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(71) Applicant: **IHI Corporation**
Tokyo 135-8710 (JP)

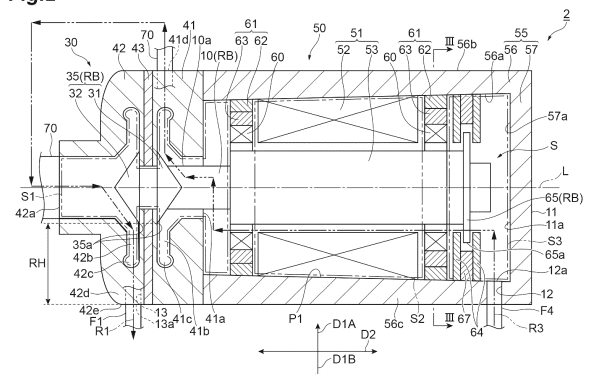
(72) Inventors:
• **TANAKA, Ryuuta**
Tokyo 135-8710 (JP)
• **NAKAJIMA, Masahiro**
Tokyo 135-8710 (JP)
• **KOBAYASHI, Hiroki**
Tokyo 135-8710 (JP)
• **AKAMATSU, Yosuke**
Tokyo 135-8710 (JP)
• **YOSHINAGA, Seiichiro**
Tokyo 135-8710 (JP)

(74) Representative: **TBK**
Bavariaring 4-6
80336 München (DE)

(54) **REFRIGERANT COMPRESSOR**

(57) A refrigerant compressor compresses a refrigerant circulating in a refrigerant circulation system. The refrigerant compressor includes: a rotating body including a shaft, and a protruding part protruding from the shaft in a radial direction and configured to rotate together with the shaft; a non-contact bearing unit rotatably supporting the rotating body; a housing including an inner space accommodating the protruding part; a suction inlet opening into the inner space and configured to supply the refrigerant to the inner space; a refrigerant passage communicating with the suction inlet and connected to an evaporator; a discharge port configured to discharge the refrigerant from the inner space; and a return passage communicating the inner space and the evaporator via a return opening provided in the inner space. The return opening is positioned more downward than the protruding part in a vertical direction.

Fig.2



Description

Technical Field

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

Background Art

[0002] Patent Literature 1 and Patent Literature 2 disclose techniques relating to heat pumps. A heat pump has a refrigerant circulation system in which, for example, a refrigerant compressor, a condenser, an expansion valve, and an evaporator are sequentially connected in a ring. In the refrigerant circulation system, the refrigerant vaporized by the evaporator is compressed in the refrigerant compressor, and then heat is dissipated in the condenser to liquefy the refrigerant. The liquefied refrigerant is supplied to the evaporator through the expansion valve, and is vaporized in the evaporator. The vaporized refrigerant is supplied to the refrigerant compressor again. In the refrigerant compressor, a shaft is rotatably supported by a pair of bearings provided inside the housing. The refrigerant is compressed by an impeller rotating together with the shaft.

Citation List

Patent Literature

[0003]

[Patent Literature 1] Japanese Unexamined Patent Publication No. 2010-071082

[Patent Literature 2] Japanese Unexamined Patent Publication No. 2019-090602

Summary of Invention

Technical Problem

[0004] An interest has emerged for non-contact bearings such as air bearings, gas bearings, or magnetic bearings as a technique for supporting a rotating body in the refrigerant circulation system described above and the like. A non-contact bearing has advantages including less energy loss due to contact friction compared to a contact bearing such as a rolling bearing. However, the rotating body tends to be displaced when external force is applied in a non-contact bearing. Thus, care must be taken to suppress contact between the rotating body and the bearing.

[0005] The present disclosure describes a refrigerant compressor that suppresses deviation in the state of contact between a rotating body and a non-contact bearing at startup.

Solution to Problem

[0006] A refrigerant compressor according to an embodiment of the present disclosure is configured to compress a refrigerant circulating in a refrigerant circulation system. The refrigerant compressor includes: a rotating body including a shaft, and a protruding part protruding from the shaft in a radial direction and configured to rotate together with the shaft; a non-contact bearing unit rotatably supporting the rotating body; a housing including an inner space accommodating the protruding part; a suction inlet opening into the inner space and configured to supply the refrigerant to the inner space; a refrigerant passage communicating with the suction inlet and connected to an evaporator; a discharge port configured to discharge the refrigerant from the inner space; and a return passage communicating the inner space and the evaporator via a return opening provided in the inner space. The return opening is positioned more downward than the protruding part in a vertical direction.

Effects of Invention

[0007] Some embodiments of the present disclosure provide a refrigerant compressor that suppresses deviation in the state of contact between a rotating body and a non-contact bearing at startup.

Brief Description of Drawings

[0008]

FIG. 1 is a block diagram illustrating the configuration of a freezer having a refrigerant compressor according to an embodiment.

FIG. 2 is a cross-sectional view illustrating the configuration of the refrigerant compressor of FIG. 1.

FIG. 3 is a cross-section of the refrigerant compressor taken along line III-III of FIG. 2.

FIG. 4(a) is a simplified cross-sectional view of the refrigerant compressor during operation. FIG. 4(b) is a simplified cross-sectional view of the refrigerant compressor when not in operation.

FIG. 5 is a diagram illustrating the connection configuration between the refrigerant compressor and the evaporator.

FIG. 6(a) is a cross-sectional view illustrating a refrigerant compressor of a comparative example when not in operation. FIG. 6(b) is a cross-sectional view illustrating the refrigerant compressor of the comparative example during operation.

FIG. 7 is a cross-sectional view illustrating a refrigerant compressor of Variation 1.

FIG. 8 is a cross-sectional view illustrating a refrigerant compressor of Variation 2.

Description of Embodiments

[0009] A refrigerant compressor according to an embodiment of the present disclosure is configured to compress a refrigerant circulating in a refrigerant circulation system. The refrigerant compressor includes: a rotating body having a shaft, and a protruding part protruding from the shaft in a radial direction and configured to rotate together with the shaft; a non-contact bearing unit rotatably supporting the rotating body; a housing having an inner space accommodating the protruding part; a suction inlet opening into the inner space and configured to supply the refrigerant to the inner space; a refrigerant passage communicating with the suction inlet and connected to an evaporator; a discharge port configured to discharge the refrigerant from the inner space; and a return passage communicating the inner space and the evaporator via a return opening provided in the inner space. The return opening is positioned more downward than the protruding part in a vertical direction.

[0010] In the refrigerant compressor above, the refrigerant vaporized in the evaporator passes through the refrigerant passage, is supplied to the inner space of the housing from the suction inlet, and is externally discharged from the discharge port. The refrigerant compressor above includes a return passage communicating the inner space and the evaporator via a return opening provided in the inner space of the housing. The return opening is positioned more downward than the protruding part of the rotating body in the vertical direction. The refrigerant liquefied in the inner space of the housing thus flows out from the inner space of the housing through the return passage before reaching the protruding part. The liquid that flows through the return passage is returned to the evaporator. The evaporator vaporizes the liquid, which is supplied to the refrigerant compressor again as the refrigerant. Such a configuration in which the liquid of the inner space is returned to the evaporator and vaporized enables the liquid to be efficiently removed from the inner space. As a result, situations in which the level of the liquid in the inner space reaches the protruding part can be suppressed, and situations in which the rotation of the shaft becomes unbalanced can be suppressed. This makes it possible to suppress deviation in the state of contact between the rotating body and the bearing unit at startup.

