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

(11) **EP 4 353 972 A1**

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

(43) Date of publication:
17.04.2024 Bulletin 2024/16

(21) Application number: **22820048.1**

(22) Date of filing: **25.05.2022**

(51) International Patent Classification (IPC):
F04C 29/04 *(2006.01)* ***F04C 18/52*** *(2006.01)*
F04C 28/12 *(2006.01)* ***F04C 29/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04C 18/52; F04C 28/12; F04C 29/00; F04C 29/04

(86) International application number:
PCT/JP2022/021326

(87) International publication number:
WO 2022/259866 (15.12.2022 Gazette 2022/50)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **08.06.2021 JP 2021095606**

(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)

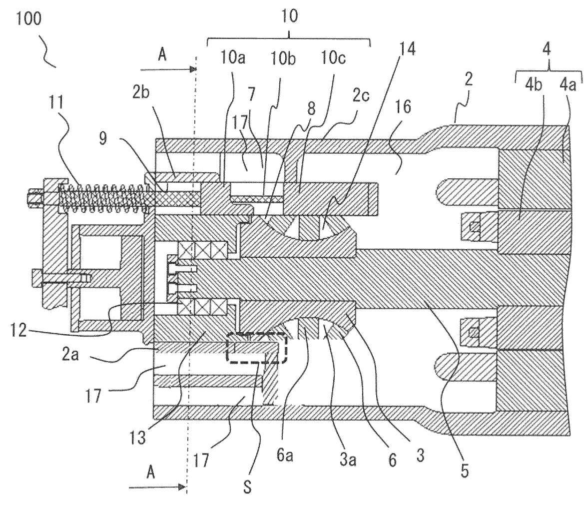
(72) Inventors:
- **MITSUI, Takao**
Tokyo 100-8310 (JP)
- **KANDA, Masahiro**
Tokyo 100-8310 (JP)
- **MITSUNARI, Naoya**
Tokyo 100-8310 (JP)

(74) Representative: **Diehl & Partner**
Patent- und Rechtsanwaltskanzlei mbB
Erika-Mann-Straße 9
80636 München (DE)

(54) ## SCREW COMPRESSOR

(57) In a screw compressor (100), on a bearing (12) side relative to a discharge port (8) of a compression chamber (14) in a casing (2), an intermediate-pressure chamber (15) to which an intermediate-pressure coolant (15G) is supplied from outside of the casing (2) is provided in a high-pressure space (17) surrounded by an outer cylinder (2c) and an intermediate cylinder (2b) of the casing (2) and communicating with the discharge port (8), and the intermediate-pressure coolant (15G) has a temperature and a pressure that are lower than those of a coolant (17G) in the high-pressure space (17) and higher than a coolant (16G) in a low-pressure space (16) on a motor (4) side relative to the discharge port (8) in the casing (2). The intermediate-pressure chamber (15) and the low-pressure space (16) communicate with each other.

FIG. 1



EP 4 353 972 A1

Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] Among screw compressors, a single screw compressor includes one screw rotor and two gate rotors. The screw rotor and the gate rotor of the single screw compressor are stored in a casing.

[0003] The screw rotor has a plurality of helical grooves (screw grooves), and the grooves are meshed and engaged with a pair of the gate rotors located on radially outer sides of the screw rotor, whereby a compression chamber is formed. In the casing, a low-pressure space and a high-pressure space are formed.

[0004] The screw rotor is fixed to a screw shaft. One end side of the screw shaft is supported by a bearing housing via a bearing located on a discharge side of the screw rotor, and similarly, another end side (suction side) of the screw shaft is also supported by a bearing housing via a bearing.

[0005] Here, the suction side of the screw shaft is connected to a motor rotor. When the screw rotor is rotationally driven by a motor, a fluid in the low-pressure space is sucked into the compression chamber and is compressed. The fluid compressed in the compression chamber passes through a discharge port and is discharged to the high-pressure space.

[0006] One end of the screw rotor is a fluid suction side and another end is a fluid discharge side, and the screw rotor may be provided with, on an outer circumference thereof, a columnar slide valve which slides in the rotation-axis direction of the screw rotor. The slide valve includes a valve portion opposed to the screw rotor and forming the compression chamber and the discharge port, a guide portion having a guide surface opposed to the bearing housing, and a connection portion connecting the valve portion and the guide portion. Thus, it is possible to adjust the compression ratio by adjusting a discharge timing of a fluid compressed in the compression chamber, or it is possible to adjust the compression capacity by sliding the slide valve in the rotation-axis direction of the screw rotor.

[0007] As described above, the compression chamber is formed by the screw rotor, the gate rotor, the casing, and the slide valve, and there are minute gaps between these components. During compression of the fluid, compressed coolant gas leaks through the gaps, and thus the gaps are a cause for reducing performance of the compressor. In normal operation, due to a difference between the pressure in the compression chamber and the pressure in the low-pressure space, a force outward in the radial direction acts on the slide valve, so that the gap between the screw rotor and the slide valve is enlarged, leading to reduction in performance of the compressor. The gaps are also enlarged by thermal deformation of the components.

[0008] In such a single screw compressor, gaps between components, which can reduce efficiency of the compressor, are designed and worked to be as narrow as possible. Meanwhile, contact between components leads to failure of the compressor and therefore needs to be avoided.

[0009] In operation of the screw compressor, a temperature difference necessarily occurs between the screw rotor and the casing, so that a thermal deformation difference occurs. If the thermal deformation difference is great, components might contact with each other. Accordingly, in order to reduce the thermal deformation difference between the screw rotor and a casing inner cylinder which is a part where the screw rotor is stored in the casing, such a structure that the casing inner cylinder is warmed by discharge gas is proposed. For example, Patent Document 1 proposes such a structure that a casing inner cylinder covering an outer circumference of a screw rotor is prevented from being greatly influenced by a temperature from a low-pressure chamber, high performance is kept without significantly enlarging a seal gap between the screw rotor and the casing inner cylinder, and galling between the screw rotor and the casing inner cylinder can be prevented, and shows, as the above structure, a screw compressor in which a discharge gas passage is routed to a position near an end-surface part on the axial-direction suction side of the screw rotor, thus performing warming by the discharge gas.

CITATION LIST

PATENT DOCUMENT

[0010] Patent Document 1: Japanese Laid-Open Patent Publication No. 6-42474

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0011] The configuration in Patent Document 1 is significantly effective when the discharge temperature sharply changes, e.g., at a time just after starting or in an abnormal case. However, in continuous operation when the temperature of the entire casing has increased sufficiently, e.g., in rated operation, thermal deformation increases due to increase in the temperature of the entire casing, so that deformation of the casing inner cylinder increases, thus enlarging the gap between the screw rotor and the casing inner cylinder. As a result, leakage of coolant gas from the gap between the screw rotor and the casing inner cylinder increases, leading to reduction in efficiency of the screw compressor.

[0012] The present disclosure has been made to solve the above problem, and an object of the present disclosure is to provide a screw compressor that can efficiently operate even in rated operation.

MEANS TO SOLVE THE PROBLEM

[0013] A screw compressor according to the present disclosure includes: a casing including an outer cylinder, an intermediate cylinder, and an inner cylinder which have cylindrical shapes and which are connected in a radial direction and arranged in a nested structure in this order from an outer side; a screw shaft rotatably provided in an axial direction in the inner cylinder; a screw rotor having a plurality of helical screw grooves extending in the axial direction around an outer circumference thereof, the screw rotor being fixed to the screw shaft; a motor to which the screw shaft is connected; a pair of gate rotors which rotate with teeth thereof meshed with the screw grooves and which form a compression chamber for compressing a coolant, together with the screw rotor; two semi-cylindrical slide valve storage grooves protruding radially outward from an inner circumferential surface of the inner cylinder and extending in the axial direction; slide valves which are provided in the respective slide valve storage grooves and which adjust a compression ratio of the coolant or adjust a compression capacity for the coolant; and a bearing and a bearing housing which are provided inside the inner cylinder on a side opposite to the motor in the axial direction, the bearing rotatably supporting the screw shaft, and the bearing housing storing the bearing. On the bearing side relative to a discharge port of the compression chamber in the casing, an intermediate-pressure chamber to which an intermediate-pressure coolant is supplied from outside of the casing is provided in a high-pressure space surrounded by the outer cylinder and the intermediate cylinder of the casing and communicating with the discharge port. The intermediate-pressure coolant has a temperature and a pressure that are lower than those of a coolant in the high-pressure space and higher than those of a coolant in a low-pressure space on the motor side relative to the discharge port in the casing. The intermediate-pressure chamber and the low-pressure space communicate with each other.

