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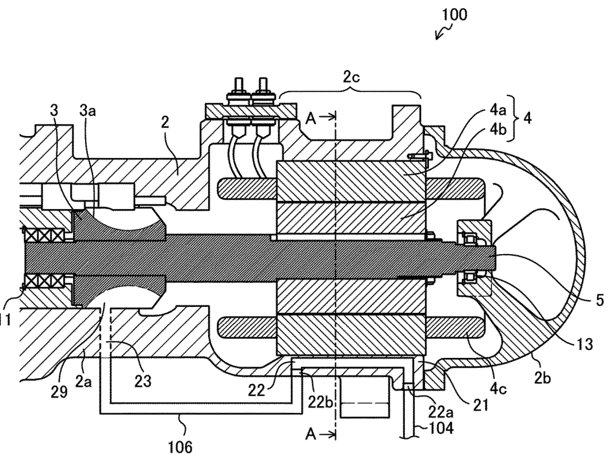
(54) **SCREW COMPRESSOR AND FREEZER**

(57) A screw compressor includes: a casing having a tubular shape; a screw rotor disposed to rotate inside the casing; and a motor disposed inside the casing and configured to drive the screw rotor. The casing includes, as a part thereof, a motor frame housing the motor, and the motor frame has a cooling hole in a high-temperature part where a temperature locally increases during operation, the cooling hole extending parallel to a rotation axis of the screw rotor, the cooling hole being configured to allow refrigerant from outside to pass therethrough.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a screw compressor having a cooling technique for cooling a motor inside a casing, and a refrigeration apparatus.

Background Art

[0002] A screw compressor mainly includes a screw rotor, a low-pressure-side bearing and a high-pressure-side bearing supporting the screw rotor, a motor configured to drive the screw rotor, and a casing housing the screw rotor, the bearings, and the motor. When the temperature of a winding of a stator of the motor increases, a tolerance to a heat-resistant temperature of a component of the compressor is reduced, which reduces the reliability. Thus, although the motor can be disposed at either the low-pressure side or the high-pressure side inside the casing, the motor is often disposed at the low-pressure side to facilitate cooling of the motor. This is because the motor disposed at the low-pressure side can be cooled using low-temperature and low-pressure refrigerant gas suctioned into the casing.

[0003] Patent Literature 1 is an example of such a technique for cooling a motor using suctioned gas. In Patent Literature 1, a collision part is provided inside a casing. The flow of refrigerant collides with the collision part. The flow of refrigerant is adjusted by allowing the refrigerant to collide with the collision part to prevent local temperature increase in a winding of the motor.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2018-178815

Summary of Invention

Technical Problem

[0005] In Patent Literature 1, the flow of refrigerant is adjusted by using the collision part. However, because the flow velocity of refrigerant flowing into the casing changes depending on operation conditions, the refrigerant may not flow as intended. Thus, the local temperature increase in the winding of the motor may not be prevented. In this case, an operation range is disadvantageously limited.

[0006] The present disclosure has been made in view of the above problem, and an object thereof is to provide a screw compressor and a refrigeration apparatus that can prevent local temperature increase in a winding of a motor to expand an operation range.

Solution to Problem

[0007] A screw compressor according to one embodiment of the present disclosure includes: a casing having a tubular shape; a screw rotor disposed to rotate inside the casing; and a motor disposed inside the casing and configured to drive the screw rotor. The casing includes, as a part thereof, a motor frame housing the motor, and the motor frame has a cooling hole in a high-temperature part where a temperature locally increases during operation, the cooling hole extending parallel to a rotation axis of the screw rotor, the cooling hole being configured to allow refrigerant from outside to pass therethrough.

[0008] A refrigeration apparatus according to another embodiment of the present disclosure includes: a refrigerant circuit configured to allow refrigerant to circulate therethrough, the refrigerant circuit including the screw compressor described above, a condenser, a main pressure reducer, and an evaporator; a first pipe branching from a pipe between the condenser and the main pressure reducer, the first pipe being connected to an inflow port of the cooling hole of the screw compressor; and a cooling pressure reducer provided on the first pipe and configured to decompress the refrigerant passing through the first pipe.

Advantageous Effects of Invention

[0009] According to one embodiment of the present disclosure, since the motor frame has the cooling hole in the high-temperature part, the high-pressure part can be intensively cooled by refrigerant flowing through the cooling hole from outside. Thus, it is possible to stably cool the high-temperature part and the motor and thus prevent local temperature increase. As a result, the operation range can be expanded.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a schematic sectional view illustrating an example of a screw compressor according to Embodiment 1.

[Fig. 2] Fig. 2 is a schematic sectional view taken along line A-A of Fig. 1.

[Fig. 3] Fig. 3 is a schematic plan view of a screw rotor and a pair of gate rotors of the screw compressor according to Embodiment 1.

[Fig. 4] Fig. 4 is a diagram illustrating an example of a suction process in a compression chamber of the screw compressor of Fig. 1.

[Fig. 5] Fig. 5 is a diagram illustrating an example of a compression process in the compression chamber of the screw compressor of Fig. 1.

[Fig. 6] Fig. 6 is a diagram illustrating an example of a discharge process in the compression chamber of the screw compressor of Fig. 1.

[Fig. 7] Fig. 7 is a diagram illustrating the configuration of a refrigeration apparatus according to Embodiment 1.

[Fig. 8] Fig. 8 is a diagram illustrating changes in the evaporating temperature and the condensing temperature during one cycle of operation of the refrigeration apparatus.

[Fig. 9] Fig. 9 is a flow chart illustrating the flow of control on a cooling pressure reducer of the refrigeration apparatus according to Embodiment 1.

[Fig. 10] Fig. 10 is a diagram illustrating the configuration of a refrigeration apparatus according to Embodiment 2.

Description of Embodiments

[0011] Embodiments of the present disclosure will be described hereinafter with reference to the drawings. Identical reference signs designate identical or corresponding parts throughout the drawings to appropriately omit or simplify description. The shape, size, and arrangement of components illustrated in the drawings can be appropriately changed within the scope of the present disclosure.

Embodiment 1.

[Screw Compressor 100]

[0012] Fig. 1 is a schematic sectional view illustrating an example of a screw compressor according to Embodiment 1. Fig. 2 is a schematic sectional view taken along line A-A of Fig. 1. Fig. 3 is a schematic plan view of a screw rotor and a pair of gate rotors of the screw compressor according to Embodiment 1.