[0011] In some embodiments, the return passage may be formed of the refrigerant passage itself. In this case, the refrigerant passage has both the function of supplying the vaporized refrigerant from the evaporator, and the function of returning the refrigerant liquefied in the inner space of the housing to the evaporator. This configuration is capable of providing the function of returning the liquefied refrigerant to the evaporator, and the function of supplying the refrigerant from the evaporator through the same passage, thereby simplifying the configuration of the refrigerant compressor.

[0012] In some embodiments, the bearing unit may in-

clude a pair of bearings disposed along the axial direction in which the shaft extends, and supporting the shaft in a radial direction. The inner space may include a first inner region, a second inner region, and a third inner region communicating with each other in the axial direction. The second inner region may be positioned between the pair of bearings in the axial direction. The first inner region may be positioned on one side of the pair of bearings in the axial direction. The third inner region may be positioned on another side of the pair of bearings in the axial direction. The suction inlet may communicate with the third inner region. The discharge port may communicate with the first inner region. In this case, the refrigerant supplied from the suction inlet passes through the pair of bearings and is discharged from the discharge port, so that the pair of bearings can be cooled using this flow of the refrigerant.

[0013] In some embodiments, the return passage may pass downward through the housing in the vertical direction from the inner space. In this case, the liquid generated in the inner space of the housing is capable of easily flowing into the return passage according to gravity. Accordingly, the liquid can be effectively removed from the inner space.

[0014] In some embodiments, the discharge port may pass downward through the housing in the vertical direction from the inner space at a position different from a position of the return passage. In this case, the discharge port can also be used as a passage for removing the liquid from the inner space of the housing in addition to the return passage. Accordingly, the liquid can be more effectively removed from the inner space.

[0015] In some embodiments, an inner wall surface of the housing may include an inclined part sloping downward toward the return opening between the discharge port and the return passage. In this case, the liquid generated in the inner space of the housing is capable of easily flowing into the return passage than into the discharge port according to gravity. Accordingly, the liquid can be actively flown to the evaporator. In such a case in which the liquid is actively flown to the evaporator that vaporizes the liquid, situations in which the flown liquid is pushed back to the refrigerant compressor does not tend to occur compared, for example, to a case in which the liquid is flown to another device such as a condenser in which the liquid tends to accumulate. Consequently, the liquid can be more effectively removed from the inner space by actively flowing the liquid to the evaporator.

[0016] In some embodiments, the discharge port may pass upward through the housing in the vertical direction from the inner space. In this case, the liquid generated in the inner space of the housing can be prevented from flowing into the discharge port, so that situations in which the flown liquid is pushed back to the refrigerant compressor does not tend to occur. Accordingly, the liquid can be more effectively removed from the inner space.

[0017] Embodiments of the present disclosure will be described below with reference to the drawings. Same

reference signs are given to the same elements in the description of the drawings, and redundant description will be omitted as appropriate.

[0018] A freezer 1 illustrated in FIG. 1 may be installed, for example, in a building or a factory to generate cooling water for ventilation. The freezer 1, for example, includes a refrigerant compressor 2, a condenser 3, an expansion valve 4, and an evaporator 5. The refrigerant compressor 2, the condenser 3, the expansion valve 4, and the evaporator 5 form a refrigerant circulation system 6 in which a refrigerant (e.g., fluorocarbon) circulates. In the refrigerant circulation system 6, thermal energy is received and transmitted by the refrigerant undergoing phase changes while circulating the refrigerant compressor 2, the condenser 3, the expansion valve 4, and the evaporator 5.

[0019] The refrigerant compressor 2 is connected to the condenser 3 via a passage F1. The condenser 3 is connected to the expansion valve 4 via a passage F2. The expansion valve 4 is connected to the evaporator 5 via a passage F3. The evaporator 5 is connected to the refrigerant compressor 2 via a passage F4. These passages F1, F2, F3, and F4 form a circulation passage for the refrigerant to flow through and circulate the refrigerant compressor 2, the condenser 3, the expansion valve 4, and the evaporator 5.

[0020] The refrigerant compressor 2 generates a compressed refrigerant gas R1 by compressing a refrigerant gas R3 supplied from the evaporator 5. The refrigerant compressor 2 supplies the generated compressed refrigerant gas R1 to the condenser 3 via the passage F1. The condenser 3 generates a liquid refrigerant R2 by cooling and liquefying the compressed refrigerant gas R1 which has high temperature and high pressure by being compressed by the refrigerant compressor 2. The condenser 3 supplies the generated liquid refrigerant R2 to the expansion valve 4 via the passage F2. The expansion valve 4 reduces the pressure of the liquid refrigerant R2 which has been liquefied by the condenser 3. The expansion valve 4 supplies the liquid refrigerant R2 having reduced pressure to the evaporator 5 via the passage F3.

[0021] The evaporator 5 generates the refrigerant gas R3 by evaporating the liquid refrigerant R2 for which the pressure has been reduced by the expansion valve 4. The evaporator 5 cools an object to be cooled (e.g., cooling water) by the heat of vaporization generated when the refrigerant gas R3 is generated due to the evaporation of the liquid refrigerant R2. The evaporator 5 supplies the generated refrigerant gas R3 to the refrigerant compressor 2 via the passage F4. The refrigerant gas R3 supplied to the refrigerant compressor 2 is supplied to the condenser 3 again as the compressed refrigerant gas R1 after being compressed by the refrigerant compressor 2. The compressed refrigerant gas R1, the liquid refrigerant R2, and the refrigerant gas R3 are examples of the potential states of the refrigerant in the refrigerant circulation system 6.

[0022] The configuration of the refrigerant compressor

2 will next be described in detail with reference to FIG. 2. The refrigerant compressor 2 is a so-called two-stage compressor. As illustrated in FIG. 2, the refrigerant compressor 2 includes a shaft 10, a compressor unit 30, and a motor unit 50. In the description below, "upward D1A" refers to upward in a vertical direction (gravity direction) when the refrigerant compressor 2 is installed in a location of use, and "downward D1B" refers to downward in the vertical direction. In this embodiment, the refrigerant compressor 2 is disposed such that an axis of rotation L of the shaft 10 extends in a horizontal direction when the refrigerant compressor 2 is installed in the location of use. Consequently, an axial direction D2 in which the axis of rotation L extends is perpendicular to the vertical direction. In the description below, "upstream" refers to upstream in a direction of flow of the refrigerant that flows through the refrigerant compressor 2, and "downstream" refers to downstream in the direction of flow.