EFFECT OF THE INVENTION

[0014] The screw compressor according to the present disclosure can efficiently operate even in rated operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

[FIG. 1] FIG. 1 is a schematic sectional view of a screw compressor according to embodiment 1.
[FIG. 2] FIG. 2 is a perspective view of a casing of the screw compressor according to embodiment 1.
[FIG. 3] FIG. 3 is a sectional view (showing only casing 2) along line A-A in FIG. 1.
[FIG. 4] FIG. 4 is a sectional view along line B-B in FIG. 3.
[FIG. 5] FIG. 5A to FIG. 5C show a compression process in the screw compressor.
[FIG. 6] FIG. 6 shows an example of a schematic circuit diagram of a coolant circuit according to embodiment 1.
[FIG. 7] FIG. 7 shows another example of a schematic circuit diagram of a coolant circuit according to embodiment 1.
[FIG. 8] FIG. 8A is a sectional view along line D-D in FIG. 2 and shows a flow path communicating from an intermediate-pressure chamber to a low-pressure space. FIG. 8B is a sectional view along line E-E in FIG. 8A and shows a flow path communicating from the intermediate-pressure chamber to the low-pressure space.
[FIG. 9] FIG. 9 is a schematic sectional view of a casing of a screw compressor according to embodiment 2.

DESCRIPTION OF EMBODIMENTS

Embodiment 1

[0016] Hereinafter, a screw compressor according to embodiment 1 will be described with reference to the drawings.

[0017] As used herein, an "axial direction", a "circumferential direction", a "radial direction", an "inner circumferential side", an "outer circumferential side", an "inner circumferential surface", and an "outer circumferential surface" respectively refer to an "axial direction", a "circumferential direction", a "radial direction", an "inner circumferential side", an "outer circumferential side", an "inner circumferential surface", and an "outer circumferential surface" of the screw compressor, unless otherwise specified.

[0018] FIG. 1 is a schematic sectional view of a screw compressor 100.

[0019] FIG. 2 is a perspective view of a casing 2 of the screw compressor 100.

[0020] FIG. 3 is a sectional view (showing only casing 2) along line A-A in FIG. 1. FIG. 1 corresponds to a sectional part along line C-C in FIG. 3 (and also shows components other than the casing 2).

[0021] A schematic configuration of the screw compressor 100 will be described with reference to FIG. 1 to FIG. 3.

[0022] As shown in FIG. 3, the casing 2 of the screw compressor 100 includes an outer cylinder 2c, an intermediate cylinder 2b, and an inner cylinder 2a which have cylindrical shapes and are connected in the radial direction. The outer cylinder 2c, the intermediate cylinder 2b, and the inner cylinder 2a are connected in a nested structure in this order from the outer side. The outer cylinder 2c, the intermediate cylinder 2b, and the inner cylinder

2a are all formed integrally.

[0023] The screw compressor 100 shown in FIG. 1 includes a screw rotor 3 stored in the inner cylinder 2a of the casing 2 and forming a plurality of helical grooves (screw grooves 3a), and a motor 4 for rotationally driving the screw rotor 3. The motor 4 includes a motor stator 4a fixed in contact with the inner side of the casing 2, and a motor rotor 4b rotatably provided on the inner side of the motor stator 4a. In a case of an inverter type, the rotational speed of the motor 4 can be freely controlled.

[0024] The screw rotor 3 and the motor rotor 4b are arranged coaxially with each other, and are fixed to a screw shaft 5 extending in the axial direction. The screw grooves 3a are meshed and engaged with teeth 6a of a pair of gate rotors 6 located in the radial direction of the screw rotor 3, thus forming a compression chamber for compressing coolant gas.

[0025] Here, one end side (left side in FIG. 1) of the screw shaft 5 is rotatably supported by a bearing housing 13 via bearings 12 located on the discharge side (side opposite to the motor 4 side in the axial direction) of the screw rotor 3. The bearing housing 13 is stored on the inner side of the inner cylinder 2a.

[0026] The casing 2 is separated into a discharge pressure side (left side in FIG. 1) and a suction pressure side (right side in FIG. 1). On the discharge pressure side, a discharge port 8 which opens to a discharge path 7 is formed. In the casing 2, a semi-cylindrical slide valve storage groove 9 protruding radially outward and extending in the rotation-axis direction of the screw rotor 3 is formed, and a slide valve 10 is provided in the slide valve storage groove 9.

[0027] The slide valve 10 is slidable in parallel to the rotation-axis direction of the screw rotor 3 by a slide valve driving mechanism 11. The compression ratio of the coolant gas compressed by the compression chamber 14 can be adjusted by the slide valve 10 sliding, or the compression capacity can be adjusted by the slide valve 10 sliding in the rotation-axis direction of the screw rotor 3.

[0028] The slide valve 10 includes a valve portion 10c opposed to the screw rotor 3 and forming the compression chamber 14 and the discharge port 8, a guide portion 10a having a guide surface opposed to the bearing housing 13 and guiding movement of the valve portion 10c, and a connection portion 10b connecting the valve portion 10c and the guide portion 10a.

[0029] FIG. 4 is a sectional view along line B-B in FIG. 3. As shown in FIG. 3 and FIG. 4, the casing 2 includes an intermediate-pressure chamber 15 at a position that is between the intermediate cylinder 2b and the outer cylinder 2c and is not adjacent to the slide valve 10. The intermediate-pressure chamber 15 (described in detail later) is formed approximately on the bearing 12 side in the axial direction relative to the discharge path 7 (and discharge port 8). The intermediate-pressure chamber 15 communicates with a low-pressure space 16 on the motor 4 side shown in FIG. 1, in the casing 2. When the casing 2 is seen from the front side, a place other than the intermediate-pressure chamber 15 is a high-pressure space 17 communicating with the discharge port 8. That is, the intermediate-pressure chamber 15 is present in the high-pressure space 17 surrounded by the outer cylinder 2c and the intermediate cylinder 2b and communicating with the discharge port 8. The screw compressor 100 is fixed to a housing or the like via two fixation legs 1a provided to the outer circumferential surface of the outer cylinder 2c.

[0030] Next, operation of the screw compressor 100 in embodiment 1 will be described.

[0031] FIG. 5A to FIG. 5C show a compression process in the screw compressor 100.

[0032] As shown in FIG. 5A to FIG. 5C, the screw rotor 3 is rotated via the screw shaft 5 by the motor 4 (see FIG. 1), whereby the teeth 6a of the gate rotor 6 move relatively in the compression chamber 14. Thus, a cycle composed of a suction process, a compression process, and a discharge process is repeated in the compression chamber 14. In FIG. 5A to FIG. 5C, each process will be described focusing on the compression chamber 14 indicated by hatching with a plurality of dots.

[0033] FIG. 5A shows the state of the compression chamber 14 in the suction process. The screw rotor 3 rotates in an arrow direction by being driven by the motor 4. Thus, as shown in FIG. 5B, the volume of the compression chamber 14 having communicated with the low-pressure space 16 is reduced, so that the coolant sucked from the low-pressure space 16 into the compression chamber 14 is compressed.

[0034] As the screw rotor 3 rotates subsequently, as shown in FIG. 5C, the compression chamber 14 communicates with the discharge port 8 formed by the inner cylinder 2a and the valve portion 10c of the slide valve 10. Thus, high-pressure coolant gas compressed in the compression chamber 14 passes through the discharge path 7 in the high-pressure space 17 from the discharge port 8 shown in FIG. 1, and then is discharged to the outside of the screw compressor 100. Then, a low-pressure coolant is sucked from the back side of the screw rotor 3 again and is compressed in the same manner. Through the above operation, the inside of the casing 2 is divided into the low-pressure space 16 and the high-pressure space 17. The above intermediate-pressure chamber 15 communicates with the low-pressure space 16.

[0035] FIG. 6 shows an example of a schematic circuit diagram of a coolant circuit according to embodiment 1. The coolant compressed in the screw compressor 100 is discharged through the discharge port 8 to the outside of the screw compressor 100, passes through a high-pressure pipe PA and a condenser 18, flows to an intermediate-pressure pipe PB and an evaporator 19, and then is supplied from a low-pressure pipe PC to the screw compressor 100 again, thus circulating.

[0036] For the purpose of improving efficiency of the screw compressor 100, a part of the coolant passes through a second intermediate-pressure pipe PD from the intermediate-pressure pipe PB between the condenser 18 and the evaporator 19, so as to be supplied to the intermediate-pressure chamber 15 provided in the casing 2, and then is supplied to the low-pressure space 16.

[0037] The part of the coolant between the condenser 18 and the evaporator 19 (hereinafter, the coolant in the intermediate-pressure space is referred to as an intermediate-pressure coolant 15G) has a temperature and a pressure that are between the temperature and the pressure of the coolant in the high-pressure space 17 (hereinafter, the coolant in the high-pressure space 17 is referred to as a high-pressure coolant 17G) and the temperature and the pressure of the coolant in the low-pressure space 16 (hereinafter, the coolant in the low-pressure space 16 is referred to as a low-pressure coolant 16G). The temperature and pressure relationship among the low-pressure coolant 16G, the intermediate-pressure coolant 15G, and the high-pressure coolant 17G is low-pressure coolant 16G < intermediate-pressure coolant 15G < high-pressure coolant 17G.

