; and
   a mechanism for preventing a reverse rotation of the compressor body during a shutdown of the compressor.

2. The oil-free air compressor according to claim 1, wherein the compressor body is an oil-free screw compressor.

3. The oil-free air compressor according to claim 1, wherein the mechanism for preventing the reverse rotation of the compressor body is a brake device.

4. The oil-free air compressor according to claim 1, wherein the mechanism for preventing the reverse rotation of the compressor body is a ratchet mechanism.

5. The oil-free air compressor according to claim 1, further comprising:

   an oil pump that supplies lubricating oil to each bearing;
   an opening-closing valve provided on a suction side of the oil pump; and
   a single motor that drives the compressor body and the oil pump,
   wherein the oil pump is a gear pump,
   the motor, the compressor body, and the oil pump are connected to each other by gears, and
   the opening-closing valve is closed during the shutdown of the compressor.

6. The oil-free air compressor according to claim 5, wherein the gear pump is a trochoid pump.

7. The oil-free air compressor according to claim 1, wherein, further, the dry air supply mechanism supplies the dry air to a suction side of the compressor body.

8. The oil-free air compressor according to claim 7, further comprising:

   an unloader provided on the suction side of the compressor body and having a valve therein for throttling a path of the compressed air ,
   wherein the dry air supply mechanism supplies the dry air to a pipe between the unloader and the compressor body.

9. An oil-free air compressor comprising:

   an oil-free low-pressure stage compressor body and an oil-free high-pressure stage compressor body that compress air, and that output the compressed air;
   an intermediate-stage pipe connecting the low-pressure stage compressor body and the high-pressure stage compressor body;
   an intercooler that is provided in an intermediate stage, and that cools the compressed high-temperature air;
   an aftercooler provided on an output side of the high-pressure stage compressor body;
   a dry air supply mechanism for supplying dry air to the intermediate-stage pipe; and
   a mechanism for preventing a reverse rotation of the low-pressure stage compressor body during a shutdown of the compressor.

10. The oil-free air compressor according to claim 9, wherein the low-pressure stage compressor body and the high-pressure stage compressor body are oil-free screw compressors.

11. The oil-free air compressor according to claim 9, wherein the mechanism for preventing the reverse rotation of the low-pressure stage compressor body is a brake device.

12. The oil-free air compressor according to claim 9, wherein the mechanism for preventing the reverse rotation of the low-pressure stage compressor body is a ratchet mechanism.

13. The oil-free air compressor according to claim 9, further comprising:

   an oil pump that supplies lubricating oil to each bearing;
   an opening-closing valve provided on a suction side of the oil pump; and
   a single motor that drives the low-pressure stage compressor body, the high-pressure stage compressor body, and the oil pump,
   wherein the oil pump is a gear pump,
   the motor, the low-pressure stage compressor body, the high-pressure stage compressor body, and the oil pump are connected to each other by gears, and
   the opening-closing valve is closed during the

shutdown of the compressor.

14. The oil-free air compressor according to claim 9, wherein, further, the dry air supply mechanism supplies the dry air to a suction side of the low-pressure stage compressor body.

15. The oil-free air compressor according to claim 14, further comprising:

an unloader provided on the suction side of the low-pressure stage compressor body and having a valve therein for throttling a path of the compressed air,
wherein the dry air supply mechanism supplies the dry air to a pipe between the unloader and the low-pressure stage compressor body.