[0023] The compressor unit 30 has a first impeller 31, a second impeller 32, a first impeller housing 41 that accommodates the first impeller 31, and a second impeller housing 42 that accommodates the second impeller 32. The first impeller 31 and the first impeller housing 41 form a low pressure-side compression stage. The second impeller 32 and the second impeller housing 42 form a high pressure-side compression stage. The first impeller 31 and the second impeller 32 are attached to one end portion 10a of the shaft 10. Each of the first impeller 31 and the second impeller 32 is a protruding part that protrudes outward from the shaft 10 in a radial direction, and rotates about the axis of rotation L integrally with the shaft 10. The first impeller 31 and the second impeller 32 are, for example, disposed such that rear surfaces thereof face each other in the axial direction D2 with a gap therebetween. The second impeller 32 is, for example, disposed coaxial with the first impeller 31, and has the same dimensions as the first impeller 31. The first impeller 31 is, for example, disposed between the second impeller 32 and the motor unit 50 in the axial direction D2. Hereinafter, when the first impeller 31 and the second impeller 32 are described without any distinction, they are collectively referred to as an "impeller 35."

[0024] The first impeller housing 41 and the second impeller housing 42 are connected to each other in the axial direction D2. An interstage plate 43 is provided between the first impeller housing 41 and the second impeller housing 42. The interstage plate 43 is connected to the first impeller housing 41 and the second impeller housing 42 in the axial direction D2. Consequently, the second impeller housing 42 is connected to the first impeller housing 41 in the axial direction D2 via the interstage plate 43.

[0025] The motor unit 50 has an electric motor 51 and a motor housing 55 that accommodates the electric motor 51. The electric motor 51 is a drive source for driving the compressor unit 30. The electric motor 51 includes a stator 52 that is fixed to the motor housing 55, and a rotor 53 that is fixed to the shaft 10. The rotor 53 faces the

stator 52 with a gap therebetween. The motor housing 55 is connected to the first impeller housing 41 in the axial direction D2. The motor housing 55, the first impeller housing 41, the interstage plate 43, and the second impeller housing 42 form a housing 11 of the refrigerant compressor 2.

[0026] The shaft 10 to which the first impeller 31 and the second impeller 32 are attached is accommodated in an inner space S of the housing 11. The inner space S is a space defined by an inner wall surface 11a of the housing 11. The shaft 10 extends across the motor housing 55, the first impeller housing 41, the interstage plate 43, and the second impeller housing 42 in the axial direction D2 in the inner space S. The shaft 10 is supported so as to be rotatable about the axis of rotation L by a pair of bearings 60, 60 and a pair of bearings 64, 64 provided inside the motor housing 55. The pair of bearings 60, 60 and the pair of bearings 64, 64 form a "bearing unit" of the present disclosure. The pair of bearings 60, 60 are provided so as to surround the shaft 10, and are disposed in positions such that the electric motor 51 is disposed therebetween in the axial direction D2.

[0027] The inner space S of the housing 11 has a first inner region S1, a second inner region S2, and a third inner region S3. The first inner region S1, the second inner region S2, and the third inner region S3 are arranged in order along the axial direction D2 and communicate with each other. The second inner region S2 is positioned between the pair of bearings 60, 60 in the axial direction D2. The second inner region S2 is surrounded by a center portion of the motor housing 55. The electric motor 51 disposed between the pair of bearings 60, 60 is disposed in the second inner region S2. The first inner region S1 is positioned on one side of the pair of bearings 60, 60 in the axial direction D2 on which the first impeller 31 and the second impeller 32 are positioned. The first inner region S1 is surrounded mainly by the first impeller housing 41, the second impeller housing 42, and the interstage plate 43. The third inner region S3 is positioned on the other side of the pair of bearings 60, 60 in the axial direction D2. The third inner region S3 is surrounded by an end portion of the motor housing 55 positioned on the opposite side from the first impeller housing 41 in the axial direction D2.

[0028] The housing 11 has a suction port 12 and a discharge port 13. The suction port 12 is a port for sucking the refrigerant gas R3 from the evaporator 5 (see FIG. 1) into the inner space S. The suction port 12 communicates with the inner space S, and is connected to the evaporator 5 via the passage F4. The refrigerant gas R3 sucked into the inner space S is compressed by the first impeller 31 and the second impeller 32 that rotate together with the shaft 10. The discharge port 13 is a port for discharging the compressed refrigerant gas R1 compressed in the inner space S from the inner space S to the condenser 3 (see FIG. 1). The discharge port 13 communicates with the inner space S, and is connected to the condenser 3 via the passage F1. The suction port 12

is, for example, formed in the motor housing 55, and communicates with the third inner region S3. The discharge port 13 is, for example, formed in the second impeller housing 42, and communicates with the first inner region S1. More specific configurations of the suction port 12 and the discharge port 13 will be described further below.

[0029] The motor housing 55, for example, has a cylindrical side wall 56 centered about the axis of rotation L, and a disk-shaped end wall 57 that closes one end of the side wall 56 in the axial direction D2. The side wall 56 surrounds the rotor 53 that is fixed to the shaft 10. The stator 52 is fixed to an inner surface 56a of the side wall 56. A pair of support parts 61, 61 that support the pair of bearings 60, 60 are provided on the inner surface 56a of the side wall 56.

[0030] As illustrated in FIG. 3, each of the pair of support parts 61, 61 includes a ring-like member 62 and four rod-like members 63. The ring-like member 62, for example, has an annular shape when viewed in the axial direction D2. The ring-like member 62 is disposed so as to surround the bearing 60 in a circumferential direction D3, and is fixed to the inner surface 56a of the side wall 56. The four rod-like members 63 extend in a cross shape centered about the bearing 60, and connects the bearing 60 to the ring-like member 62. The shaft 10 is disposed so as to pass through the inside of the bearing 60. The bearing 60 is a non-contact radial bearing. Examples of the bearing 60 include an air bearing, a gas bearing, and a magnetic bearing. During the rotation of the shaft 10, the bearing 60 is disposed with a gap between the rotor 53 (see FIG. 2), and supports the rotor 53 and the shaft 10 in the radial direction without contact.

[0031] Reference is made back to FIG. 2. The second inner region S2 communicates with the first inner region S1 via the spaces between the rod-like members 63 in the circumferential direction D3 (see FIG. 3) and the gap between the rotor 53 and one of the bearings 60. The second inner region S2 communicates with the third inner region S3 via the spaces between the rod-like members 63 in the circumferential direction D3 and the gap between the rotor 53 and the other of the bearings 60. Consequently, a fluid such as the refrigerant gas R3 is capable of moving through the first inner region S1, the second inner region S2, and the third inner region S3 in the inner space S of the housing 11.

[0032] The pair of bearings 64, 64 are, for example, provided so as to surround the shaft 10 in the third inner region S3, and disposed with gaps therebetween in the axial direction D2. The pair of bearings 64, 64 are non-contact thrust bearings. Examples of the pair of bearings 64, 64 include an air bearing, a gas bearing, and a magnetic bearing. A thrust collar 65 is provided between the pair of bearings 64, 64. The thrust collar 65 is a flange-shaped protruding part protruding from the shaft 10, and rotates about the axis of rotation L integrally with the shaft 10. An annular spacer 67 that surrounds the circumference of the thrust collar 65 is provided between the pair of bearings 64, 64.