[0013] As illustrated in Figs. 1 and 2, a screw compressor 100 of Embodiment 1 includes a casing 2 having a tubular shape, a screw rotor 3 housed inside the casing 2, and a motor 4 configured to drive the screw rotor 3 to rotate the screw rotor 3.

[0014] The motor 4 includes a stator 4a fixed to the inside of the casing 2, and a motor rotor 4b disposed inside the stator 4a.

[0015] The motor 4 may be a constant-speed motor having a constant rotation speed or may be an inverter variable-speed motor whose rotation speed can be changed to adjust an operation capacity. In the present specification, the motor 4 is the variable-speed motor. The change of the rotation speed is controlled by a controller 109 (refer to Fig. 7 described later).

[0016] The screw rotor 3 and the motor rotor 4b are coaxially disposed and fixed to a rotation shaft 5. The screw rotor 3 is coupled to the motor rotor 4b fixed to the rotation shaft 5 and driven to rotate.

[0017] Both ends of the rotation shaft 5 are supported by a main bearing 11 and a sub bearing 13 so that the rotation shaft 5 can rotate. The main bearing 11 is disposed inside a main bearing housing (not illustrated). The main bearing housing is provided on an end of the rotation shaft 5 at a discharge side (the left side in Fig. 1) of the screw rotor 3. The sub bearing 13 is provided on an end of the rotation shaft 5 at a suction side (the right side in Fig. 1) of the screw rotor 3.

[0018] The screw rotor 3 has a cylindrical shape. The screw rotor 3 has an outer peripheral face having a plurality of screw grooves 3a formed in a helical shape. As illustrated in Fig. 3, a space of the plurality of screw grooves 3a surrounded by an inner peripheral face of the casing 2 and a pair of gate rotors 6 engaged with the plurality of screw grooves 3a serves as a compression chamber 29. The gate rotors 6 rotate in response to rotation of the screw rotor 3.

[0019] The casing 2 includes a main casing 2a and a suction casing 2b. The screw rotor 3 and the motor 4 are housed inside the main casing 2a. The suction casing 2b has a suction port (not illustrated) through which refrigerant is suctioned from a refrigerant circuit located outside. Hereinbelow, refrigerant suctioned into the casing 2 through the suction port is referred to as the suction refrigerant.

[0020] A space inside the casing 2 is partitioned by a partition wall (not illustrated) into a high-pressure space (not illustrated) having a discharge pressure and a low-pressure space (not illustrated) having a suction pressure. In the high-pressure space, the casing 2 has a discharge port 8 (refer to Fig. 3) open to a discharge chamber (not illustrated). Hereinbelow, a part of the main casing 2a with the stator 4a of the motor 4 fixed thereto is referred to as a motor frame 2c.

[0021] As illustrated in Figs. 1 and 2, the motor frame 2c has holding parts 21 configured to hold the stator 4a. Each of the holding parts 21 projects to the stator 4a from an inner peripheral face of the motor frame 2c to be in contact with an outer peripheral face of the motor 4 to hold the stator 4a. As illustrated in Fig. 2, the holding parts 21 are spaced in the circumferential direction. The space between the holding parts 21 serves as a passage for refrigerant suctioned into the casing 2 to pass.

[0022] The casing 2 has a high-temperature part 24 where the temperature locally increases during operation due to, for example, heat generation of a winding 4c of the motor 4 and lubricating oil that flows into the casing 2 together with the refrigerant and accumulates on the bottom of the main casing 2a. Of the holding parts 21, the holding part 21 located in the high-temperature part 24 has a cooling hole 22 configured to allow the refrigerant from the refrigerant circuit located outside to pass therethrough. Hereinbelow, the refrigerant flowing into the cooling hole 22 is referred to as the cooling refrigerant.

[0023] In this example, the high-temperature part 24 is located below the rotation shaft 5. Thus, the cooling hole 22 is also provided below the rotation shaft 5. In this example, two cooling holes 22 are provided. However, the number of cooling holes 22 may be any number and may be one or three or more. The position of the high-temperature part 24 on the motor frame 2c varies depending on, for example, the shape of the passage for the refrigerant inside the casing 2. It is only required that the holding part 21 located in the high-temperature part 24 have the cooling hole 22.

[0024] The cooling hole 22 of the motor frame 2c extends parallel to the axis of the rotation shaft 5. The cooling hole 22 is open, at both ends thereof, on the side face of the main casing 2a. One opening of the cooling hole 22 serves as an inflow port 22a through which the cooling refrigerant flows into the cooling hole 22, whereas the other opening serves as an outflow port 22b through which the cooling refrigerant flows out of the cooling hole 22. A first pipe 104 communicating with the refrigerant circuit is connected to the inflow port 22a. One end of a second pipe 106 is connected to the outflow port 22b. The other end of the second pipe 106 is connected to an opening of an injection hole 23 provided in the main casing 2a, the opening being located on the outer face of the casing 2. An opening of the injection hole 23, the opening being located on the inner face of the casing 2, communicates with the compression chamber 29.

[Compressing Operation]

[0025] Next, operation of the screw compressor 100 according to Embodiment 1 will be described.

[0026] Fig. 4 is a diagram illustrating an example of a suction process in the compression chamber of the screw compressor of Fig. 1. Fig. 5 is a diagram illustrating an example of a compression process in the compression chamber of the screw compressor of Fig. 1. Fig. 6 is a diagram illustrating an example of a discharge process in the compression chamber of the screw compressor of Fig. 1.

[0027] As illustrated in Figs. 4 to 6, the screw rotor 3 rotated by the motor 4 relatively moves teeth 6a of the gate rotors 6 inside the screw grooves 3a. Accordingly, inside the screw grooves 3a, a cycle including a suction process, a compression process, and a discharge process is repeated. A portion surrounded by a dotted line in Figs. 4 to 6 shows the casing 2. The screw groove 3a surrounded by the casing 2 serves as the compression chamber 29. Hereinbelow, each process will be described focusing on the compression chamber 29 hatched with dots in Figs. 4 to 6.

[0028] Suction refrigerant suctioned through a suction port (not illustrated) of the casing 2 passes through an area around the motor 4 (refer to Fig. 1) and then flows into the screw groove 3a in the suction process. Fig. 4 illustrates the compression chamber 29 immediately after completion of the suction process, that is, at start of compression. Then, when the screw rotor 3 rotates in the direction shown by a solid arrow, the capacity of the compression chamber 29 decreases as illustrated in Fig. 5.