FIG.1

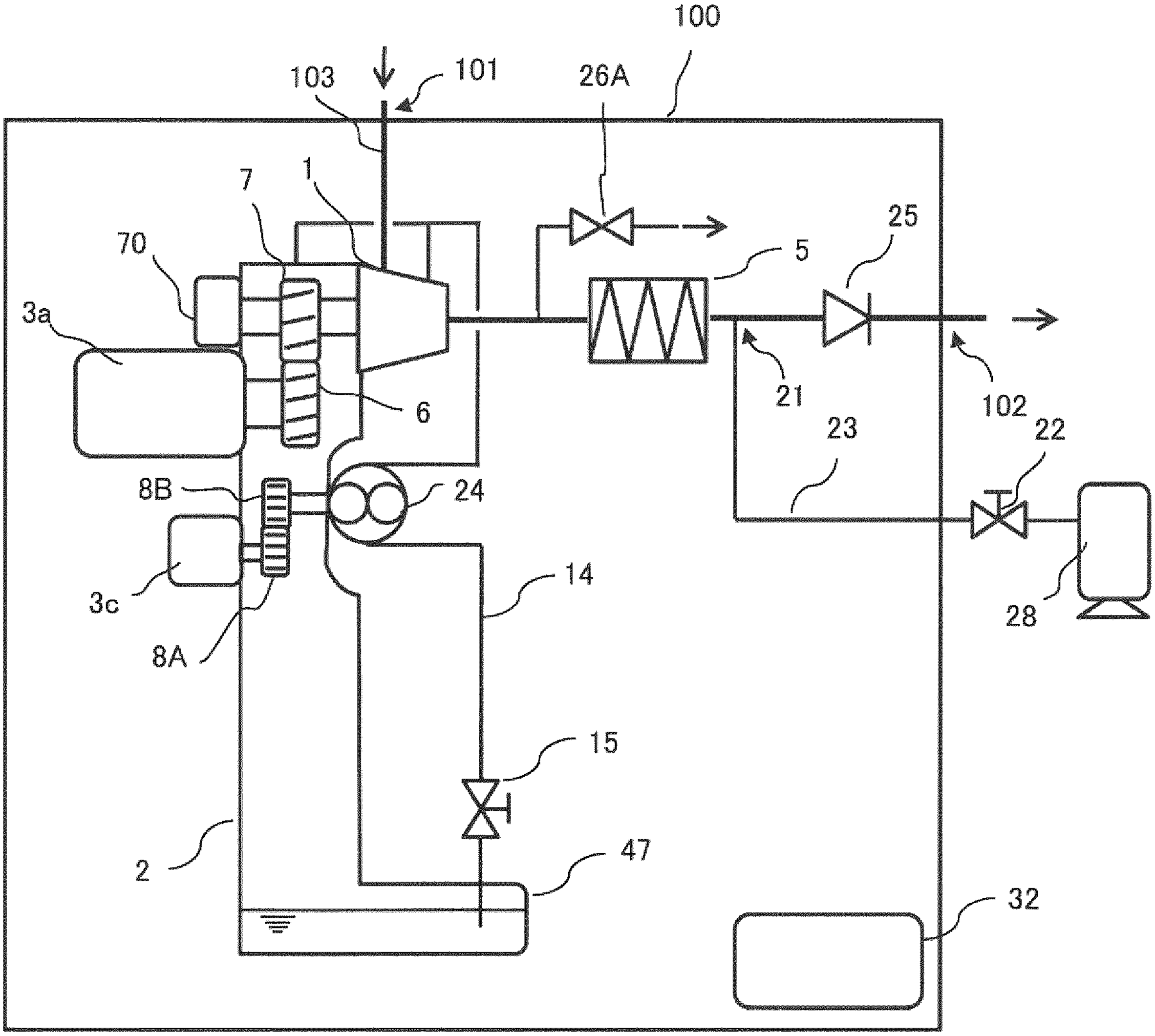

100
103
101
26A
7
1
70
25
5
3a
21
6
102
23
22
8B
24
3c
14
28
8A
15
2
47
32

FIG.2

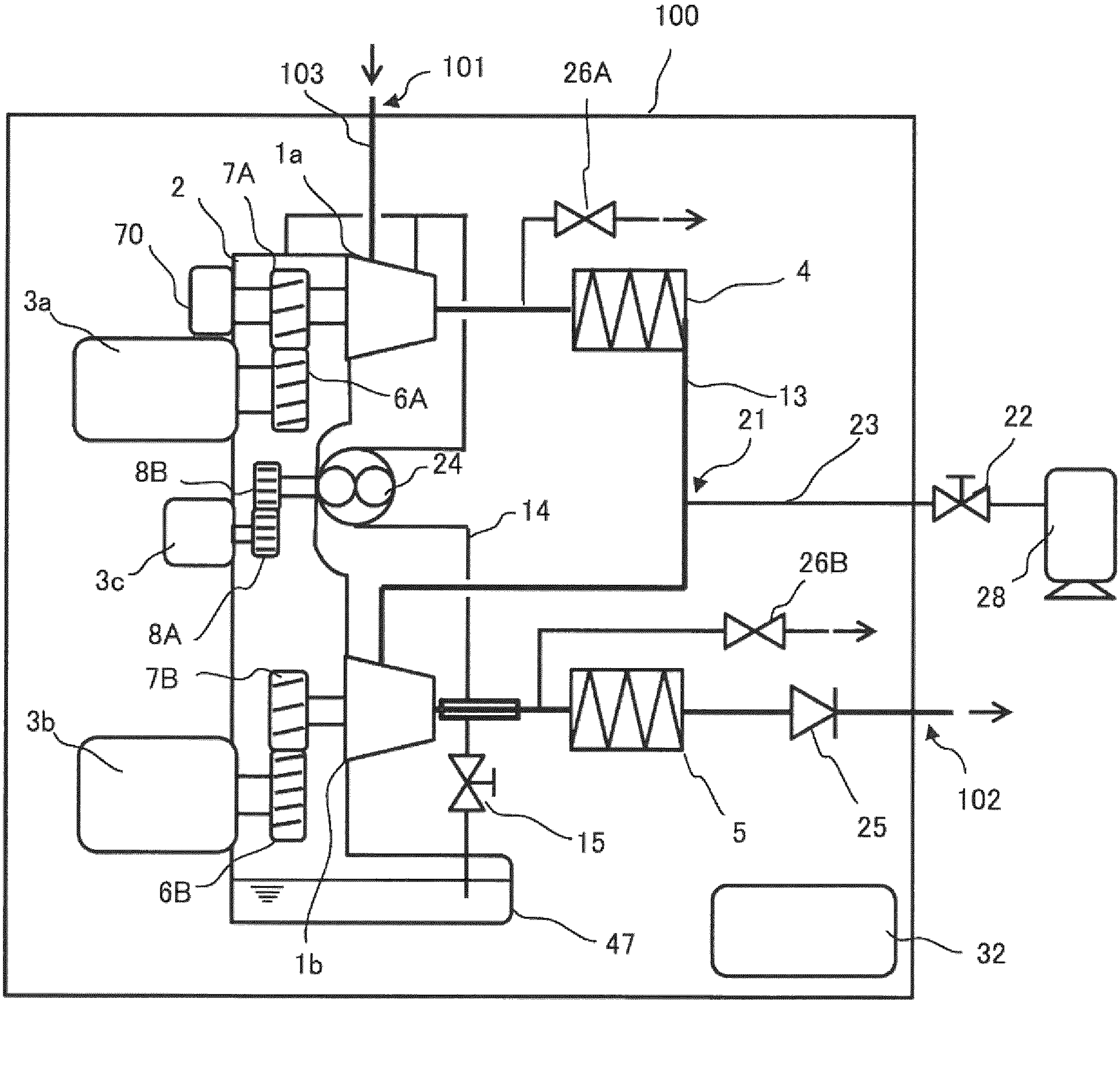

100
103
101
26A
1a
7A
2
70
3a
4
6A
13
21
23
22
8B
24
14
3c
26B
28
8A
7B
3b
15
5
25
102
6B
47
1b
32