[0033] The pair of bearings 64, 64 and the spacer 67 are fastened so as to be integrated by a plurality of fastening bolts. The pair of bearings 64, 64 and the spacer 67 integrated with each other are fixed to the inner surface 56a of the side wall 56. The pair of bearings 64, 64 and the spacer 67 define an accommodation space in which the thrust collar 65 is accommodated. In this accommodation space, the thrust collar 65 rotates about the axis of rotation L together with the shaft 10 in a non-contact manner with the pair of bearings 64, 64 and the spacer 67. The pair of bearings 64, 64, the spacer 67, and the thrust collar 65 support the rotor 53 and the shaft 10 in an axial direction D1 without contact. The thrust collar 65, the impeller 35, and the shaft 10 rotate integrated with each other to form a rotating body RB.

[0034] The first impeller housing 41 is disposed so as to close the opening of the side wall 56 opposite from the end wall 57 in the axial direction D2. The first impeller housing 41 includes an inlet 41a, a diffuser passage 41b, a scroll passage 41c, and an outlet 41d. The inlet 41a is an opening that is coaxial with the shaft 10, and communicates with the inside of the motor housing 55. Consequently, the refrigerant gas R3 sucked into the motor housing 55 flows into the inlet 41a. The first impeller 31 is disposed inward of the inlet 41a. Speed energy is applied to the refrigerant gas R3 by the rotation of the first impeller 31.

[0035] The scroll passage 41c is formed so as to surround the first impeller 31. The diffuser passage 41b is formed between the first impeller 31 and the scroll passage 41c. The diffuser passage 41b compresses the refrigerant gas R3 by converting the speed energy applied to the refrigerant gas R3 into compression energy. The scroll passage 41c discharges the refrigerant gas R3 compressed by the diffuser passage 41b outside the first impeller housing 41 from the outlet 41d. The outlet 41d is, for example, an opening that opens on a circumferential surface of the first impeller housing 41.

[0036] The second impeller housing 42 includes an inlet 42a, a diffuser passage 42b, a scroll passage 42c, and the discharge port 13. The inlet 42a is an opening that is coaxial with the inlet 41a of the first impeller housing 41, and faces away from the inlet 41a. The inlet 42a is connected to the outlet 41d of the first impeller housing 41 via an external pipe 70. Consequently, the refrigerant gas R3 from the outlet 41d flows into the inlet 42a via the external pipe 70. The second impeller 32 is disposed inward of the inlet 42a. Speed energy is applied to the refrigerant gas R3 by the rotation of the second impeller 32.

[0037] The scroll passage 42c is formed so as to surround the second impeller 32. The diffuser passage 42b is formed between the second impeller 32 and the scroll passage 42c. The diffuser passage 42b further compresses the refrigerant gas R3 by converting the speed energy applied to the refrigerant gas R3 into compression energy. As a result, the compressed refrigerant gas R1 is generated. The scroll passage 42c discharges the gen-

erated compressed refrigerant gas R1 outside the second impeller housing 42 from the discharge port 13.

[0038] The configurations of the suction port 12 and the discharge port 13 above will be described more specifically. The suction port 12 includes a suction inlet 12a that opens on the inner wall surface 11a. The suction inlet 12a is disposed more downward D1B than the protruding part of the rotating body RB in the vertical direction. The suction inlet 12a being disposed more downward D1B than the protruding part of the rotating body RB refers to the suction inlet 12a being positioned more downward D1B than a lower end of the protruding part when the refrigerant compressor 2 is installed in a location of installation. The "protruding part" herein may be one of the impeller 35 and the thrust collar 65 that is positioned more downward than the other. For example, in a case in which the "protruding part" refers to the impeller 35 (i.e., in a case in which the impeller 35 is positioned more downward D1B than the thrust collar 65), the lower end of the "protruding part" refers to a lower end 35a of the impeller 35. In this case, the suction inlet 12a is positioned more downward D1B than the lower end 35a of the impeller 35. In other words, the suction inlet 12a is positioned in a region RH between an outer surface 56b positioned at a lower end of the housing 11, and the lower end 35a of the impeller 35. The lower end 35a of the impeller 35 is a most downward D1B portion of the impeller 35. It can be said that the lower end 35a of the impeller 35 is a lowermost tip end of the impeller 35, that is, a tip end of the impeller 35 that is closest to the lower end of the housing 11.

[0039] The suction inlet 12a being positioned more downward D1B than the impeller 35 refers to at least a part of the suction inlet 12a being positioned more downward D1B than the lower end 35a of the impeller 35. That is, the suction inlet 12a at least has a portion that is positioned in the region RH. Consequently, the suction inlet 12a may have a portion that overlaps the impeller 35 in the horizontal direction. In this embodiment, the first impeller 31 and the second impeller 32 are disposed at the same height with each other, and have the same dimensions. Thus, the height of the lower end of the first impeller 31 and the height of the lower end of the second impeller 32 are the same. In a case in which the lower end of the first impeller 31 and the lower end of the second impeller 32 are different from each other, the lower end 35a of the impeller 35 may be the lower end of one of the first impeller 31 and the second impeller 32 that has a greater outer diameter.

[0040] In a case in which the "protruding part" refers to the thrust collar 65 (i.e., in a case in which the thrust collar 65 is positioned more downward D1B than the impeller 35), the lower end of the "protruding part" refers to a lower end 65a of the thrust collar 65. In this case, the suction inlet 12a is positioned more downward D1B than the lower end 65a of the thrust collar 65. The lower end 65a of the thrust collar 65 is a most downward D1B portion of the thrust collar 65. It can be said that the lower end

65a of the thrust collar 65 is a lowermost tip end of the thrust collar 65, that is, a tip end of the thrust collar 65 that is closest to the lower end of the housing 11. The suction inlet 12a being positioned more downward D1B than the thrust collar 65 refers to at least a part of the suction inlet 12a being positioned more downward D1B than the lower end 65a of the thrust collar 65. Which one of the impeller 35 and the thrust collar 65 is positioned downward D1B is determined as appropriate according to design requirements.

[0041] The suction port 12 is, for example, formed so as to pass downward D1B through the side wall 56 from the third inner region S3 of the motor housing 55. Specifically, the suction port 12 passes through a lower end portion 56c of the side wall 56 surrounding the third inner region S3, in the vertical direction, from the inner surface 56a to the outer surface 56b. The lower end portion 56c is a downward D1B wall portion of the side wall 56 in the cross-section illustrated in FIG. 2. Consequently, the suction inlet 12a opens on the inner surface 56a of the lower end portion 56c, and communicates with the third inner region S3. The discharge port 13 is, for example, formed so as to pass downward D1B through the second impeller housing 42 from the first inner region S1 of the second impeller housing 42. That is, the discharge port 13 passes through a lower end portion 42d of the second impeller housing 42 surrounding the first inner region S1, in the vertical direction. The lower end portion 42d is a downward D1B wall portion of the second impeller housing 42 in the cross-section illustrated in FIG. 2. The discharge port 13 communicates with the first inner region S1. A discharge outlet 13a of the discharge port 13 opens on an outer surface 42e of the lower end portion 42d.