[0029] When the screw rotor 3 further rotates, as illustrated in Fig. 6, the compression chamber 29 communicates with the discharge port 8. Accordingly, high-pressure refrigerant gas compressed inside the compression chamber 29 is discharged to outside through the discharge port 8.

[Cooling Operation]

[0030] Next, a cooling operation in the screw compressor 100 will be described.

[0031] The cooling refrigerant from the refrigerant circuit passes through the cooling hole 22. More specifically, the cooling refrigerant from the first pipe 104 flows into the cooling hole 22 through the inflow port 22a and then flows out of the cooling hole 22 through the outflow port 22b. Since the motor frame 2c has the cooling hole 22 in the high-temperature part 24, the cooling refrigerant flowing through the cooling hole 22 can intensively cool the high-temperature part 24. The local temperature increase in the motor 4 can be prevented by intensively cooling the high-temperature part 24. More specifically, the high-temperature part 24 of the motor frame 2c has a higher temperature than the other part under the influence of local temperature increase in the winding 4c of the motor 4. Thus, the local temperature increase in the winding 4c of the motor 4 can also be prevented by lowering the temperature of the high-temperature part 24. Since, in the holding part 21, the cooling hole 22 extends parallel to the axis of the rotation shaft 5, the motor 4 can be wholly cooled in the axial direction.

[0032] When the rotation speed of the motor 4 as an operation condition changes from a low rotation speed to a high rotation speed, the cooling refrigerant constantly flows through the cooling hole 22 provided in the high-temperature part 24. That is, the high-temperature part 24 can be intensively cooled regardless of the rotation speed of the motor 4. Thus, the high-temperature part 24 can be stably cooled as compared to the conventional technique that adjusts the flow of refrigerant using the collision part to prevent the local temperature increase in the winding of the motor. This eliminates the necessity of limiting an operation range to make the temperature of the winding 4c of the motor 4 equal to or lower than a heat-resistant temperature, which enables expansion of the operation range. In addition, it is possible to prevent reduction in a motor efficiency caused by the temperature increase in the motor 4 and also reduce the size of the motor 4.

[0033] The cooling refrigerant passes through the cooling hole 22, then flows out of the casing 2 through the outflow port 22b once, then passes through the second pipe 106, then flows into the casing 2 again, and flows into the compression chamber 29. That is, the cooling refrigerant flows into not the screw groove 3a before completion of suction, but the compression chamber 29 after completion of the suction of gas refrigerant. Thus, it is possible to prevent disadvantageous reduction in performance caused by reduction in the refrigerant circulation amount due to the cooling refrigerant interfering with the suction of the suction refrigerant into the compression chamber 29. In the present embodiment, the cooling refrigerant flows out of the casing 2 once through the outflow port 22b, then returns into the casing 2, and then flows into the compression chamber 29. However, the cooling refrigerant may flow into the compression chamber 29 through the inside of the casing 2. That is, it is only required that a passage configured to allow the cooling refrigerant flowing out of the cooling hole 22 through the outflow port 22b to flow into the compression chamber 29 be provided.

[0034] The cooling refrigerant may be gas refrigerant, two-phase refrigerant, or liquid refrigerant. In view of preventing reduction in operation capacity caused by reduction in the refrigerant circulation amount, the cooling refrigerant is preferably gas refrigerant or two-phase refrigerant. However, when the cooling refrigerant is liquid refrigerant, the cooling effect is high. Thus, the phase of the cooling refrigerant may be appropriately selected taking into consideration a balance between the cooling effect and the operation capacity.

[Refrigerant Circuit]

[0035] Next, a refrigeration apparatus including the screw compressor 100 configured as described above will be described.

[0036] Fig. 7 is a diagram illustrating the configuration of the refrigeration apparatus according to Embodiment 1. A refrigeration apparatus 110 includes a refrigerant circuit configured to allow refrigerant to circulate therethrough. The refrigerant circuit includes the screw compressor 100 described above, a condenser 101, a main pressure reducer 102, and an evaporator 103 connected in this order through refrigerant pipes. The refrigeration apparatus 110 further includes the first pipe 104, a cooling pressure reducer 105, and the second pipe 106. The first pipe 104 branches from the pipe between the condenser 101 and the main pressure reducer 102 and is connected to the inflow port 22a of the casing 2 of the screw compressor 100. Since the second pipe 106 is described above, redundant description will be omitted.

[0037] The condenser 101 cools and condenses refrigerant gas discharged from the screw compressor 100. The main pressure reducer 102 expands the refrigerant liquid flowing out of the condenser 101 by throttling. Examples of the pressure reducer include an electronic expansion valve, a capillary tube, and a thermal expansion valve. The evaporator 103 evaporates the refrigerant flowing out of the main pressure reducer 102. The cooling pressure reducer 105 adjusts the flow rate of the refrigerant passing through the first pipe 104. Examples of the cooling pressure reducer 105 include an electronic expansion valve and a thermal expansion valve.

[0038] A discharge temperature sensor 107 is provided at the discharge side of the screw compressor 100. The discharge temperature sensor 107 measures the temperature of the refrigerant discharged from the screw compressor 100 (hereinbelow, referred to as the discharge temperature). The information on the discharge temperature measured by the discharge temperature sensor 107 is output to the controller 109, which is described later. Further, the screw compressor 100 is provided with a motor frame temperature sensor 108. The motor frame temperature sensor 108 measures the temperature of the motor frame 2c (hereinbelow, referred to as the motor frame temperature) where the motor 4 is attached. The information on the motor frame temperature measured by the motor frame temperature sensor 108 is output to the controller 109.

[0039] The refrigeration apparatus 110 further includes the controller 109. The controller 109 controls the entire refrigeration apparatus 110. The controller 109 controls the opening degree of the cooling pressure reducer 105 based on values measured by the discharge temperature sensor 107 and the motor frame temperature sensor 108. The controller 109 may be hardware such as a circuit device that implements the functions thereof or may be a combination of an arithmetic device such as a microcomputer or a CPU and software executed thereon.

[0040] The refrigerant circulating through the refrigerant circuit is not limited to any particular refrigerant. For example, refrigerant having a low GWP is preferably used taking environmental impacts into consideration. Examples of the refrigerant having a low GWP include R32, R513A, HFO-1234yf, HFO-1234ze, and mixed refrigerant containing at least one of these refrigerants. The refrigerant used in the screw compressor 100 may be natural refrigerant such as carbon dioxide.