[0038] There are several methods for supplying the intermediate-pressure coolant 15G having passed through the condenser 18 to the screw compressor 100 in the coolant circuit.

[0039] FIG. 7 shows another example of a schematic circuit diagram of a coolant circuit.

[0040] As shown in FIG. 7, for example, an intermediate heat exchanger 20 may be provided between the condenser 18 and the evaporator 19. In this case, the coolant having a pressure reduced by an expansion valve EX provided before the intermediate heat exchanger 20 in the coolant circuit is passed through the intermediate heat exchanger 20 so as to undergo heat exchange (deprived of heat), and then is supplied as the intermediate-pressure coolant 15G to the intermediate-pressure chamber 15 of the screw compressor 100. In order to obtain effects of the present disclosure, any method may be used as long as the temperature and pressure relationship satisfies low-pressure coolant 16G < intermediate-pressure coolant 15G < high-pressure coolant 17G.

[0041] Since the condenser 18 and the evaporator 19 are separate from the screw compressor 100, as shown in FIG. 2, a connection hole 15in to the second intermediate-pressure pipe PD is provided at an outer surface of the intermediate-pressure chamber 15 of the casing 2 of the screw compressor 100.

[0042] FIG. 8A is a sectional view along line D-D in FIG. 2 and shows a part of a flow path communicating from the intermediate-pressure chamber 15 to the low-pressure space 16.

[0043] FIG. 8B is a sectional view along line E-E in FIG. 8A and shows a part of a flow path communicating from the intermediate-pressure chamber 15 to the low-pressure space 16.

[0044] In FIG. 8A and FIG. 8B, only the casing 2 and the bearing housing 13 are shown.

[0045] As shown in FIG. 8A and FIG. 8B, the connection hole 15in provided to the outer cylinder 2c communicates with the intermediate-pressure chamber 15. At the bearing housing 13, a first groove 13m recessed in the axial direction toward the motor 4 side is provided in an annular shape. The intermediate-pressure chamber 15 and the first groove 13m are connected via a communication path P1 so as to communicate with each other.

[0046] At the inner cylinder 2a, a second groove 2am recessed radially outward is formed to extend in the axial direction, and the above first groove 13m and the second groove 2am communicate with each other in the radial direction. Then, the second groove 2am communicates with the low-pressure space 16 on the motor 4 side. Therefore, the intermediate-pressure coolant 15G having entered the intermediate-pressure chamber 15 from the outside passes through the communication path P1, the first groove 13m, and the second groove 2am, and then flows to the low-pressure space 16 as indicated by arrows in FIG. 8A and FIG. 8B.

[0047] In general, in the compressor, a coolant leaks through gaps between components, so that efficiency is deteriorated. Therefore, how to reduce the gaps is a problem. Accordingly, improvements for reducing deformation due to working accuracy, assembly accuracy, operation pressure, and temperature change have always been attempted, and gap reduction has been thus far accumulated on a several-micrometer basis. Therefore, even slight deformation reduction is significant. Hereinafter, reduction of a gap (formed in area S in FIG. 1) between the inner cylinder 2a of the casing 2 and the screw rotor 3 will be described.

[0048] Deformation of the casing 2 is classified into deformation due to pressure and deformation due to temperature change. Since the inner cylinder 2a, the intermediate cylinder 2b, and the outer cylinder 2c are connected, deformation of the entire casing 2 needs to be reduced in order to reduce deformation of the inner cylinder 2a. For reducing deformation of the casing 2, deformation due to pressure and deformation due to temperature change described above need to be reduced, but if rigidity of the casing 2 is not less than a certain value, deformation due to pressure is extremely small and deformation due to temperature change is dominant.

[0049] Therefore, if rigidity of the casing 2 can be ensured to be high enough that, of the above two deformations, deformation due to temperature change is dominant, it is difficult to further reduce deformation by further increasing rigidity of the casing 2. Accordingly, deformation due to temperature change is to be reduced.

[0050] In order to reduce deformation due to the temperature of the casing 2, it is necessary to reduce temperature change in the casing 2. Deformation due to temperature change in the screw compressor 100 occurs when the casing 2 is warmed by the coolant in the high-pressure space 17, or the like.

[0051] As methods for reducing temperature increase in the casing, a method of cooling the casing by an external cooling system and a method of cooling the casing by circulating the coolant in the coolant circuit to the casing, are conceivable.

[0052] However, the method of cooling the casing by an external cooling system is not practical because of size increase of the device, significant cost increase, power consumption increase, and the like. Accordingly, in embodiment 1, the method of cooling the casing 2 by circulating the coolant in the coolant circuit to the casing 2 is adopted.

[0053] In the coolant circuit as a cooling system, which has already been described with reference to FIG. 6, for the purpose of improving efficiency of the screw compressor 100, the intermediate-pressure coolant 15G between the condenser 18 and the evaporator 19 is branched and supplied through the intermediate-pressure chamber 15 to the low-pressure space 16, thereby improving efficiency of the screw compressor 100.

[0054] That is, the intermediate-pressure chamber 15 for storing the intermediate-pressure coolant 15G in the casing 2 once is provided in the casing 2, whereby the casing 2 is cooled and thus deformation thereof can be reduced. In this method, the intermediate-pressure coolant 15G which has originally flowed in the coolant circuit is used, whereby, without size increase of the device and power consumption increase, it becomes possible to reduce deformation of the entire casing 2 in continuous operation at lower cost than in a case of using an external cooling system.

[0055] In a case of using a structure in which the intermediate-pressure coolant 15G returns to the low-pressure space 16 for the purpose of improving efficiency of the screw compressor 100, since pipes and the like are originally provided to the screw compressor 100, the purpose can be achieved without great change in structure. It is noted that it is also possible to reduce temperature increase by introducing a coolant corresponding to the intermediate-pressure coolant 15G from an external cooling system to the intermediate-pressure chamber 15, instead of using the intermediate-pressure coolant 15G.

[0056] It is also conceivable that a place for storing the low-pressure coolant 16G that has passed through the evaporator 19 is provided in the casing 2. However, since the low-pressure coolant 16G is a lowest-pressure coolant in the coolant circuit, it is difficult to supply the coolant to the low-pressure space 16 and circulate the low-pressure coolant 16G, unless an additional device is used. Therefore, this method is not suitable.

[0057] On the other hand, regarding the intermediate-pressure coolant 15G, the pressure relationship is intermediate-pressure coolant 15G > low-pressure coolant 16G, and therefore, if the intermediate-pressure chamber 15 and the low-pressure space 16 communicate with each other, the intermediate-pressure coolant 15G is naturally supplied to the low-pressure space 16 owing to the coolant pressure difference, that is, the coolant can be circulated without any special device. Thus, a cooling structure for the casing 2 can be achieved without adding any device and deformation of the casing 2 can be reduced.

[0058] Here, around the intermediate-pressure chamber 15 of the casing 2 as a cooling target, the temperature gradient becomes great at the time of starting or in continuous operation. Therefore, because of difference between deformations due to temperature, there is a possibility of causing "warp" in which a circumferential-direction width W of an opening 91 of the slide valve storage groove 9 where the wall of the inner cylinder 2a is discontinuous is increased. In particular, around the slide valve 10, the wall of the inner cylinder 2a is discontinuous, and therefore this area has lower rigidity than the surrounding area and is more likely to warp.

[0059] If the temperature gradient becomes great in such a place, the warp increases. As a result, the clearance between the screw rotor 3 and the inner cylinder 2a is locally narrowed so that they might interfere with each other, or conversely, the clearance increases so that efficiency of the screw compressor 100 might be deteriorated.

[0060] In addition, in a case of cooling the inner cylinder 2a, when the coolant discharge temperature sharply changes, e.g., at a time just after starting of the screw compressor 100 or in an abnormal case, there is a possibility that the temperature of the inner cylinder 2a does not increase and the screw rotor 3 and the inner cylinder 2a interfere with each other.

[0061] Accordingly, the intermediate-pressure chamber 15 is provided between the intermediate cylinder 2b and the outer cylinder 2c, whereby excessive cooling of the inner cylinder 2a is suppressed and the inner cylinder 2a can expand so as to follow expansion of the screw rotor 3 due to sharp temperature increase of the coolant.

[0062] Therefore, it is appropriate that the intermediate-pressure chamber 15 is provided between the intermediate cylinder 2b and the outer cylinder 2c while avoiding the part where the slide valve 10 is present on the radially inner side, as described above. Further, since the fixation legs 1a are fixed to a housing or the like, deformation of a circumferential-direction part between the two fixation legs 1a is originally reduced owing to rigidity of the housing (not shown) and the fixation legs 1a. Therefore, providing the intermediate-pressure chamber 15 on the radially inner side of the above part brings only a small effect in deformation reduction.