FIG.3

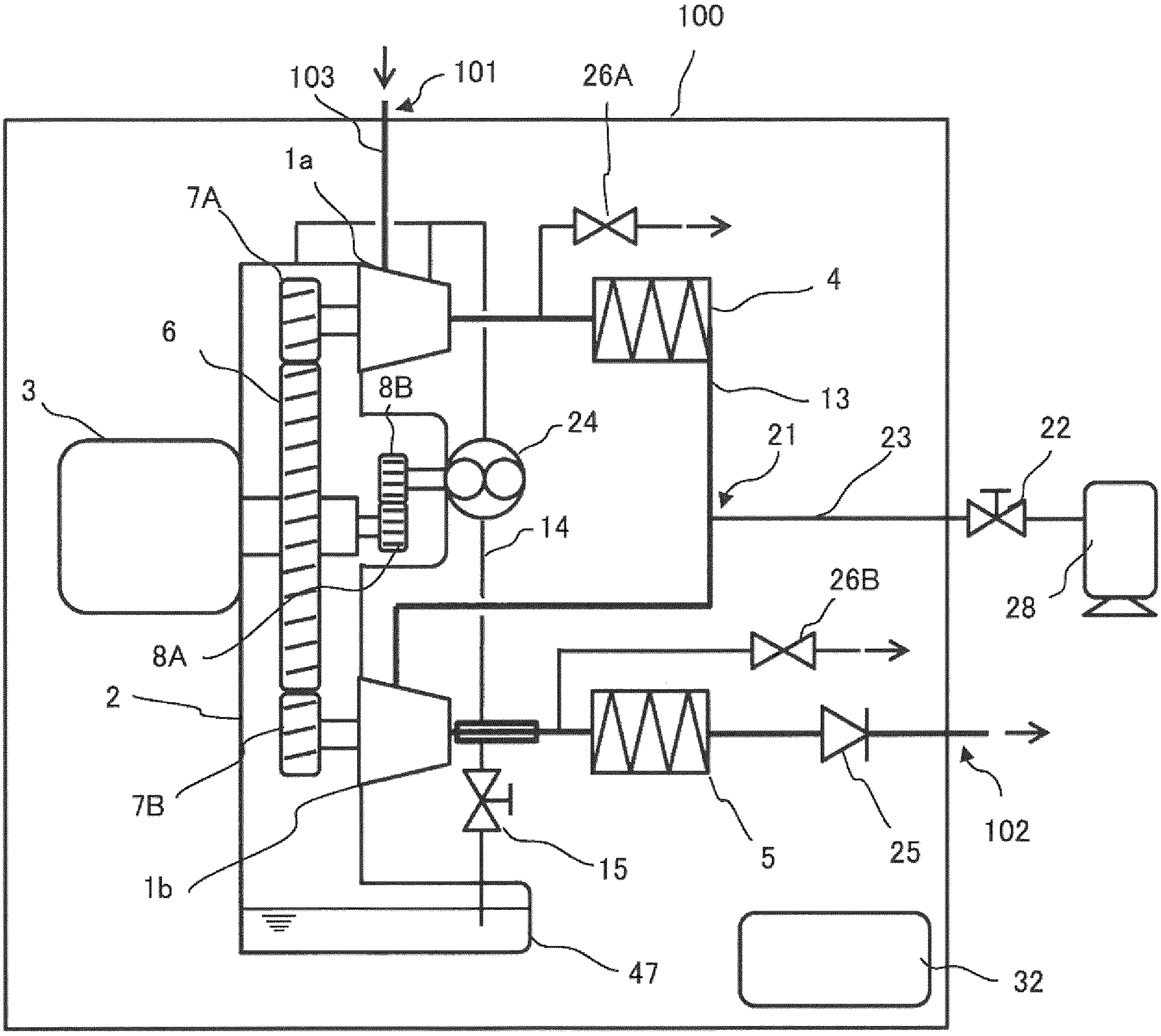

100
103
101
26A
1a
7A
4
6
8B
13
3
24
21
23
22
14
28
26B
8A
2
7B