[Description for Operation in Refrigerant Circuit]

[0041] The high-temperature and high-pressure refrigerant compressed by the screw compressor 100 rejects heat while being condensed by the condenser 101. The refrigerant condensed by the condenser 101 branches into main-flow refrigerant and cooling refrigerant after passing through the condenser 101. The main-flow refrigerant is decompressed and thus expanded by the main pressure reducer 102. The refrigerant expanded by the main pressure reducer 102 receives heat while evaporating in the evaporator 103. The refrigerant evaporated by the evaporator 103 is suctioned into the screw compressor 100 and compressed again. In this manner, one cycle is finished.

[0042] On the other hand, the cooling refrigerant flows into the first pipe 104 when the cooling pressure reducer 105 is open, is decompressed by the cooling pressure reducer 105, and then flows into the inflow port 22a of the screw compressor 100. The cooling refrigerant flowing into the inflow port 22a cools the high-temperature part 24 while passing through the cooling hole 22, then passes through the second pipe 106, and is then injected into the compression chamber 29 as described above.

[0043] Fig. 8 is a diagram illustrating changes in the evaporating temperature and the condensing temperature during one cycle of operation of the refrigeration apparatus. In Fig. 8, a portion surrounded by a dotted line corresponds to an operation condition having a high discharge temperature. As illustrated in Fig. 8, the discharge temperature is likely to excessively increase under the condition where the condensing temperature is high in the operation range. Thus, the refrigerant is injected into the compression chamber 29 to hold down the increase in the discharge temperature. The amount of the refrigerant is controlled in the cooling pressure reducer 105. Hereinbelow, the control on the cooling pressure reducer 105 will be described.

[0044] Fig. 9 is a flow chart illustrating the flow of control on the cooling pressure reducer of the refrigeration apparatus.

[0045] The controller 109 determines whether the discharge temperature measured by the discharge temperature sensor 107 is higher than a set temperature previously set for the discharge temperature or whether the motor frame temperature measured by the motor frame temperature sensor 108 is higher than a set temperature previously set for the motor frame temperature (step S1). When the discharge temperature or the motor frame temperature is higher than its corresponding set temperature, the controller 109 controls the cooling pressure reducer 105 based on the temperature that exceeds the set temperature first to adjust the flow rate of the refrigerant passing through the cooling hole 22 (step S2 to step S5).

[0046] Specifically, when the discharge temperature is higher than the set temperature (step S2), the controller 109 controls the cooling pressure reducer 105 to lower the discharge temperature (step S3). More specifically, the controller 109 increases the opening degree of the cooling pressure reducer 105. On the other hand, when the motor frame temperature is higher than the set temperature (step S4), the controller 109 controls the cooling pressure reducer 105 to lower the motor frame temperature (step S5). More specifically, the controller 109 increases the opening degree of the cooling pressure reducer 105.

[0047] When the discharge temperature measured by the discharge temperature sensor 107 is equal to or lower than its corresponding set temperature and the motor frame temperature is equal to or lower than its corresponding set temperature, it is not necessary to cool the motor 4. Thus, the controller 109 makes the opening degree of the cooling pressure reducer 105 zero (step S6).

[0048] The present embodiment describes an example in which the cooling pressure reducer 105 is controlled based on the discharge temperature. However, the cooling pressure reducer 105 may be controlled using a discharge superheat degree calculated by subtracting the condensing temperature from the discharge temperature. That is, the cooling pressure reducer 105 may be controlled based on an index value corresponding to the state of the refrigerant discharged from the screw compressor 100. Specifically, when the index value is higher than a set index value, the cooling pressure reducer 105 may be controlled to lower the discharge temperature. When the cooling pressure reducer 105 is controlled using the discharge superheat degree, cost is cheaper when a thermal expansion valve is used as the cooling pressure reducer 105 than when an electronic expansion valve is used because of the following reason. A thermal expansion valve is a mechanical valve whose opening degree is mechanically adjusted depending on a value measured in a temperature-sensitive cylinder (not illustrated). Thus, the number of components of a thermal expansion valve is smaller than that of an electronic expansion valve, which requires a control board.

[Effects]

[0049] The screw compressor 100 of Embodiment 1 includes the casing 2 having a tubular shape, the screw rotor 3 disposed to rotate inside the casing 2, and the motor 4 disposed inside the casing 2 and configured to drive the screw rotor 3. The casing 2 includes, as a part thereof, the motor frame 2c housing the motor 4. The motor frame 2c has the cooling hole 22 in the high-temperature part 24 where the temperature locally increases during operation. The cooling hole 22 extends parallel to the rotation axis of the screw rotor 3 and allows refrigerant from outside to pass therethrough. In this manner, since the motor frame 2c has the cooling hole 22 in the high-temperature part 24, the high-temperature part 24 can be intensively cooled by the cooling refrigerant flowing through the cooling hole 22 from outside. Thus, it is possible to stably cool the high-temperature part 24 and the motor 4 and thus prevent local temperature increase. As a result, the operation range can be expanded.

[0050] In the screw compressor 100 of Embodiment 1, the motor frame 2c has the holding part 21 projecting inward from the inner peripheral face of the motor frame 2c. The holding part 21 is in contact with the outer peripheral face of the motor 4 to hold the motor 4. The holding part 21 has the cooling hole 22. Since the holding part 21 kept in contact with the motor 4 has the cooling hole 22 in this manner, the motor 4 can be efficiently cooled.

[0051] The motor frame 2c has a plurality of cooling holes 22. This makes it possible to more efficiently cool the motor 4.

[0052] The refrigeration apparatus 110 of Embodiment 1 includes the screw compressor 100 described above, the condenser 101, the main pressure reducer 102, and the evaporator 103. The refrigeration apparatus 110 further includes the refrigerant circuit configured to allow refrigerant to circulate therethrough, the first pipe 104 branching from the pipe between the condenser 101 and the main pressure reducer 102, the first pipe 104 being connected to the inflow port 22a of the cooling hole 22 of the screw compressor 100, and the cooling pressure reducer 105 provided on the first pipe 104 and configured to decompress the refrigerant passing through the first pipe 104. The screw compressor 100 described above enables the refrigeration apparatus to expand the operation range.

[0053] The refrigeration apparatus 110 of Embodiment 1 includes the controller 109 configured to control the cooling pressure reducer 105. The controller 109 is configured to control the cooling pressure reducer 105 based on the index value related to the state of refrigerant discharged from the screw compressor 100 or based on the motor frame temperature that is the temperature of the motor frame 2c. Accordingly, it is possible to adjust the flow rate of the cooling refrigerant flowing into the cooling hole 22 and thus appropriately cool the motor 4.