[0063] If the intermediate-pressure chamber 15 is enlarged, there is such a problem that the necessary amount of the intermediate-pressure coolant 15G increases and thus the usage amount of the coolant increases, for example. Therefore, an advantage obtained by providing a large-sized intermediate-pressure chamber 15 at a small-effect place is small. Further, the high-pressure space 17 is present at a subsequent coolant path from the discharge path 7. Therefore, it suffices that the intermediate-pressure chamber 15 is formed approximately on the bearing 12 side on the side opposite to the motor 4 side in the axial direction, relative to the discharge path 7.

[0064] At an upper part of the casing 2, a flow path for the coolant discharged from the discharge port 8 is present, and for providing the intermediate-pressure chamber 15 there, significant design change is needed. Therefore, as shown in FIG. 3, FIG. 8A, and FIG. 8B, providing the intermediate-pressure chamber 15 at a place that is between the intermediate cylinder 2b and the outer cylinder 2c and other than the radially inner side between the fixation legs 1a while avoiding the slide valve 10, is most appropriate for obtaining the maximum effect at minimum cost. That is, as shown in FIG. 3, the intermediate-pressure chamber 15 is provided at a circumferential-direction position between two slide valves 10 and on the radially outer side relative to the slide valves 10.

[0065] In a case of providing the intermediate-pressure chamber 15 around the slide valve 10, a measure of increasing rigidity around the slide valve 10 is conceivable, but there is such a problem that the thermal capacity increases and thus the inner cylinder 2a of the casing 2 is not warmed and deformed sufficiently, e.g., at the time of starting or in an abnormal case, or efficiency of the screw compressor 100 is reduced due to increase in coolant pressure loss and the like. However, if such a problem is solved, it is possible to provide the intermediate-pressure chamber 15 around the slide valve 10, and therefore a configuration of providing the intermediate-pressure chamber 15 around the slide valve 10 is not completely excluded.

[0066] In general, in the screw compressor, an area where the intermediate-pressure coolant is stored is often provided outside the outer cylinder. The purpose of this is to obtain a buffer for preventing vibration of pipes. However, the outside of the outer cylinder during usage is subjected to the outside temperature. In the environment where the screw compressor is actually used, in many cases, the temperature of the intermediate-pressure coolant is higher than that of the outside air. Therefore, it is difficult to obtain an effect of reducing temperature increase of the casing, using the above buffer. Even if cooling is attempted by an intermediate-pressure coolant from the outside of the outer cylinder, the distance to the inner cylinder 2a storing the screw rotor 3 for which deformation reduction is most required is long, and thus a sufficient effect is not obtained.

[0067] With the screw compressor according to embodiment 1, interference between the screw rotor 3 and the inner cylinder 2a can be prevented. In addition, expansion of the gap between the inner cylinder 2a of the casing 2 and the screw rotor 3 due to heat can be effectively reduced. Thus, it is possible to perform operation efficiently even in rated operation.

Embodiment 2

[0068] Hereinafter, a screw compressor according to embodiment 2 will be described focusing on difference from embodiment 1.

[0069] FIG. 9 is a front view of a casing 202 of the screw compressor 100.

[0070] In embodiment 2, the intermediate-pressure chambers 15 described in embodiment 1 are provided at two locations, and are provided at symmetric positions with respect to the center axis of the casing 202.

[0071] By providing the intermediate-pressure chambers 15 at two locations, it becomes possible to not only reduce deformation of the casing 202 but also maintain the roundness of the inner cylinder 2a because the casing 202 is cooled equally in the circumferential direction.

[0072] If the roundness is low, even though the average clearance of gaps between the inner cylinder 2a of the casing 202 and the screw rotor 3 is small, leakage through some gaps that largely open increases, so that the property of the screw compressor might be deteriorated. In addition, the clearance between the screw rotor 3 and the inner cylinder 2a is partially narrowed, resulting in interference therebetween.

[0073] In contrast, in the screw compressor 100 according to embodiment 2, the roundness of the casing 2 can be maintained, so that the clearance between the screw rotor 3 and the inner cylinder 2a is more uniformed as compared to the structure in which only one side is cooled. Thus, efficiency of the screw compressor 100 is improved and interference between the screw rotor 3 and the inner cylinder 2a can be prevented.

[0074] Although the disclosure is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects, and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations to one or more of the embodiments of the disclosure.

[0075] It is therefore understood that numerous modifications which have not been exemplified can be devised without departing from the scope of the present disclosure. For example, at least one of the constituent components may be modified, added, or eliminated. At least one of the constituent components mentioned in at least one of the preferred embodiments may be selected and combined with the constituent components mentioned in another preferred embodiment.

DESCRIPTION OF THE REFERENCE CHARACTERS

[0076]

100 screw compressor
10 slide valve
10a guide portion
10b connection portion
10c valve portion
11 slide valve driving mechanism
12 bearing
13 bearing housing

13m first groove
14 compression chamber
15 intermediate-pressure chamber
16 low-pressure space
17 high-pressure space
15G intermediate-pressure coolant
15in connection hole
16G low-pressure coolant
17G high-pressure coolant
18 condenser
19 evaporator
1a fixation leg
20 intermediate heat exchanger
EX expansion valve
2, 202 casing
2a inner cylinder
2am second groove
2b intermediate cylinder
2c outer cylinder
3 screw rotor
3a screw groove
4 motor
4a motor stator
4b motor rotor
5 screw shaft
6 gate rotor
6a tooth
7 discharge path
8 discharge port
9 slide valve storage groove
91 opening
P1 communication path
PA high-pressure pipe
PB intermediate-pressure pipe
PC low-pressure pipe
PD second intermediate-pressure pipe
W width

Claims

1. A screw compressor comprising:

   a casing including an outer cylinder, an intermediate cylinder, and an inner cylinder which have cylindrical shapes and which are connected in a radial direction and arranged in a nested structure in this order from an outer side;
   a screw shaft rotatably provided in an axial direction in the inner cylinder;
   a screw rotor having a plurality of helical screw grooves extending in the axial direction around an outer circumference thereof, the screw rotor being fixed to the screw shaft;
   a motor to which the screw shaft is connected;
   a pair of gate rotors which rotate with teeth thereof meshed with the screw grooves and which form a compression chamber for compressing a coolant, together with the screw rotor;
   two semi-cylindrical slide valve storage grooves protruding radially outward from an inner circumferential surface of the inner cylinder and extending in the axial direction;
   slide valves which are provided in the respective slide valve storage grooves and which adjust a compression ratio of the coolant or adjust a compression capacity for the coolant; and
   a bearing and a bearing housing which are provided inside the inner cylinder on a side opposite to the motor in the axial direction, the bearing rotatably supporting the screw shaft, and the bearing housing storing the bearing, wherein
   on the bearing side relative to a discharge port of the compression chamber in the casing, an intermediate-pressure chamber to which an intermediate-pressure coolant is supplied from outside of the casing is provided in a high-pressure space surrounded by the outer cylinder and the intermediate cylinder of the casing and communicating with the discharge port,
   the intermediate-pressure coolant has a temperature and a pressure that are lower than those of a coolant in the high-pressure space and higher than those of a coolant in a low-pressure space on the motor side relative to the discharge port in the casing, and
   the intermediate-pressure chamber and the low-pressure space communicate with each other.

2. The screw compressor according to claim 1, wherein the intermediate-pressure chamber is provided at a position that is not adjacent to the slide valves.

3. The screw compressor according to claim 1 or 2, wherein
   the intermediate-pressure chamber is provided at a circumferential-direction position between the two slide valves and on a radially outer side relative to the slide valves.

4. The screw compressor according to any one of claims 1 to 3, wherein
   in a coolant circuit circulating from the screw compressor through an external condenser and an external evaporator to the screw compressor, the intermediate-pressure coolant is branched from a coolant circuit part leading from the condenser to the evaporator, so as to be supplied to the intermediate-pressure chamber.

5. The screw compressor according to any one of claims 1 to 4, wherein

   the bearing housing has an annular first groove recessed in the axial direction toward the motor side,

the intermediate-pressure chamber and the first groove communicate with each other via a communication path,
the inner cylinder has a second groove recessed radially outward and extending in the axial direction so as to communicate with the low-pressure space, and
the first groove and the second groove communicate with each other in the radial direction.

6. The screw compressor according to any one of claims 1 to 5, wherein

two fixation legs for fixation are provided to an outer circumferential surface of the outer cylinder, and
the intermediate-pressure chamber is provided at a part other than a radially inner side between the two fixation legs.

7. The screw compressor according to any one of claims 1 to 6, wherein
the intermediate-pressure chambers are respectively provided at symmetric positions with respect to a center axis of the casing.