[0042] The inner surface 56a of the side wall 56 has an inclined part P1 between the suction port 12 and the discharge port 13 in the axial direction D2. The inclined part P1 may be a tapered surface that has a gradually decreasing diameter from the suction port 12 to the discharge port 13. In the cross-section illustrated in FIG. 2, the inclined part P1 is inclined so as to slope downward toward the suction inlet 12a. That is, the inclined part P1 is inclined so as to be positioned gradually downward D1B from the discharge port 13 to the suction inlet 12a. The inclined part P1 is, for example, formed continuously from an end portion of the side wall 56 closer to the first impeller housing 41 to the suction inlet 12a.

[0043] The flow of the refrigerant that flows through the refrigerant compressor 2 having the configuration above will be described. A simplified model of the refrigerant compressor 2 as illustrated in FIGS. 4(a) and 4(b) will be used here for the sake of simplicity. In FIGS. 4(a) and 4(b), the first impeller 31 and the second impeller 32 are collectively shown as the impeller 35, and the first impeller housing 41, the interstage plate 43, and the second impeller housing 42 are collectively shown as an impeller housing 45. Additionally, for the sake of simplicity, the pair of bearings 64, 64, the thrust collar 65, and the spacer 67 are omitted, and the "impeller 35" is considered the

"protruding part" of the present disclosure in the simplified model below. It should be noted that in the case in which the "thrust collar 65" is considered the "protruding part" of the present disclosure, the "impeller 35" in the explanation can be replaced with the "thrust collar 65."

[0044] As illustrated in FIG. 4(a), during operation of the refrigerant compressor 2, the refrigerant gas R3 supplied to the refrigerant compressor 2 from the upstream evaporator 5 (see FIG. 1) is sucked (supplied) into the third inner region S3 from the suction port 12 formed in downward D1B of the motor housing 55. The refrigerant gas R3 sucked into the third inner region S3 passes the second inner region S2 and the first inner region S1 in order, during which the refrigerant gas R3 cools the pair of bearings 60, 60, the rotor 53, and the stator 52 along the flow path. The refrigerant gas R3 that reaches the impeller 35 in the first inner region S1 is compressed by the rotation of the impeller 35. The compressed refrigerant gas R1 is thus generated. The generated compressed refrigerant gas R1 is discharged from the discharge port 13 formed in downward D1B of the impeller housing 45 to the downstream condenser 3.

[0045] As illustrated in FIG. 4(b), when the refrigerant compressor 2 is not in operation, the refrigerant gas R3 filling the inner space S of the housing 11 may liquefy due to the drop in temperature, and become a liquid R4 in the inner space S. The liquid R4 may be a liquid that includes the liquid refrigerant R2 which is the liquefied refrigerant gas R3. In this embodiment, the suction port 12 is formed in downward D1B of the motor housing 55, so that the liquid R4 in the inner space S flows out of the housing 11 from the suction port 12 according to gravity. The suction port 12 is connected to the upstream evaporator 5 (see FIG. 1). Consequently, the liquid R4 that flows out from the suction port 12 returns to the evaporator 5. The liquid R4 that returns to the evaporator 5 is vaporized in the evaporator 5, and supplied to the inner space S from the suction port 12 again as the refrigerant gas R3.

[0046] Consequently, in this embodiment, the suction port 12 has the function of a return port that returns the liquid R4 that may accumulate in the inner space S to the upstream evaporator 5, in addition to the function of a suction port that sucks the refrigerant gas R3 from the upstream evaporator 5 into the inner space S of the housing 11. The suction inlet 12a of the suction port 12 thus also serves as a return opening through which the liquid R4 that returns to the upstream evaporator 5 flows. That is, in this embodiment, the suction port 12 is an inlet path for the refrigerant gas R3 that flows into the inner space S of the housing 11 from the upstream evaporator 5 as well as an outlet path for the liquid R4 that flows out from the inner space S to the upstream evaporator 5. It can be said that the return port that returns the liquid R4 generated in the inner space S to the evaporator 5 is formed by the suction port 12 itself (i.e., formed integrally with the suction port 12). That is, it can be said that the return opening is formed by the suction inlet 12a itself. The suc-

tion inlet 12a is connected to the evaporator 5 via the suction port 12 and the passage F4 (see FIG. 1). The suction port 12 and the passage F4 form a refrigerant passage that supplies the refrigerant gas R3 from the evaporator 5 to the inner space S. It can be said that the suction port 12 and the passage F4 form a return passage that returns the liquid R4 generated in the inner space S to the evaporator 5.

[0047] Furthermore, in this embodiment, the discharge port 13 is formed in downward D1B of the impeller housing 45. Thus, as illustrated in FIG. 4(b), the liquid R4 generated in the first inner region S1 flows out from the discharge port 13 according to gravity. The liquid R4 discharged from the discharge port 13 flows to the downstream condenser 3 (see FIG. 1), and circulates the refrigerant circulation system 6. Consequently, this embodiment is configured so as to externally remove the liquid R4 generated in the inner space S from the inner space S through the suction port 12 and the discharge port 13 which are formed in downward D1B of the housing 11.

[0048] FIG. 5 illustrates the connection configuration of the suction inlet 12a of the refrigerant compressor 2 and the evaporator 5. As illustrated in FIG. 5, the evaporator 5 is positioned more downward D1B than the suction inlet 12a of the refrigerant compressor 2. The evaporator 5 is connected to the suction inlet 12a via the passage F4 and the suction port 12. It can be said that the passage F4 and the suction port 12 communicate the inner space S of the refrigerant compressor 2 (see FIG. 2) and the evaporator 5 via the suction inlet 12a. The passage F4 has a linear passage FP1 and a linear passage FP2. The linear passage FP1 extends downward D1B from the suction inlet 12a. The linear passage FP2 extends in the axial direction D2 from a lower end of the linear passage FP1, and is connected to a downstream flow port 5a of the evaporator 5.

[0049] After flowing downward D1B through the linear passage FP1 according to gravity, the liquid R4 from the suction inlet 12a flows through the linear passage FP2 in the axial direction D1, and then flows into the flow port 5a of the evaporator 5. This configuration enables the liquid R4 generated in the refrigerant compressor 2 to return easily to the evaporator 5 using gravity. The connection configuration between the refrigerant compressor 2 and the evaporator 5 is not limited to the example illustrated in FIG. 5. For example, the passage F4 may be connected to the downstream flow port 5a of the evaporator 5, and another passage may be connected to an upstream flow port 5b of the evaporator 5. The flow port 5b may be connected to the suction inlet 12a or to an opening other than the suction inlet 12a via this other passage. In this case, the liquid R4 can be returned to the evaporator 5 by the other passage. A curved part that is curved downward D1B may be formed on the entirety or a part of the linear passage FP2 of the passage F4. In this case, the refrigerant compressor 2 may have a mechanism to evaporate the accumulated liquid R4 that may be generated in the curved part.