[0054] The controller 109 is configured to control the cooling pressure reducer 105 to lower the discharge temperature that is the temperature of refrigerant discharged from the screw compressor 100 when the index value is higher than the set index value previously set, and control the cooling pressure reducer 105 to lower the motor frame temperature when the motor frame temperature is higher than the set temperature previously set. Accordingly, it is possible to adjust the flow rate of the cooling refrigerant flowing into the cooling hole 22 and thus appropriately cool the motor 4.

[0055] The index value is the discharge temperature that is the temperature of refrigerant discharged from the screw compressor 100 or the discharge superheat degree calculated by subtracting the condensing temperature from the discharge temperature. In this manner, the index value may be the discharge temperature or the discharge superheat degree.

[0056] The refrigeration apparatus 110 of Embodiment 1 includes the passage configured to allow refrigerant flowing out of the cooling hole 22 through the outflow port 22b of the cooling hole 22 to flow into the compression chamber 29. This prevents disadvantageous reduction in performance caused by reduction in the refrigerant circulation amount due to the cooling refrigerant interfering with the suction of the suction refrigerant into the compression chamber 29.

Embodiment 2.

[0057] Next, Embodiment 2 will be described. In Embodiment 1, the refrigerant flows into the compression chamber 29 after passing through the cooling hole 22. On the other hand, in Embodiment 2, the refrigerant cools an inverter of the controller 109 after passing through the cooling hole 22 and then flows into the compression chamber 29. Hereinbelow, differences between Embodiment 1 and Embodiment 2 will be mainly described. A part that is not described in Embodiment 2 is similar to that in Embodiment 1.

[0058] Fig. 10 is a diagram illustrating the configuration of a refrigeration apparatus according to Embodiment 2.

[0059] A refrigeration apparatus 110 of Embodiment 2 includes a cooler 121 configured to cool the controller 109 in addition to the elements of the refrigeration apparatus 110 of Embodiment 1 illustrated in Fig. 7. The cooler 121 includes a refrigerant pipe (not illustrated) configured to allow refrigerant to pass therethrough. The cooler 121 is disposed in contact with the controller 109.

[0060] The controller 109 includes an inverter (not illustrated). An inverter component that is an electronic component of the inverter generates heat. The cooler 121 is used to cool the heat. The refrigerant flows through the cooler 121 after cooling the motor 4 and passing through the cooling hole 22, and the heat transmitted from the inverter component to the cooler 121 is transferred to the refrigerant. In this manner, the controller 109 can be cooled.

[0061] According to Embodiment 2, in addition to an effect similar to the effect obtained in Embodiment 1, the following effect can be obtained. Embodiment 2 includes the cooler 121 disposed in contact with the controller 109, and the refrigerant passes through the cooler 121 after passing through the cooling hole 22. Thus, the inverter component of the controller 109 can be cooled. This reduces the capacity of the inverter component having a high heat generation amount such as an IGBT or a power module. Thus, it is possible to reduce the size of the inverter component and reduce cost.

[0062] The configuration of the refrigerant circuit is not limited to the configuration illustrated in Fig. 10. A thermal efficiency mechanism may be further provided in addition to the configuration illustrated in Fig. 10. The thermal efficiency mechanism is, for example, an intermediate cooler configured to exchange heat between refrigerant flowing between the condenser 101 and the cooling pressure reducer 105 and refrigerant flowing between the cooling pressure reducer 105 and the inflow port 22a.

Reference Signs List

[0063] 2: casing, 2a: main casing, 2b: suction casing, 2c: motor frame, 3: screw rotor, 3a: screw groove, 4: motor, 4a: stator, 4b: motor rotor, 4c: winding, 5: rotation shaft, 6: gate rotor, 6a: tooth, 8: discharge port, 11: main bearing, 13: sub bearing, 21: holding part, 22: cooling hole, 22a: inflow port, 22b: outflow port, 23: injection hole, 24: high-temperature part, 29: compression chamber, 100: screw compressor, 101: condenser, 102: main pressure reducer, 103: evaporator, 104: first pipe, 105: cooling pressure reducer, 106: second pipe, 107: discharge temperature sensor, 108: motor frame temperature sensor, 109: controller, 110: refrigeration apparatus, 121: cooler

Claims

1. A screw compressor comprising:

a casing having a tubular shape;
a screw rotor disposed to rotate inside the casing; and
a motor disposed inside the casing and configured to drive the screw rotor, wherein
the casing includes, as a part thereof, a motor

frame housing the motor, and the motor frame has a cooling hole in a high-temperature part where a temperature locally increases during operation, the cooling hole extending parallel to a rotation axis of the screw rotor, the cooling hole being configured to allow refrigerant from outside to pass therethrough.

2. The screw compressor of claim 1, wherein the motor frame has a holding part projecting inward from an inner peripheral face of the motor frame, the holding part being in contact with an outer peripheral face of the motor to hold the motor, and the holding part has the cooling hole.

3. The screw compressor of claim 1 or 2, wherein the motor frame has a plurality of the cooling holes.

4. A refrigeration apparatus comprising:

a refrigerant circuit configured to allow refrigerant to circulate therethrough, the refrigerant circuit including the screw compressor of any one of claims 1 to 3, a condenser, a main pressure reducer, and an evaporator;
a first pipe branching from a pipe between the condenser and the main pressure reducer, the first pipe being connected to an inflow port of the cooling hole of the screw compressor; and
a cooling pressure reducer provided on the first pipe and configured to decompress the refrigerant passing through the first pipe.

5. The refrigeration apparatus of claim 4, further comprising a controller configured to control the cooling pressure reducer, wherein
the controller is configured to control the cooling pressure reducer based on an index value related to a state of refrigerant discharged from the screw compressor or based on a motor frame temperature that is a temperature of the motor frame.

6. The refrigeration apparatus of claim 5, wherein

the controller is configured to
control the cooling pressure reducer to lower a discharge temperature that is a temperature of refrigerant discharged from the screw compressor when the index value is higher than a set index value previously set, and
control the cooling pressure reducer to lower the motor frame temperature when the motor frame temperature is higher than a set temperature previously set.

7. The refrigeration apparatus of claim 5 or 6, wherein the index value is a discharge temperature that is a temperature of refrigerant discharged from the screw compressor or a discharge superheat degree calculated by subtracting a condensing temperature from the discharge temperature.