15
5
25
102
1b
47
32

FIG.4A

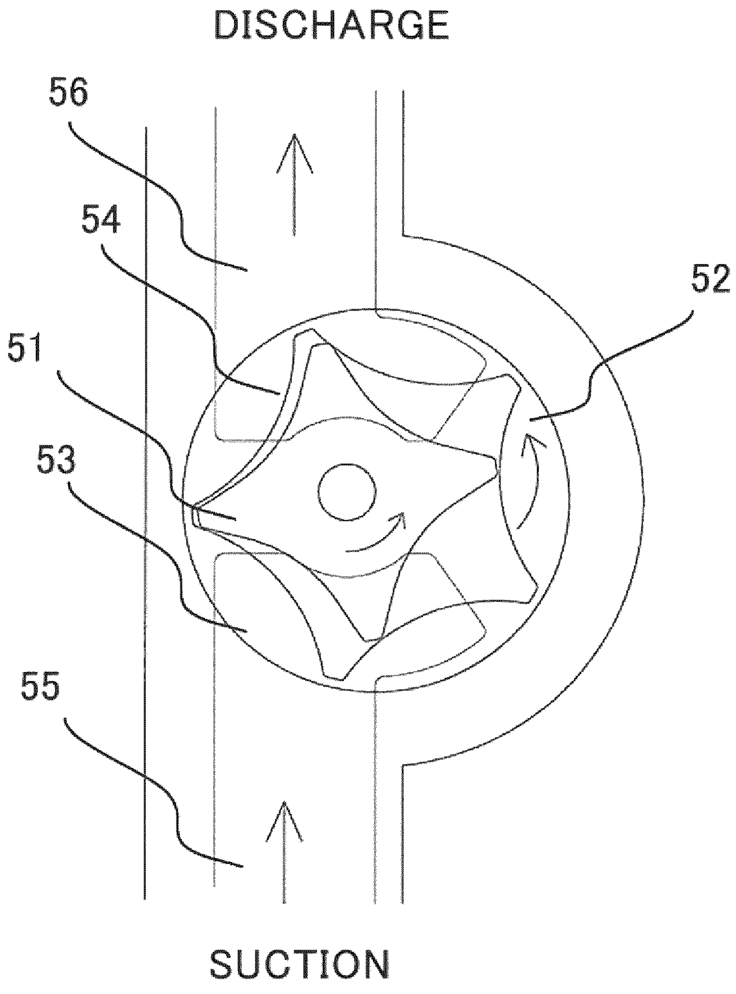
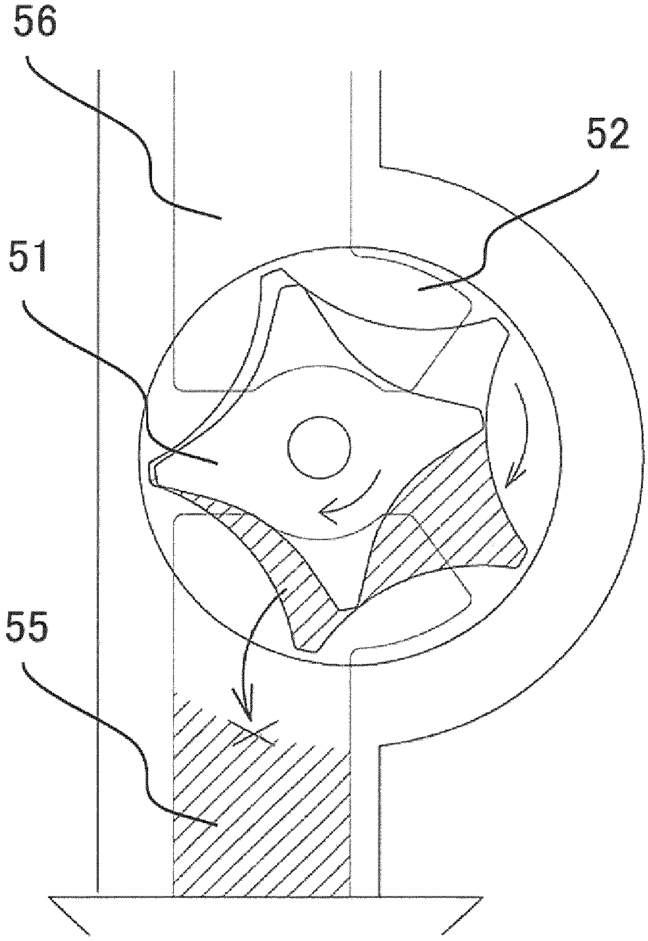