[0050] The operation and effects of the refrigerant compressor 2 and the freezer 1 according to this embodiment described above will now be described together with the problem of a comparative example. FIGS. 6(a) and 6(b) illustrate a simplified refrigerant compressor 200 according to a comparative example. In the refrigerant compressor 200, a suction port 112 formed in a motor housing 155 of a housing 111 is positioned more upward D1A than an impeller 135 that is attached to a shaft 100. A discharge port 113 formed in an impeller housing 145 is positioned more upward D1A than the impeller 135. In the refrigerant compressor 200, the refrigerant gas R3 sucked into an inner space S100 from the suction port 112 passes through a pair of bearings 160, 160, and the like, and reaches the impeller 135. The refrigerant gas R3 is compressed by the rotation of the impeller 135, and is discharged from the discharge port 113 of the impeller housing 145 as the compressed refrigerant gas R1.

[0051] The inventors of the present disclosure have discovered that, when the refrigerant compressor 200 is not in operation, the refrigerant gas R3 filling the inner space S100 may liquefy and accumulate in the inner space S100 as the liquid R4, and as a result, the level of the liquid R4 may reach the impeller 135 in the inner space S100 as illustrated in FIG. 6(a). The inventors of the present disclosure recognized that since the lower portion of the impeller 135 is soaked in the liquid R4, when the refrigerant compressor 200 is operated in this state, the impeller 135 rotates while being exposed to a large resistive force from the liquid R4, and that due to rotating while being exposed to a large resistive force from the liquid R4, a deviation may occur in the state of contact between the rotating body and the non-contact bearings.

[0052] The upper portion of the impeller 135, however, is not soaked in the liquid R4, and rotates without being exposed to the large resistive force that acts on the lower portion of the impeller 135.

[0053] As a result, as illustrated in FIG. 6(b), the rotation of the shaft 100 may become unbalanced, to thereby cause the shaft 100 to tilt, and apply excessive load on the bearings 160, 160 that support the shaft 100. When such load is applied on the non-contact bearings 160, 160, the bearings 160, 160 may not be able to withstand the load, and the desired performance of the bearings 160, 160 may be inhibited due to damage or the like. As a result, defects such as reduction in the compression performance may occur. In a case in which high-strength bearings or large bearings are used to be able to withstand the excessive load, the cost and size of the refrigerant compressor 200 may increase.

[0054] However, in this embodiment, the suction inlet 12a is positioned more downward D1B than the impeller 35 in the vertical direction. Thus, as illustrated in FIG. 4(b), the liquid R4 generated in the inner space S flows out from the inner space S through the suction port 12 before reaching the impeller 35. The liquid R4 that flows through the suction port 12 is returned to the upstream

evaporator 5 via the passage F4. The evaporator 5 vaporizes the liquid R4, and supplies it to the refrigerant compressor 2 again via the passage F4 and the suction port 12 as the refrigerant gas R3. Such a configuration in which the liquid R4 of the inner space S is returned to the evaporator 5 and vaporized enables the liquid R4 to be efficiently removed from the inner space S. As a result, situations in which the level of the liquid R4 in the inner space S reaching the impeller 35 can be suppressed, and situations in which the rotation of the shaft 10 becomes unbalanced can be suppressed. This makes it possible to suppress the deviation in the state of contact between the rotating body RB and the bearing unit (pair of bearings 60, 60 and pair of bearings 64, 64) at startup (start of rotation). As a result, situations in which excessive load is applied on the bearing unit can be suppressed, and situations in which defects such as reduction in the compression performance occur due to reduction in the performance of the bearing unit can be suppressed.

[0055] In this embodiment, the suction port 12 and the passage F4 also function as a return passage that returns the liquid R4 of the inner space S to the evaporator 5. That is, the suction port 12 and the passage F4 have both the function of sucking in the refrigerant gas R3 from the evaporator 5, and the function of returning the liquid R4 of the inner space S to the evaporator 5. This configuration is capable of providing the function of returning the liquid R4 to the evaporator 5 and the function of supplying the refrigerant gas R3 from the evaporator 5 in the same passage. In this embodiment, the configuration of the refrigerant compressor 2 is further simplified, since a return passage that returns the liquid R4 to the evaporator 5 is not separately provided.

[0056] In this embodiment, the suction inlet 12a communicates with the third inner region S3, and the discharge port 13 communicates with the first inner region S1. In this configuration, the refrigerant gas R3 sucked in from the suction inlet 12a passes through the pair of bearings 60, 60 and the electric motor 51 and is discharged from the discharge port 13, so that the pair of bearings 60, 60 and the electric motor 51 can be cooled using this flow of the refrigerant. This configuration is capable of employing a configuration in which a mechanism for cooling the pair of bearings 60, 60 and the electric motor 51 is not separately provided. Alternatively, the configuration of the refrigerant compressor 2 can be simplified, since a simplified mechanism for cooling the bearings 60, 60 and the electric motor 51 can be used. In practice, as illustrated in FIG. 2, the refrigerant gas R3 also passes through the pair of bearings 64, 64, so that the refrigerant gas R3 is also capable of cooling the pair of bearings 64, 64 in addition to cooling the pair of bearings 60, 60 and the electric motor 51.

[0057] In this embodiment, the suction port 12 passes downward D1B through the side wall 56 from the third inner region S3. This configuration enables the liquid R4 generated in the inner space S to easily flow into the

suction inlet 12a according to gravity. Accordingly, the liquid R4 can be effectively removed from the inner space S.

[0058] In this embodiment, the discharge port 13 passes downward D1B through the second impeller housing 42 from the first inner region S1. This configuration also enables the liquid R4 to be effectively removed from the inner space S, since the discharge port 13 can also be used as a passage for removing the liquid R4 from the inner space S.

[0059] In this embodiment, the inner surface 56a of the side wall 56 includes the inclined part P1 that slopes downward toward the suction inlet 12a. This configuration enables the liquid R4 generated in the inner space S to more easily flow into the suction port 12 than into the discharge port 13 according to gravity. Accordingly, the liquid R4 can be actively flown to the upstream evaporator 5 than to the downstream condenser 3. In the case in which the liquid R4 is actively flown to the evaporator 5 that vaporizes the liquid R4, situations in which the flown liquid R4 is pushed back to the inner space S does not tend to occur compared to a case in which the liquid R4 is actively flown to the condenser 3 in which the liquid R4 tends to accumulate. In the configuration in which the liquid R4 is actively flown to the condenser 3, the liquid R4 tends to accumulate in the condenser 3 since the condenser 3 is a device for generating the liquid refrigerant R2. When the compressed refrigerant gas R1 flows into the condenser 3 from the discharge port 13 in this state, the liquid R4 accumulated in the condenser 3 may be pushed back into the inner space S by the amount of the compressed refrigerant gas R1 that has flown into the condenser 3. Thus, in the configuration in which the liquid R4 is actively flown to the evaporator 5 and not to the condenser 3, situations in which the liquid R4 is pushed back into the inner space S can be suppressed, so that the liquid R4 can be more effectively removed from the inner space S.