FIG. 1

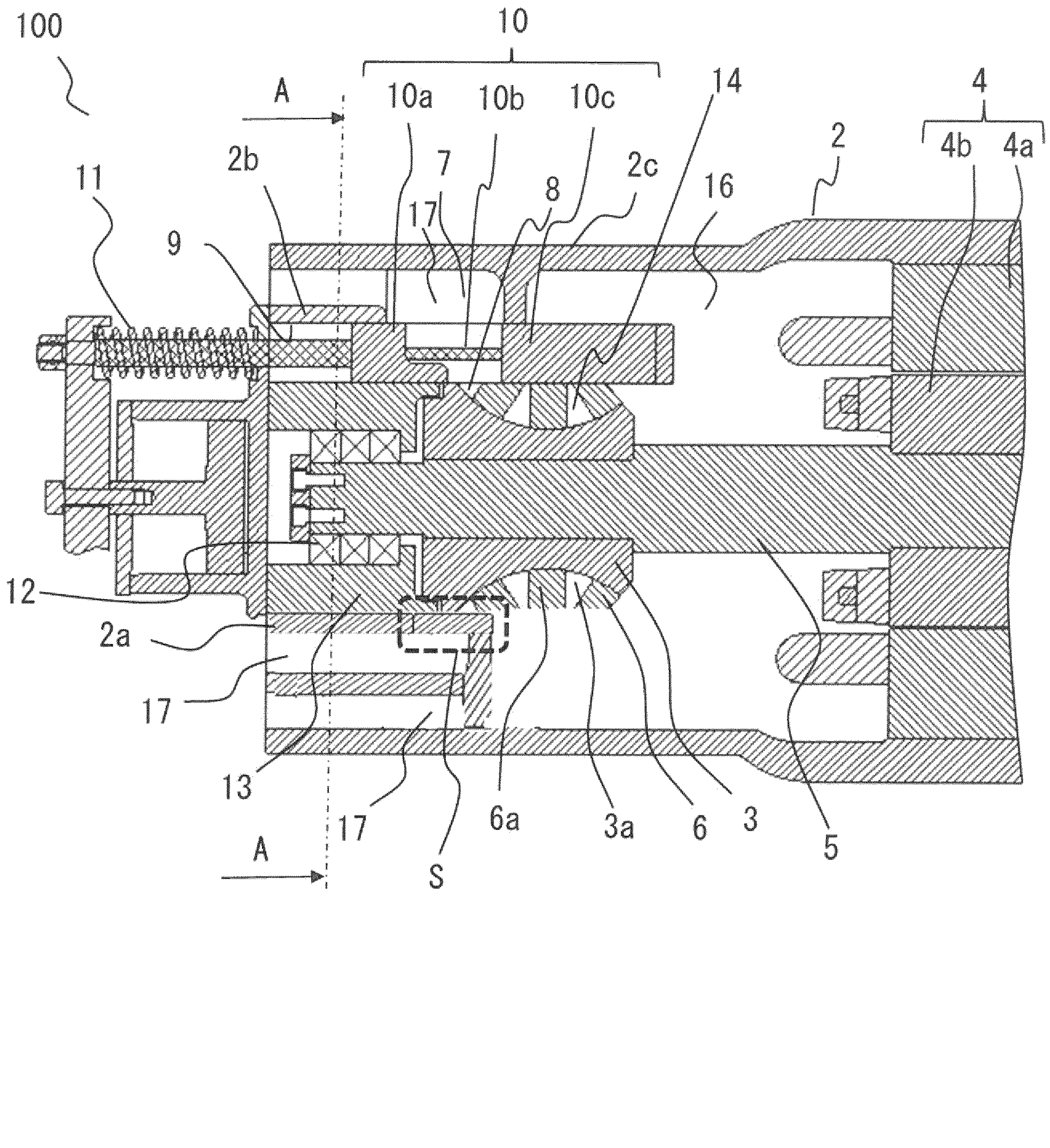

100
10
10a
10b
10c
14
4
4b
4a
A
2
2b
7
8
2c
16
11
17
9
12
2a
17
13
17
6a
3a
6
3
5
A
S