FIG.4B



CLOSED

FIG.5

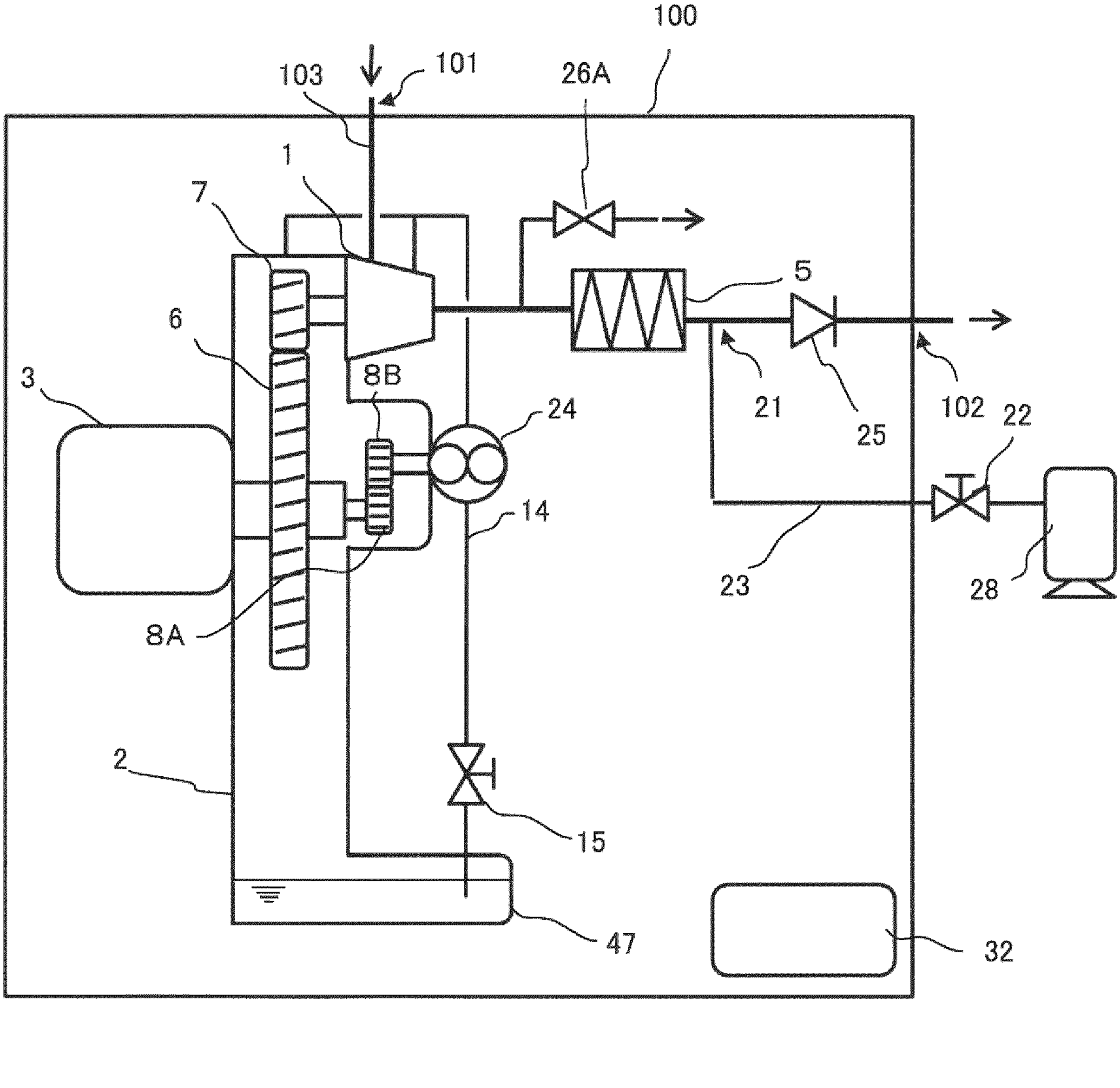
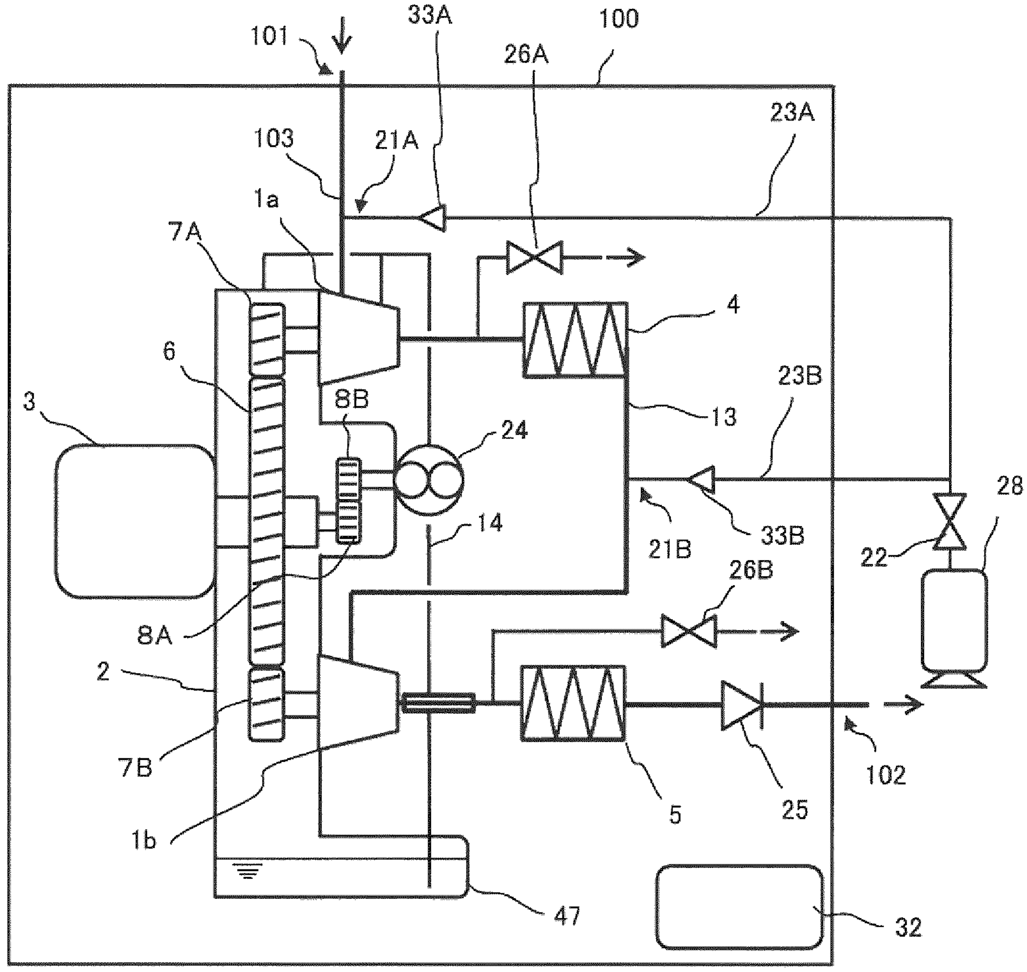