[0060] Although one embodiment of the present disclosure has been described, the present disclosure is not limited to the embodiment above.

<Variation 1>

[0061] FIG. 7 illustrates a simplified refrigerant compressor 2A according to Variation 1. In the embodiment described above, an example in which the suction port 12 also functions as a return port that returns the liquid R4 in the inner space S to the evaporator 5 has been described. In this variation, a case in which a return port 12B is formed separately from a suction port 12A is described. That is, in this variation, the return port 12B is not configured by the suction port 12A itself, but is configured as a separate body from the suction port 12A.

[0062] The suction port 12A is, for example, formed so as to communicate with the third inner region S3 in a motor housing 55A, and is positioned more upward D1A than the impeller 35. The suction port 12A is connected

to the upstream evaporator 5 (see FIG. 1) via the passage F4. The refrigerant gas R3 sucked into the third inner region S3 from the suction port 12A passes through the second inner region S2 and the first inner region S1 in order, during which the refrigerant gas R3 cools the pair of bearings 60, 60, and the electric motor 51 in the flow path. The refrigerant gas R3 that reaches the impeller 35 in the first inner region S1 is compressed by the rotation of the impeller 35. The compressed refrigerant gas R1 is thus generated. The generated compressed refrigerant gas R1 is discharged from the discharge port 13 formed in downward D1B of the impeller housing 45 to the downstream condenser 3 (see FIG. 1). The passage F4 and the suction port 12A form a refrigerant passage that supplies the refrigerant gas R3 from the evaporator 5 to the inner space S.

[0063] The return port 12B is formed in the same position as the suction port 12 of the embodiment described above. That is, the return port 12B is formed so as to pass downward D1B through the motor housing 55A from the third inner region S3 of a housing 11A. Consequently, a return opening 12b of the return port 12B that opens on the inner surface 56a of the motor housing 55A is positioned more downward D1B than the lower end 35a of the impeller 35, similarly to the suction inlet 12a according to the embodiment described above. The return port 12B is connected to the upstream evaporator 5 (see FIG. 1) via a passage different from the passage F4. This passage and the return port 12B form a return passage for returning the liquid R4 to the evaporator 5.

[0064] The liquid R4 generated in the inner space S such as when not in operation flows into the return port 12B from the downward D1B return opening 12b, and is returned to the evaporator 5 via the return port 12B. The liquid R4 that is returned to the evaporator 5 is vaporized in the evaporator 5, and supplied to the inner space S from the suction port 12A again as the refrigerant gas R3. Even in this embodiment, the liquid R4 generated in the inner space S can be removed from the inner space S through the return port 12B, so that operation and effects similar to those of the embodiment described above can be produced.

<Variation 2>

[0065] FIG. 8 illustrates a simplified refrigerant compressor 2B according to Variation 2. In the embodiment described above, an example in which the discharge port 13 is formed in downward D1B of the impeller housing 45 has been described. In this variation, an example in which a discharge port 13A is formed in upward D1A of an impeller housing 45A is described. The discharge port 13A is, for example, formed so as to pass upward D1A through the impeller housing 45A from the first inner region S1 of a housing 11B. That is, the discharge port 13A passes through an upper end portion 42f of the impeller housing 45A that surrounds the first inner region S1, in the vertical direction. The upper end portion 42f may be

an upward D1A wall portion of the impeller housing 45A.

[0066] Even in this embodiment, the liquid R4 generated in the inner space S can be removed from the inner space S through the suction port 12, so that operation and effects similar to those of the embodiment described above can be produced. Furthermore, this variation is capable of preventing the liquid R4 generated in the inner space S from flowing into the discharge port 13A, which makes it more difficult for situations in which the flown liquid R4 is pushed back to the refrigerant compressor 2 to occur. Accordingly, the liquid R4 can be more effectively removed from the inner space S.

[0067] The present disclosure is not limited to the embodiment described above and the variations, and various other variations are possible. For example, the embodiment described above and the variations may be combined with each other according to the required object and effect. In the embodiment described above, the refrigerant compressor 2 has two impellers (first impeller and second impeller). However, the refrigerant compressor may have one impeller. The orientation of the rear surface of the impeller is not particularly limited, and may be changed as appropriate according to the required specification.

[0068] In the embodiment described above, the suction port 12 is formed so as to communicate with the third inner region S3, and the discharge port 13 is formed so as to communicate with the first inner region S1. However, the suction port 12 and the discharge port 13 may both be formed so as to communicate with the first inner region S1. That is, the suction port 12 and the discharge port 13 may both be formed in the impeller housing 45. In this case, a port through which a cooling medium flows for cooling the pair of bearings 60, 60 and the electric motor 51 may be separately formed. The suction port 12 may be formed in the end wall 57 as long as it is positioned more downward D1B than the impeller 35.

[Appendix]

[0069] The present disclosure includes the following configurations.

[0070] A refrigerant compressor of the present disclosure is [1] "a refrigerant compressor configured to compress a refrigerant circulating in a refrigerant circulation system, the refrigerant compressor including: a rotating body including a shaft, and a protruding part protruding from the shaft in a radial direction and configured to rotate together with the shaft; a non-contact bearing unit rotatably supporting the rotating body; a housing including an inner space accommodating the protruding part; a suction inlet opening into the inner space and configured to supply the refrigerant to the inner space; a refrigerant passage communicating with the suction inlet and connected to an evaporator; a discharge port configured to discharge the refrigerant from the inner space; and a return passage communicating the inner space and the evaporator via a return opening provided in the inner

space, wherein the return opening is positioned more downward than the protruding part in a vertical direction."

[0071] The refrigerant compressor of the present disclosure is [2] "the refrigerant compressor according to [1], wherein the return passage is formed of the refrigerant passage itself."

[0072] The refrigerant compressor of the present disclosure is [3] "the refrigerant compressor according to [1] or [2], wherein the bearing unit includes a pair of bearings disposed along an axial direction in which the shaft extends, and supporting the shaft in a radial direction, wherein the inner space includes a first inner region, a second inner region, and a third inner region communicating with each other in the axial direction, wherein the second inner region is positioned between the pair of bearings in the axial direction, wherein the first inner region is positioned on one side of the pair of bearings in the axial direction, wherein the third inner region is positioned on another side of the pair of bearings in the axial direction, wherein the suction inlet communicates with the third inner region, and wherein the discharge port communicates with the first inner region."

[0073] The refrigerant compressor of the present disclosure is [4] "the refrigerant compressor according to any one of [1] to [3], wherein the return passage passes downward through the housing in the vertical direction from the inner space."

[0074] The refrigerant compressor of the present disclosure is [5] "the refrigerant compressor according to [4], wherein the discharge port passes downward through the housing in the vertical direction from the inner space at a position different from a position of the return passage."