FIG. 2

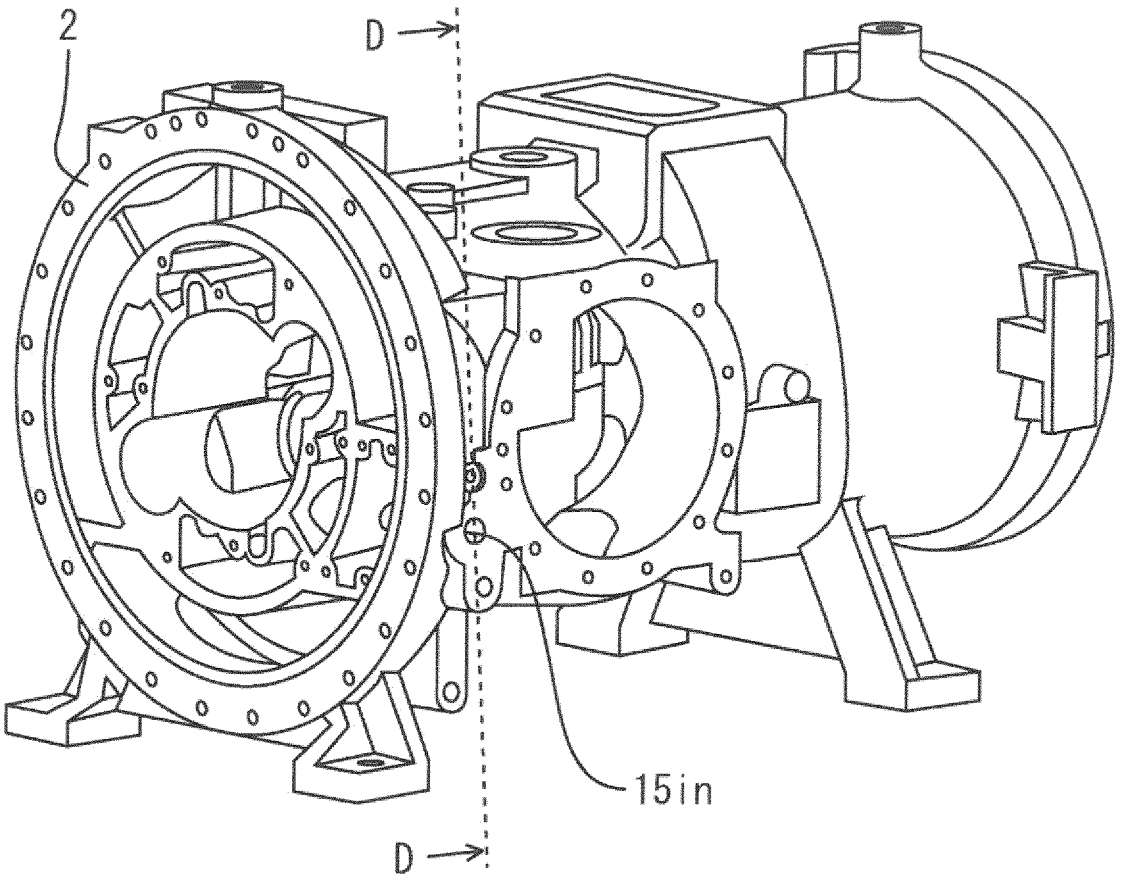


FIG. 3

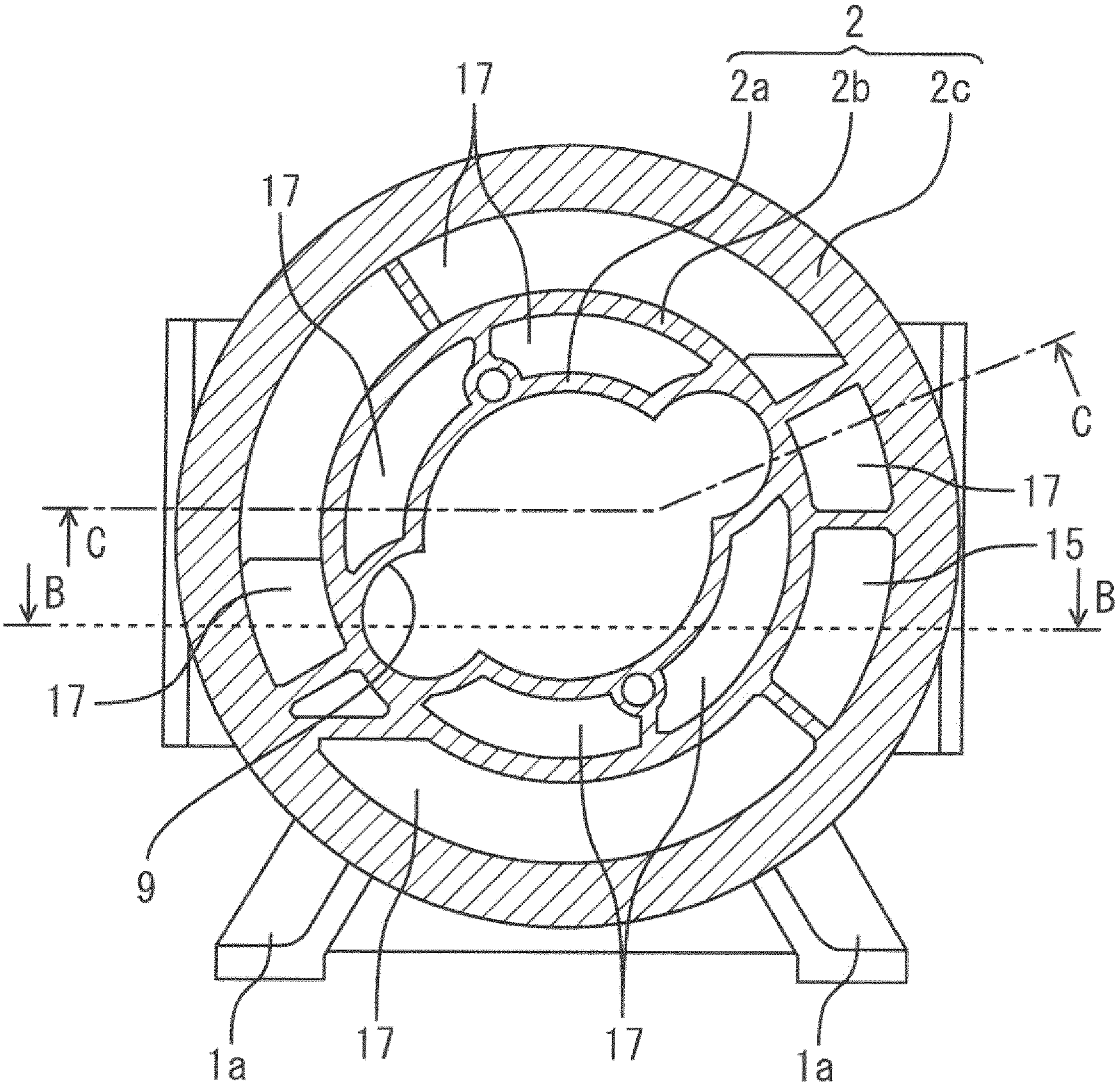


FIG. 4

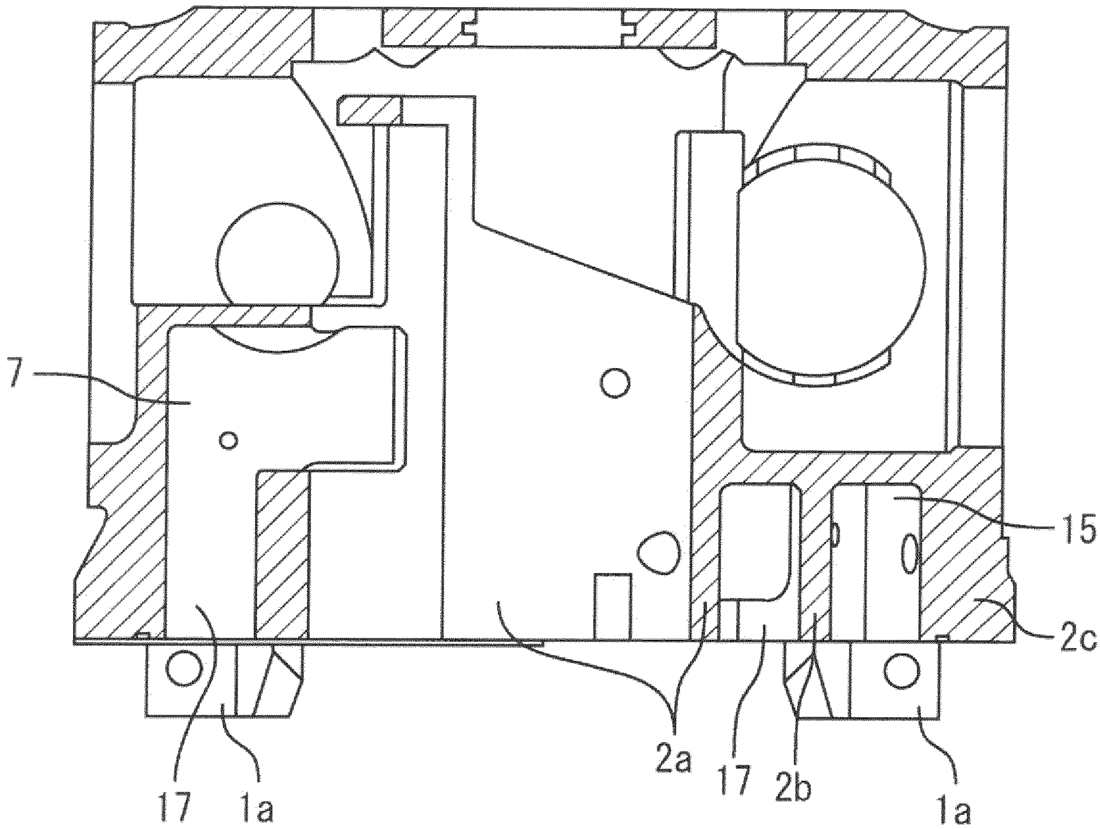


FIG. 5C

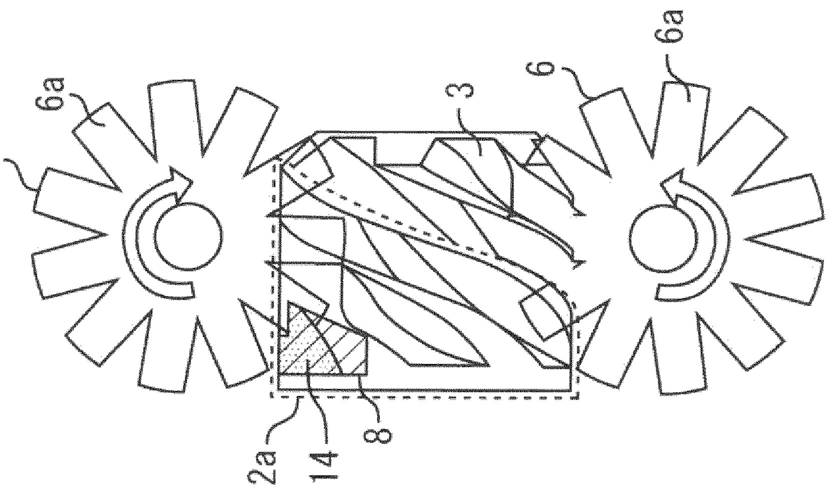