FIG.6



101
33A
100
26A
23A
103
21A
1a
7A
4
6
23B
3
8B
13
24
28
33B
14
21B
22
26B
8A
2
7B
102
1b
5
25
47
32

FIG.7

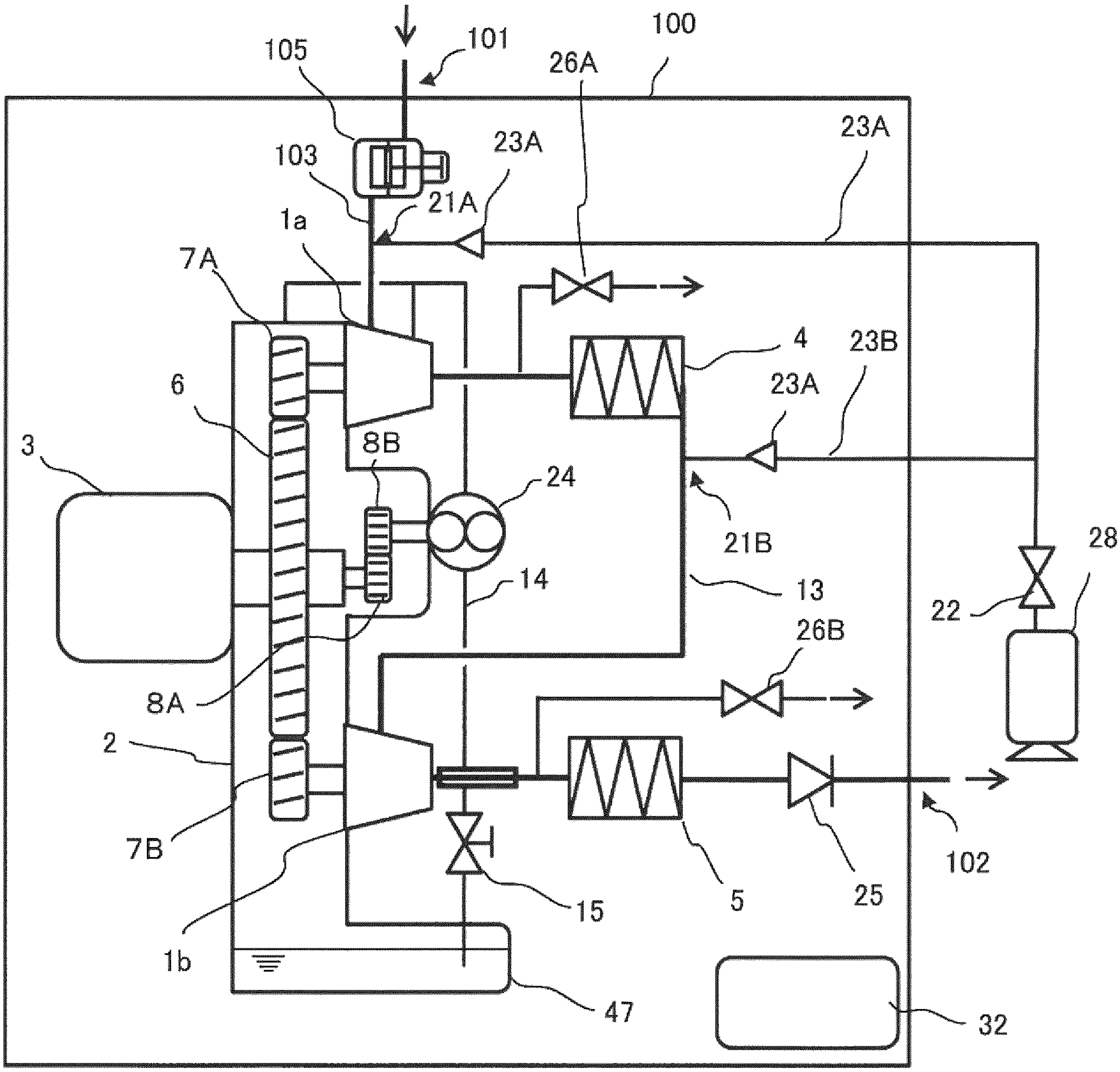

101
100
105
26A
103