8. The refrigeration apparatus of any one of claims 5 to 7, further comprising a passage configured to allow refrigerant flowing out of the cooling hole through an outflow port of the cooling hole to flow into a refrigerant compression chamber provided in the screw compressor.

9. The refrigeration apparatus of any one of claims 5 to 8, further comprising a cooler disposed in contact with the controller, wherein refrigerant passes through the cooler after passing through the cooling hole of the screw compressor.

FIG. 1

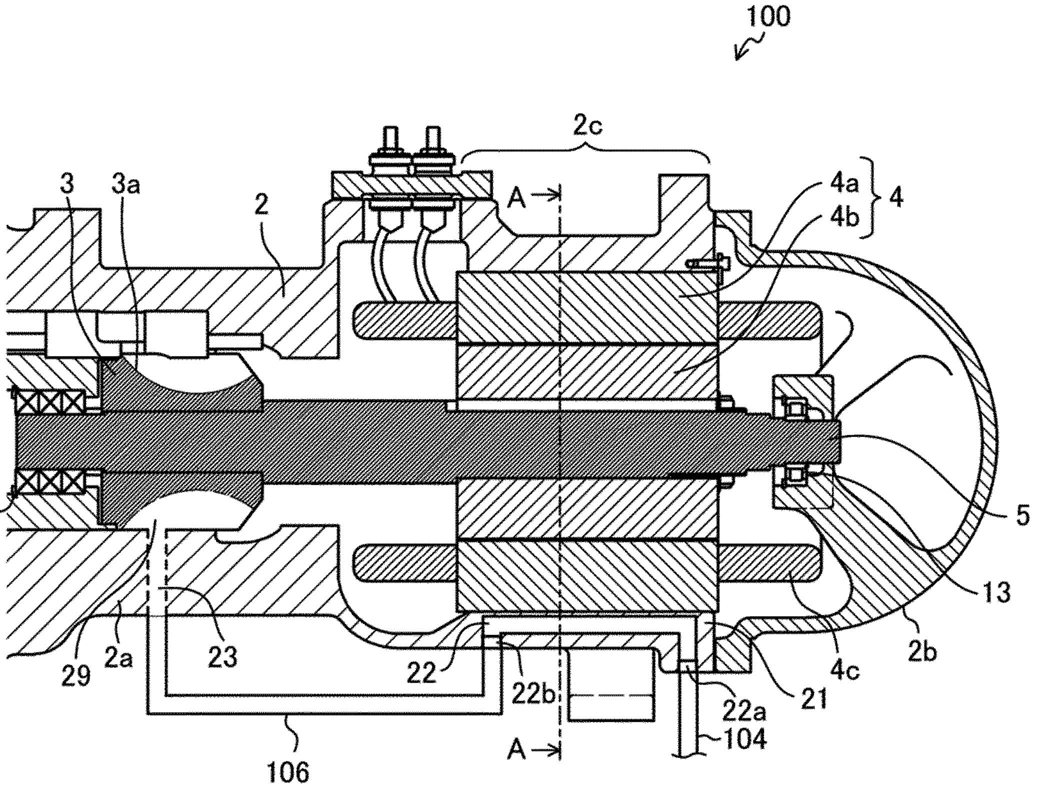


FIG. 2

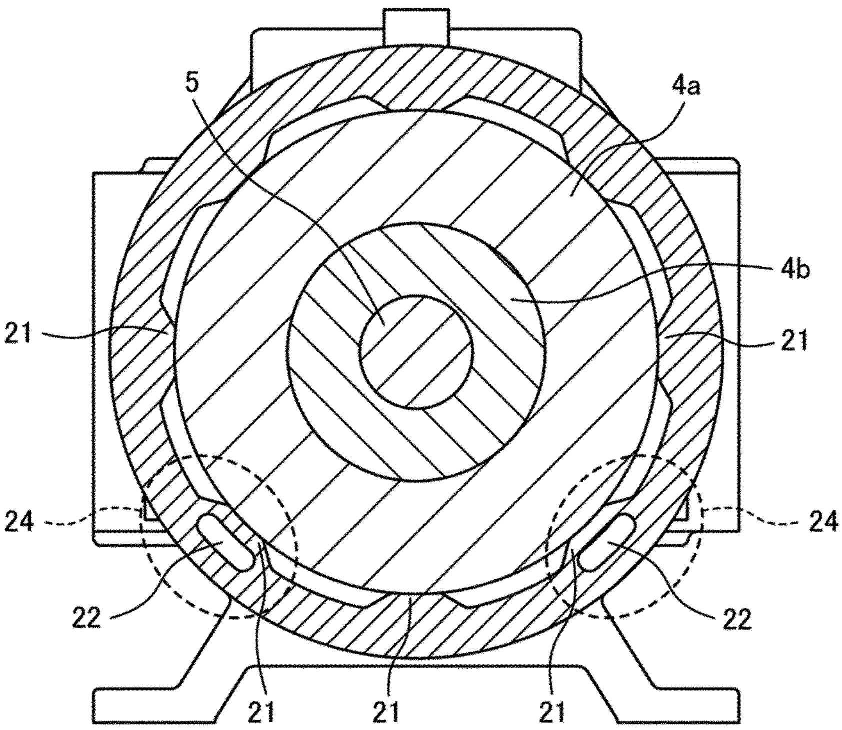


FIG. 3

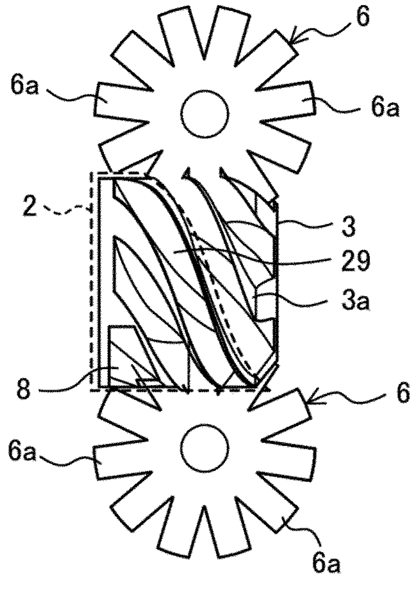


FIG. 4

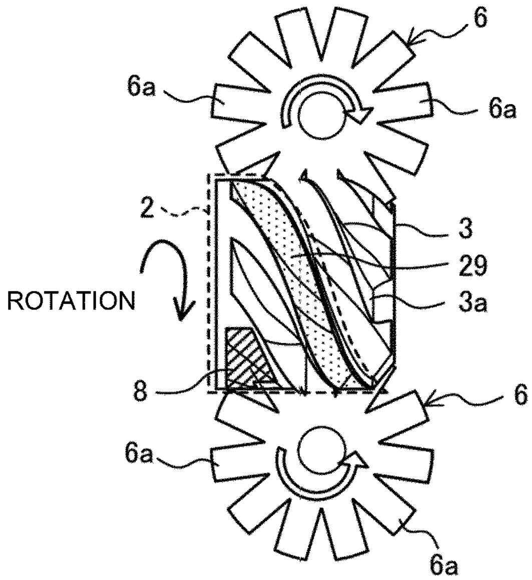


FIG. 5

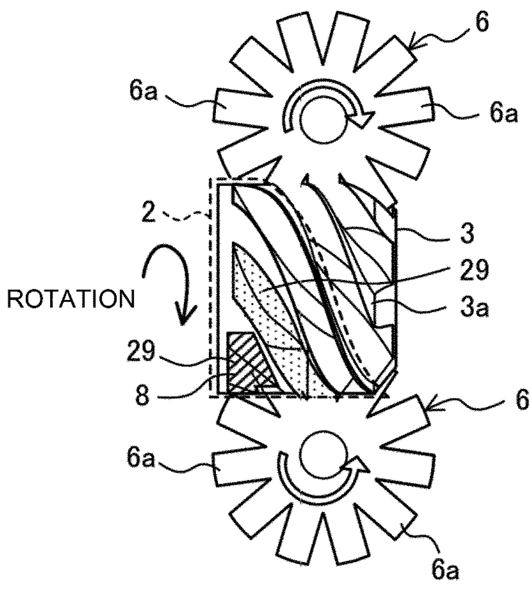


FIG. 6

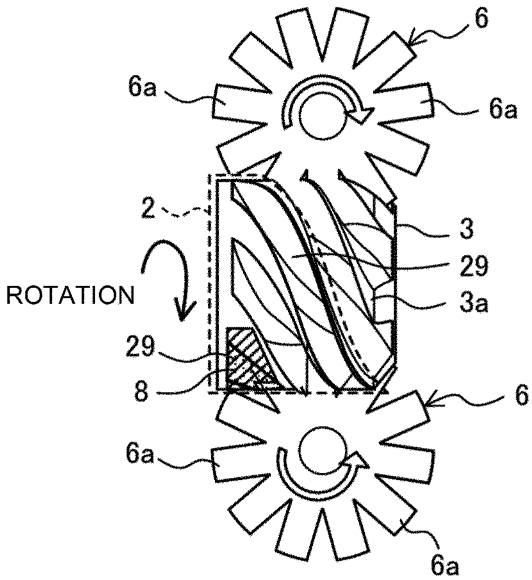


FIG. 7

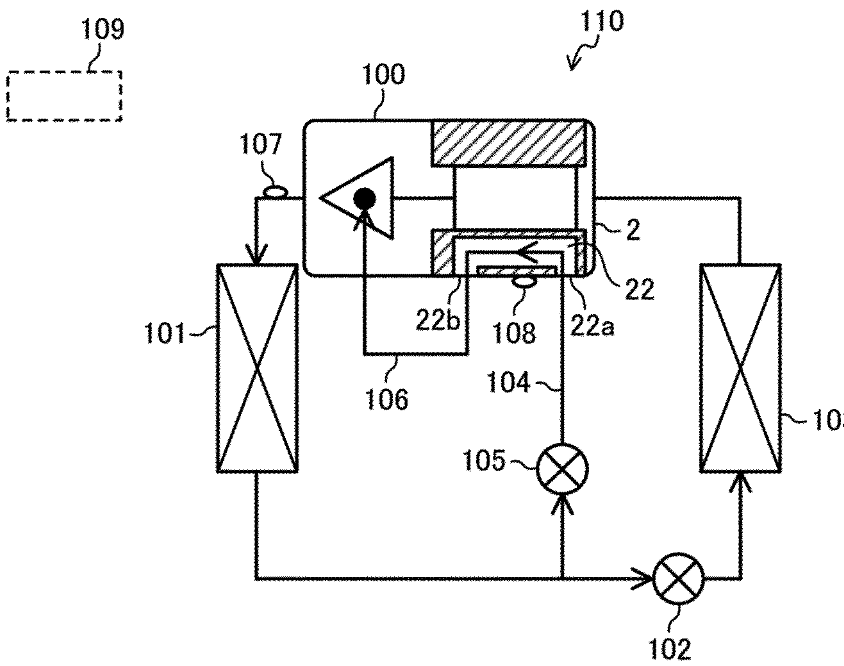


FIG. 8