FIG. 5B

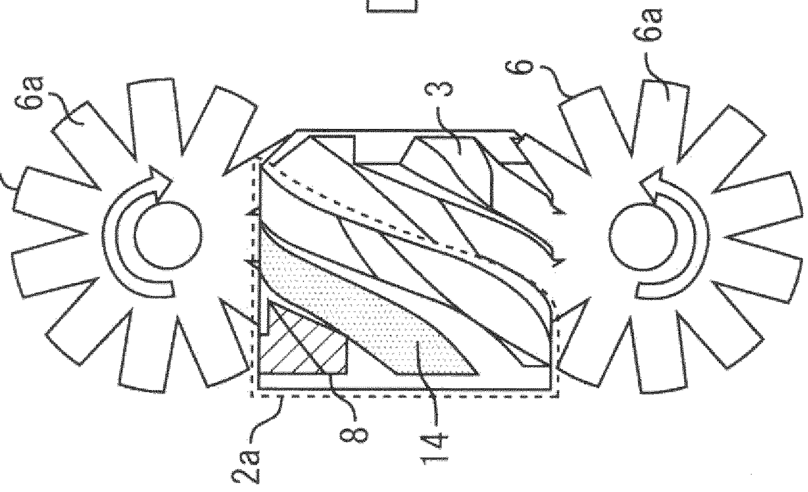


FIG. 5A

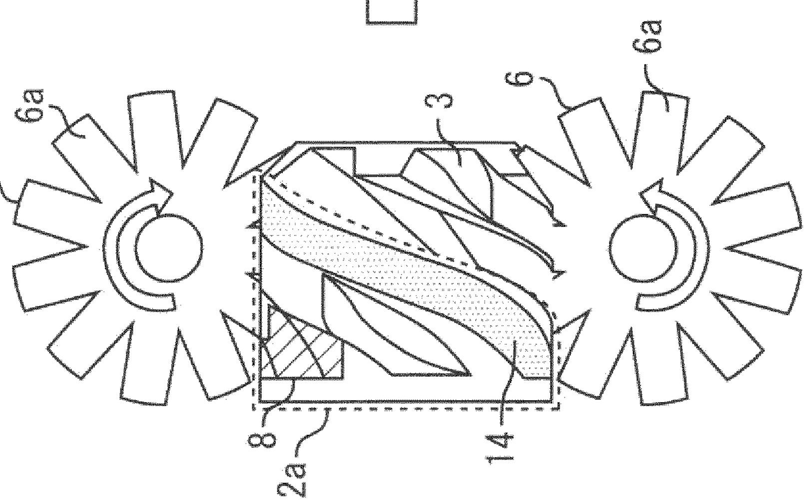


FIG. 6

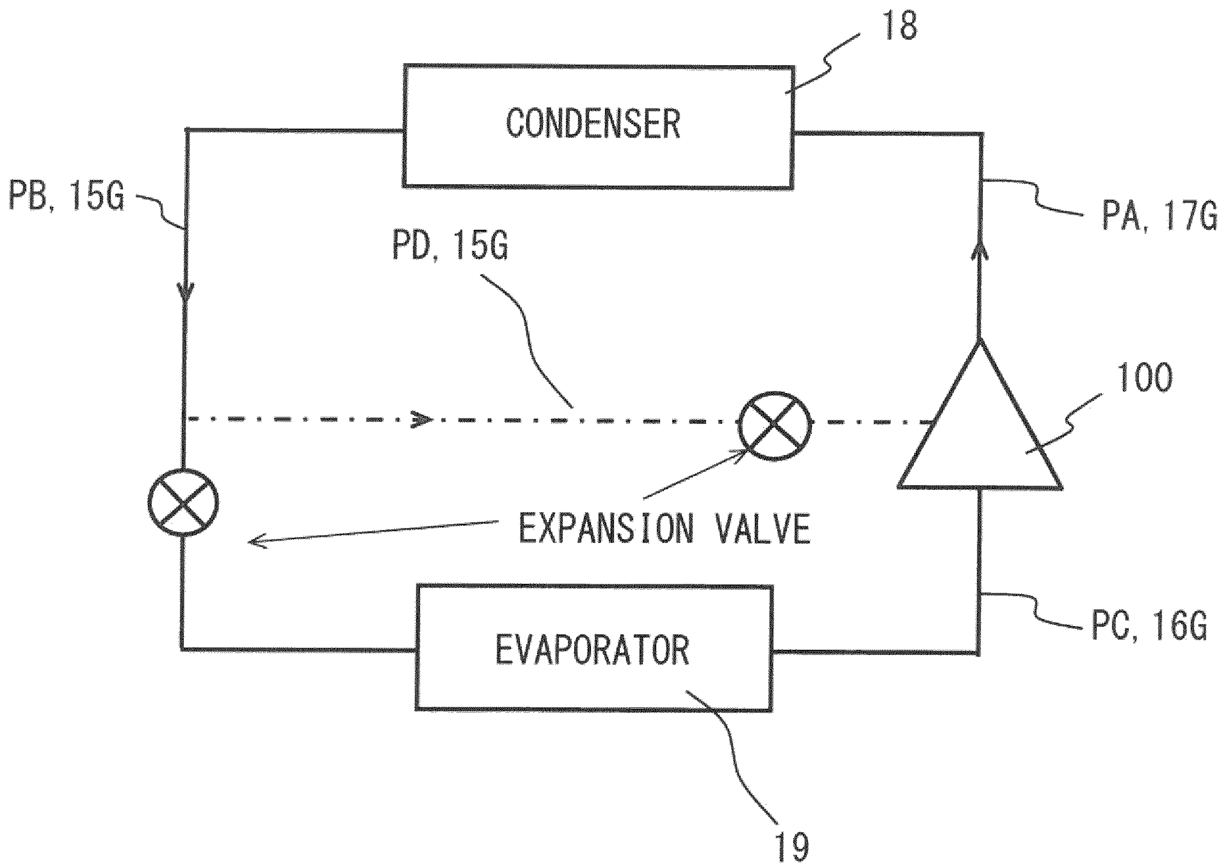
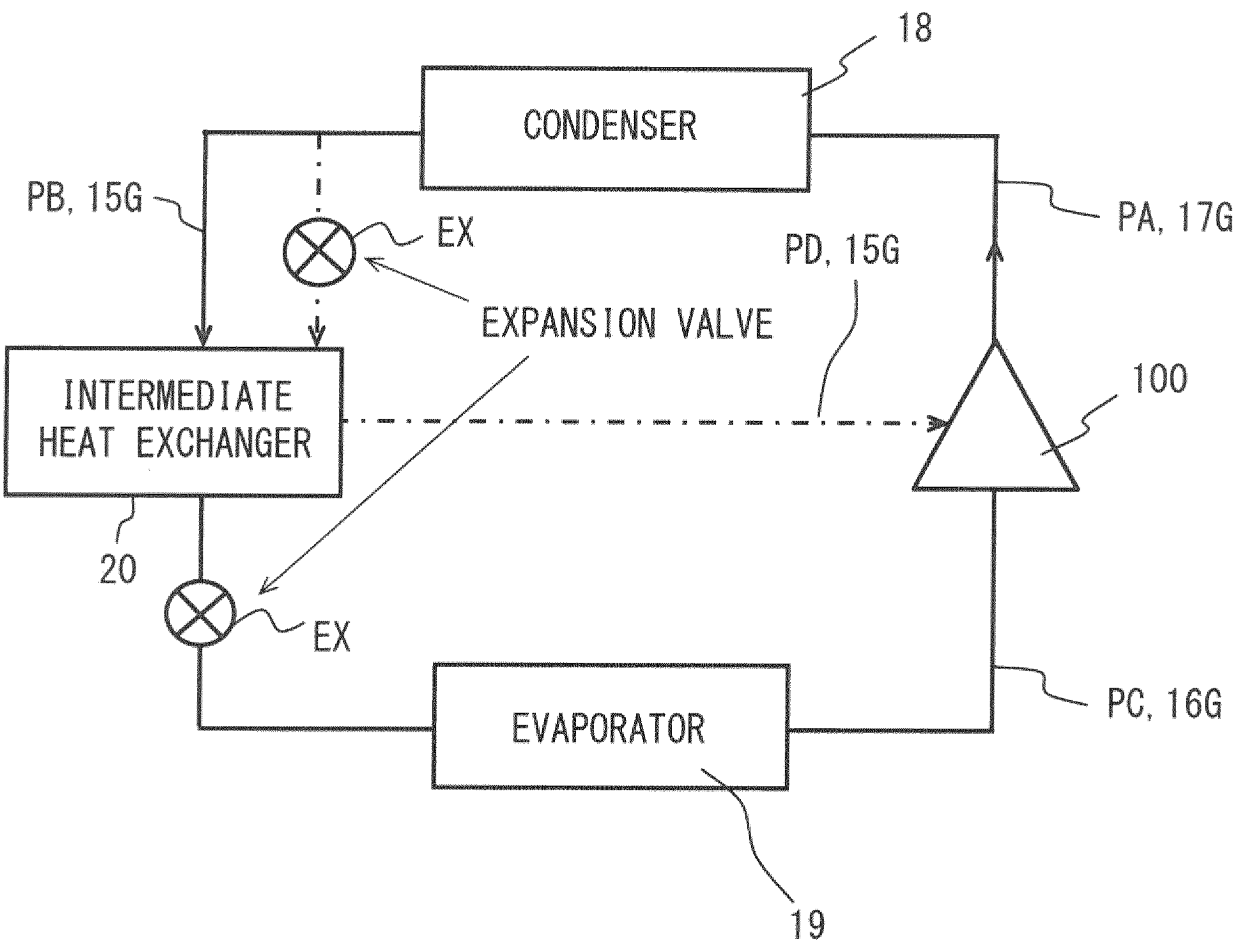