23A
23A
21A
1a
7A
4
23B
6
23A
3
8B
24
21B
28
14
13
22
26B
8A
2
7B
15
5
25
102
1b
47
32

FIG.8A

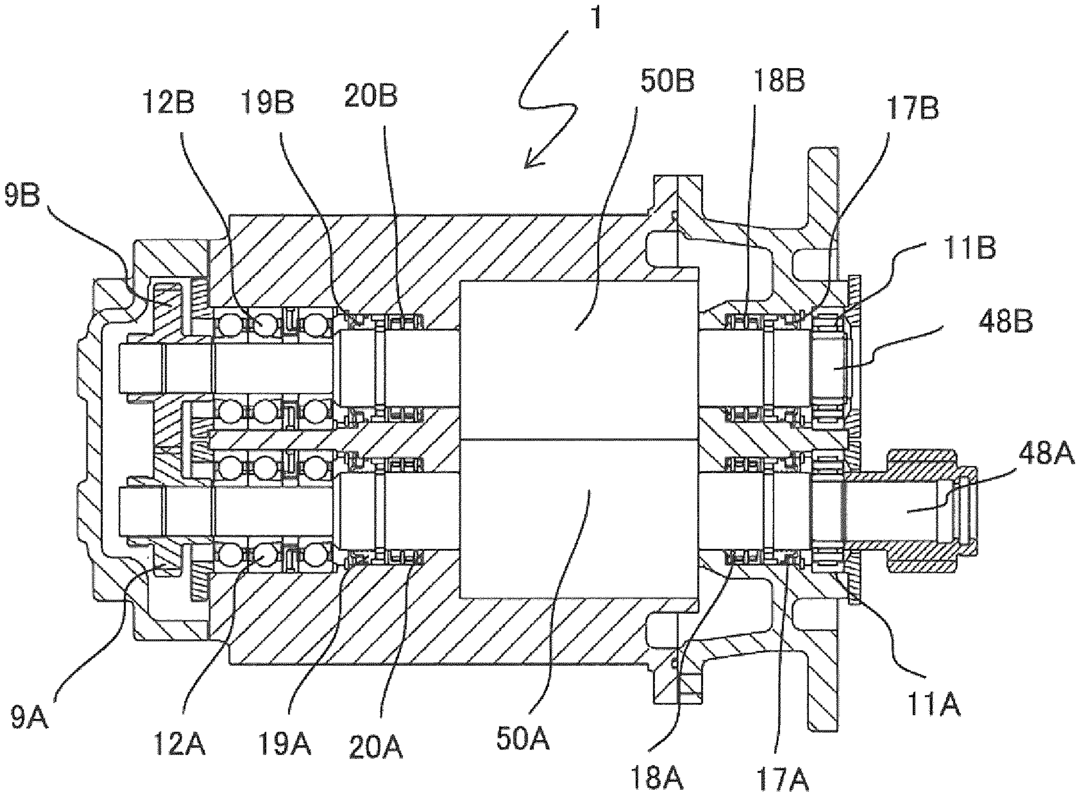
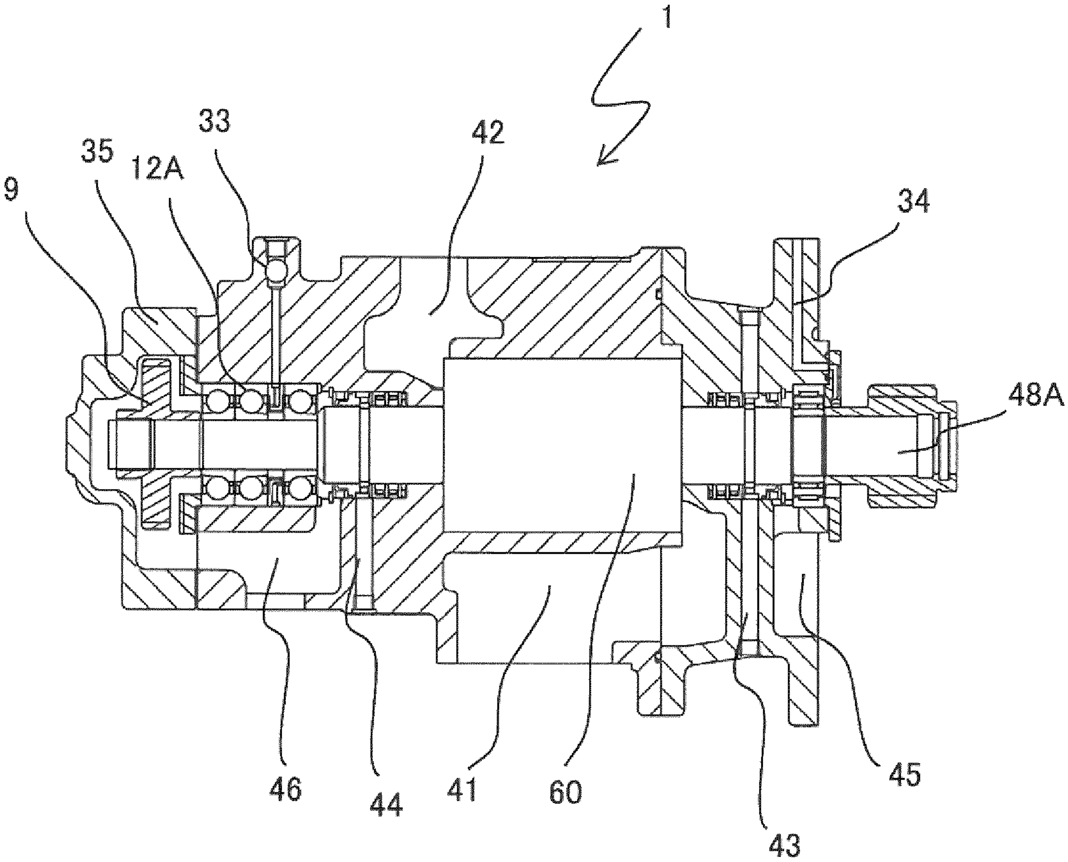