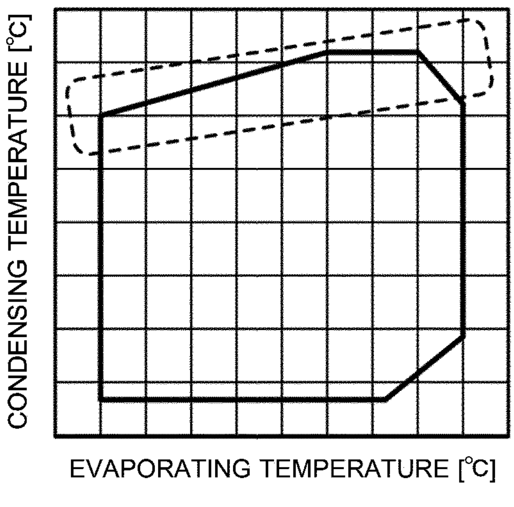


FIG. 9

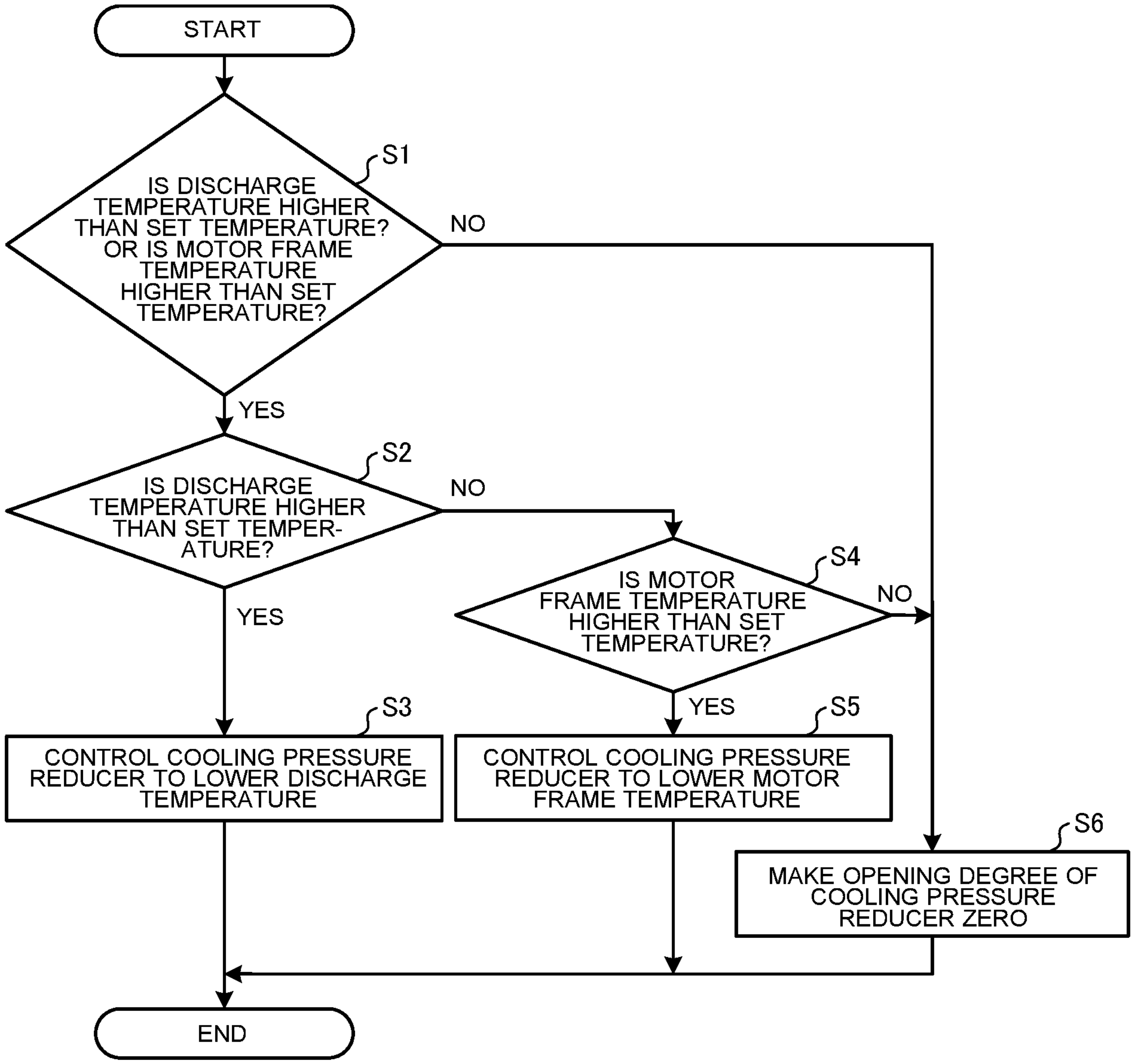
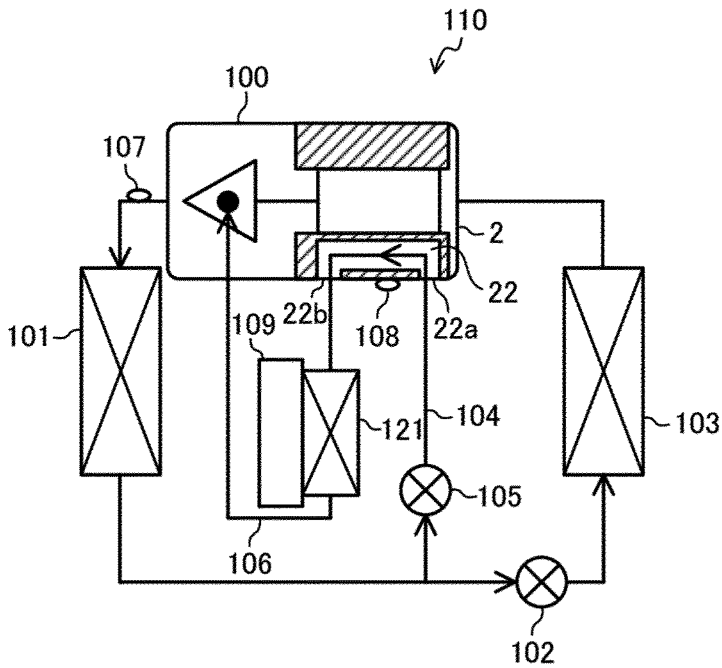

START
S1
IS DISCHARGE TEMPERATURE HIGHER THAN SET TEMPERATURE? OR IS MOTOR FRAME TEMPERATURE HIGHER THAN SET TEMPERATURE?
NO
YES
S2
IS DISCHARGE TEMPERATURE HIGHER THAN SET TEMPER-ATURE?
NO
YES
S4
IS MOTOR FRAME TEMPERATURE HIGHER THAN SET TEMPERATURE?
NO
YES
S3
CONTROL COOLING PRESSURE REDUCER TO LOWER DISCHARGE TEMPERATURE
S5
CONTROL COOLING PRESSURE REDUCER TO LOWER MOTOR FRAME TEMPERATURE
S6
MAKE OPENING DEGREE OF COOLING PRESSURE REDUCER ZERO
END

FIG. 10



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/008051

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F04C29/04(2006.01)i
FI: F04C29/04 K

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)
Int. Cl. 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	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 113824/1974 (Laid-open No. 41115/1976) (HITACHI, LTD.) 26 March 1976, description, page 2, line 14 to page 5, line 16, drawings	1-3 4-9
Y	JP 2015-194294 A (MITSUBISHI ELECTRIC CORP.) 05 November 2015, paragraphs [0016]-[0039], fig. 1, 2	4-9
Y	JP 2002-81391 A (KOBE STEEL, LTD.) 22 March 2002, fig. 8, 12, 14, 16	5-9
Y	JP 2008-57875 A (MITSUBISHI ELECTRIC CORP.) 13 March 2008, paragraphs [0009], [0010]	9

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

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13.03.2020	31.03.2020

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/008051

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 51-41115 U1	26.03.1976	(Family: none)	
JP 2015-194294 A	05.11.2015	(Family: none)	
JP 2002-81391 A	22.03.2002	US 2001/0054294 A1 fig. 8, 12, 14, 16	
JP 2008-57875 A	13.03.2008	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2018178815 A **[0004]**