18
CONDENSER
PB, 15G
PA, 17G
PD, 15G
100
EXPANSION VALVE
PC, 16G
EVAPORATOR
19

FIG. 7


18
CONDENSER
PB, 15G
EX
PA, 17G
PD, 15G
EXPANSION VALVE
100
INTERMEDIATE
HEAT EXCHANGER
20
EX
EVAPORATOR
PC, 16G
19

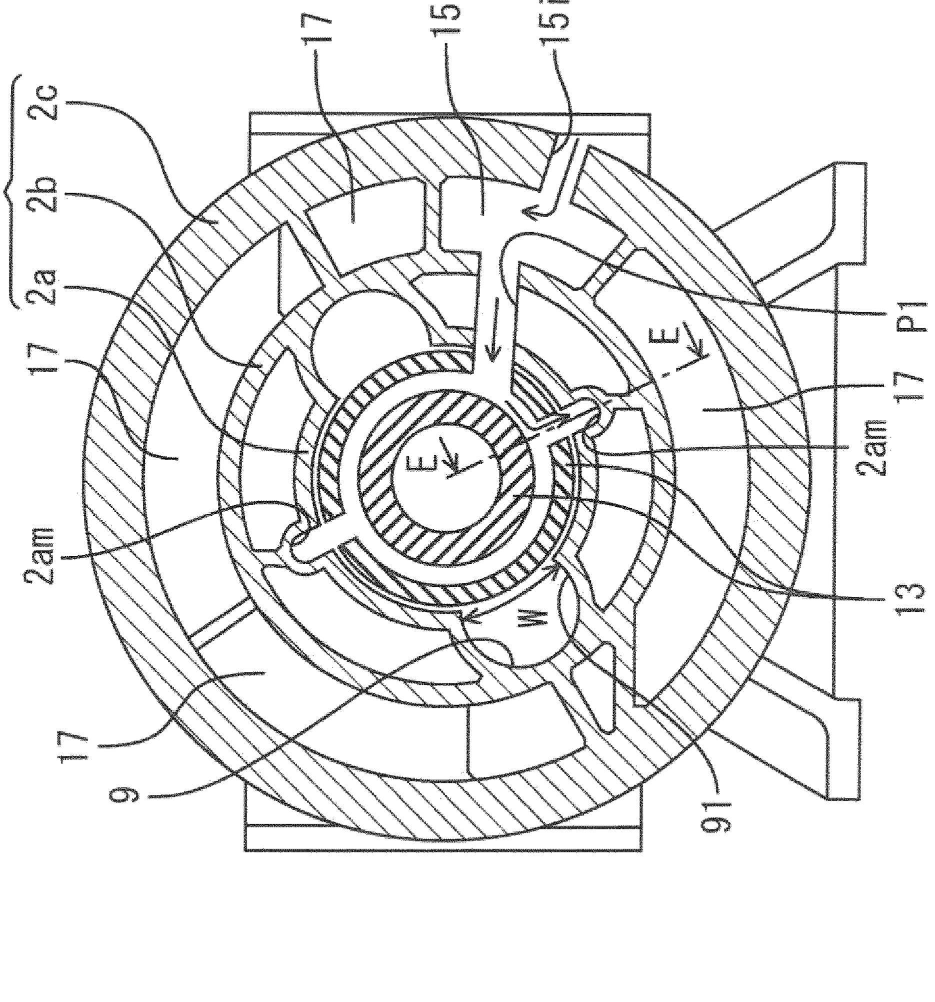

2
2a
2b
2c
17
17
17
17
17
15
15in
P1
E
E
2am
2am
13
W
9
91

FIG. 8A

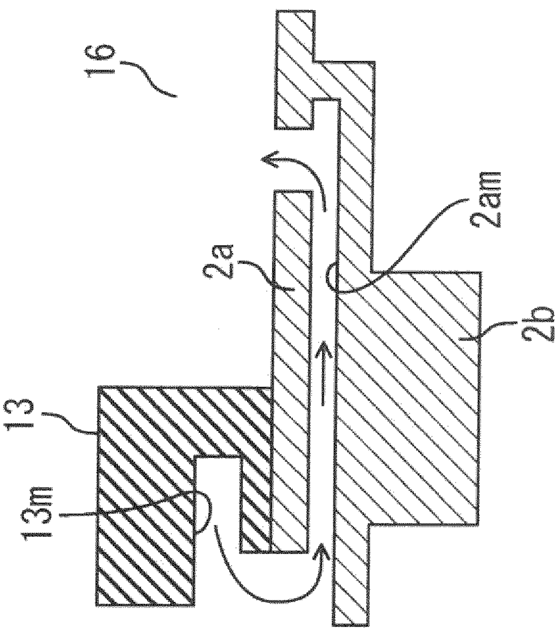
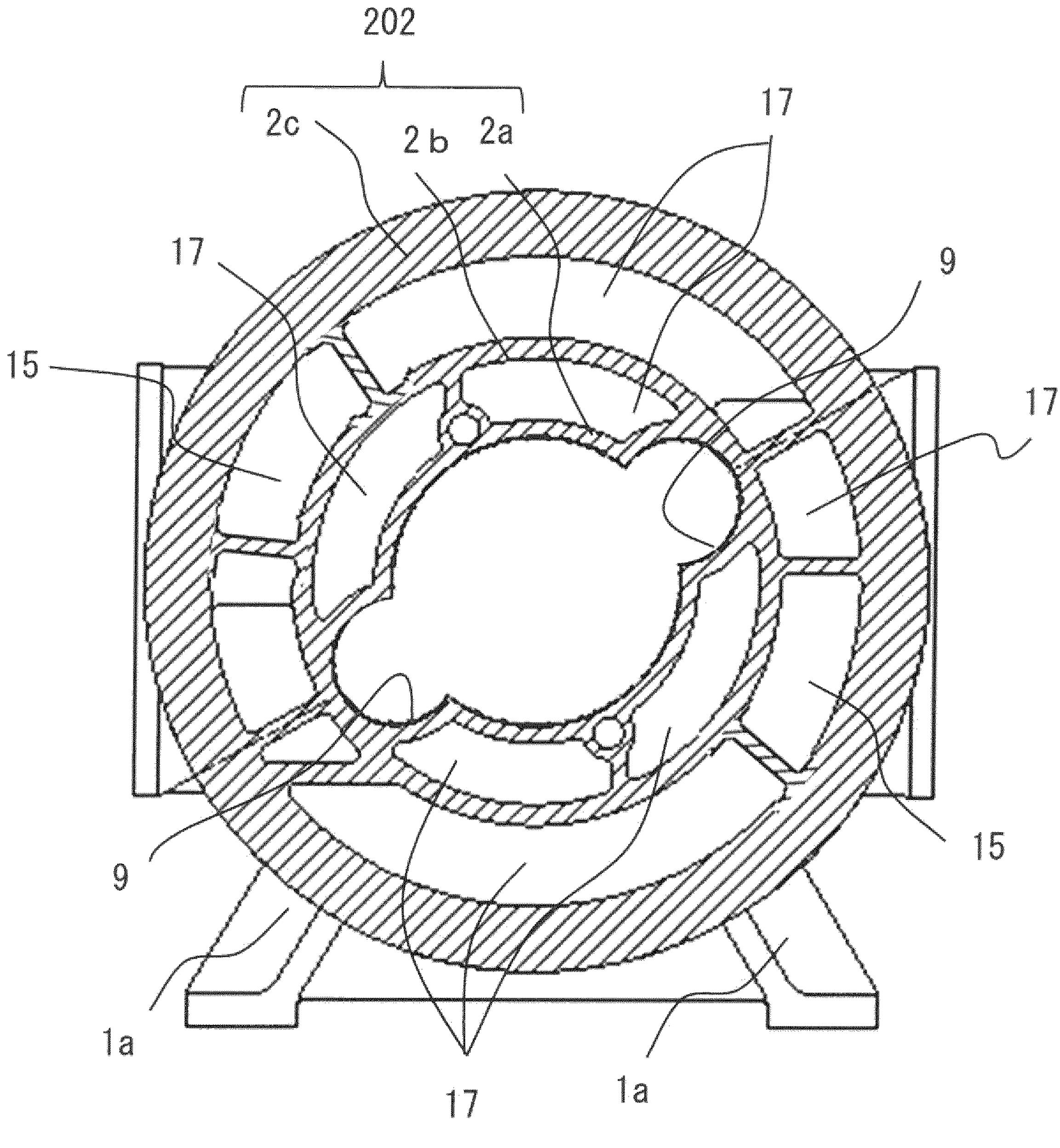

16
13
13m
2a
2am
2b

FIG. 8B

FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/021326

A. CLASSIFICATION OF SUBJECT MATTER

F04C 29/04(2006.01)i; ***F04C 18/52***(2006.01)i; ***F04C 28/12***(2006.01)i; ***F04C 29/00***(2006.01)i
FI: F04C29/04 H; F04C29/00 C; F04C18/52; F04C28/12

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)

F04C29/04; F04C18/52; F04C28/12; F04C29/00

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 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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.
A	JP 2017-145732 A (DAIKIN IND., LTD.) 24 August 2017 (2017-08-24) paragraphs [0033], [0043], [0048], [0056], [0058], fig. 1-2, 5-6	1-7
A	JP 2012-107613 A (DAIKIN IND., LTD.) 07 June 2012 (2012-06-07) paragraphs [0037], [0055], [0060], [0069], fig. 1-3, 12	1-7
A	WO 2015/114846 A1 (MITSUBISHI ELECTRIC CORP.) 06 August 2015 (2015-08-06) paragraphs [0021]-[0028], fig. 1-2, 8	1-7
A	JP 2016-142178 A (MITSUBISHI ELECTRIC CORP.) 08 August 2016 (2016-08-08) paragraphs [0009], [0013], [0029], fig. 1-2, 7	1-7
A	JP 2001-65480 A (DAIKIN IND., LTD.) 16 March 2001 (2001-03-16) paragraph [0023], fig. 1-2	1-7

☐ 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
01 August 2022	**09 August 2022**

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/JP2022/021326

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2017-145732 A	24 August 2017	US 2021/0190069 A1 paragraphs [0039], [0049], [0054], [0062], [0064], fig. 1-2, 5-6	
		WO 2017/141768 A1	
		EP 3385539 A1	
		CN 108431421 A	
JP 2012-107613 A	07 June 2012	US 2013/0216418 A1 paragraphs [0049], [0067], [0073], [0082], fig. 1-3, 12	
		WO 2012/056728 A1	
		EP 2634432 A1	
		CN 103189652 A	
WO 2015/114846 A1	06 August 2015	GB 2537996 A paragraphs [0021]-[0028], fig. 1-2, 8	
		CN 105849412 A	
JP 2016-142178 A	08 August 2016	(Family: none)	
JP 2001-65480 A	16 March 2001	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 6042474 A **[0010]**