1
12B
19B
20B
50B
18B
17B
9B
11B
48B
48A
9A
12A
19A
20A
50A
18A
17A
11A

FIG.8B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/046606

A. CLASSIFICATION OF SUBJECT MATTER

F04B 39/00(2006.01)i; ***F04B 39/16***(2006.01)i; ***F04C 23/00***(2006.01)i; ***F04C 29/00***(2006.01)i; ***F04C 29/04***(2006.01)i
FI: F04B39/00 C; F04C29/04 E; F04B39/16 F; F04C29/00 Z; F04C23/00 H

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)

F04B39/00; F04B39/16; F04C23/00; F04C29/00; F04C29/04

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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.
Y A	JP 4-128595 A (HITACHI LTD) 30 April 1992 (1992-04-30) p. 4, upper right column, line 7 to p. 5, lower left column, line 6, fig. 1-2	1-4, 7-12, 14-15 5-6, 13
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 135425/1977 (Laid-open No. 60712/1979) (KOBE STEEL, LTD) 26 April 1979 (1979-04-26), specification, p. 1, line 12 to p. 4, line 20, fig. 2-5	1-4, 7-12, 14-15
Y	JP 2013-199891 A (MITSUBISHI HEAVY IND LTD) 03 October 2013 (2013-10-03) paragraphs [0025]-[0039], fig. 1	7-12, 14-15
Y	JP 5-141350 A (HITACHI LTD) 08 June 1993 (1993-06-08) paragraphs [0029]-[0035], fig. 2-3	7-12, 14-15
A	JP 61-234291 A (HITACHI LTD) 18 October 1986 (1986-10-18) p. 2, lower left column, lines 5-20, fig. 1	5-6, 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
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
31 January 2023	**07 February 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/046606

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 4-128595 A	30 April 1992	(Family: none)	
JP 54-60712 U1	26 April 1979	(Family: none)	
JP 2013-199891 A	03 October 2013	(Family: none)	
JP 5-141350 A	08 June 1993	(Family: none)	
JP 61-234291 A	18 October 1986	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H5141350 A **[0005]**