[0075] The refrigerant compressor of the present disclosure is [6] "the refrigerant compressor according to [5], wherein an inner wall surface of the housing includes an inclined part sloping downward toward the return opening between the discharge port and the return passage."

[0076] The refrigerant compressor of the present disclosure is [7] "the refrigerant compressor according to any one of [1] to [4], wherein the discharge port passes upward through the housing in the vertical direction from the inner space."

Reference Signs List

[0077]

2, 2A, 2B Refrigerant compressor
3 Condenser
5 Evaporator
6 Refrigerant circulation system
10 Shaft
11, 11A Housing
11a Inner wall surface
12, 12A Suction port (Refrigerant passage, Return passage)

12a Suction inlet (Return opening)
12b Return opening
12B Return port (Return passage)
13, 13A Discharge port
35 Impeller (Protruding part)
60, 64 Bearing (Bearing unit)
65 Thrust collar (Protruding part)
D1A Upward
D1B Downward
D2 Axial direction
F4 Passage (Refrigerant passage, Return passage)
P1 Inclined part
RB Rotating body
S Inner space
S1 First inner region
S2 Second inner region
S3 Third inner region

Claims

1. A refrigerant compressor configured to compress a refrigerant circulating in a refrigerant circulation system, the refrigerant compressor comprising:

a rotating body including a shaft, and a protruding part protruding from the shaft in a radial direction and configured to rotate together with the shaft;
a non-contact bearing unit rotatably supporting the rotating body;
a housing having an inner space accommodating the protruding part;
a suction inlet opening into the inner space and configured to supply the refrigerant to the inner space;
a refrigerant passage communicating with the suction inlet and connected to an evaporator;
a discharge port configured to discharge the refrigerant from the inner space; and
a return passage communicating the inner space and the evaporator via a return opening provided in the inner space, wherein the return opening is positioned more downward than the protruding part in a vertical direction.

2. The refrigerant compressor according to claim 1, wherein the return passage is formed of the refrigerant passage itself.

3. The refrigerant compressor according to claim 1, wherein the bearing unit includes a pair of bearings disposed along an axial direction in which the shaft extends, and supporting the shaft in the radial direction, wherein the inner space includes a first inner

region, a second inner region, and a third inner region communicating with each other in the axial direction,
 wherein the second inner region is positioned between the pair of bearings in the axial direction, 5
 wherein the first inner region is positioned on one side of the pair of bearings in the axial direction,
 wherein the third inner region is positioned on another side of the pair of bearings in the axial direction, 10
 wherein the suction inlet communicates with the third inner region, and
 wherein the discharge port communicates with the first inner region. 15

4. The refrigerant compressor according to claim 1, wherein the return passage passes downward through the housing in the vertical direction from the inner space. 20
5. The refrigerant compressor according to claim 4, wherein the discharge port passes downward through the housing in the vertical direction from the inner space at a position different from a position of the return passage. 25
6. The refrigerant compressor according to claim 5, wherein an inner wall surface of the housing includes an inclined part sloping downward toward the return opening between the discharge port and the return passage. 30
7. The refrigerant compressor according to claim 1, wherein the discharge port passes upward through the housing in the vertical direction from the inner space. 35

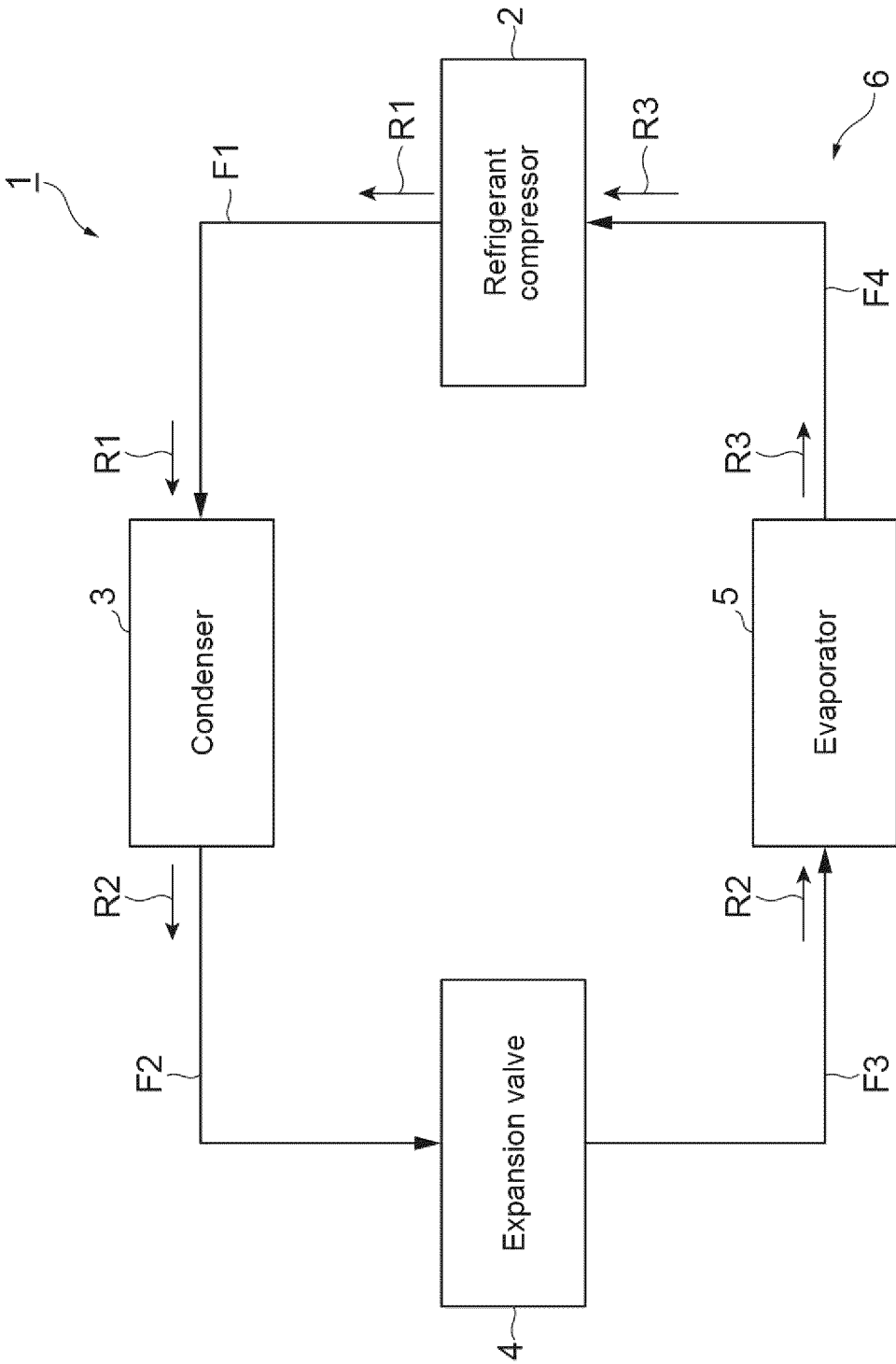
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Fig.1



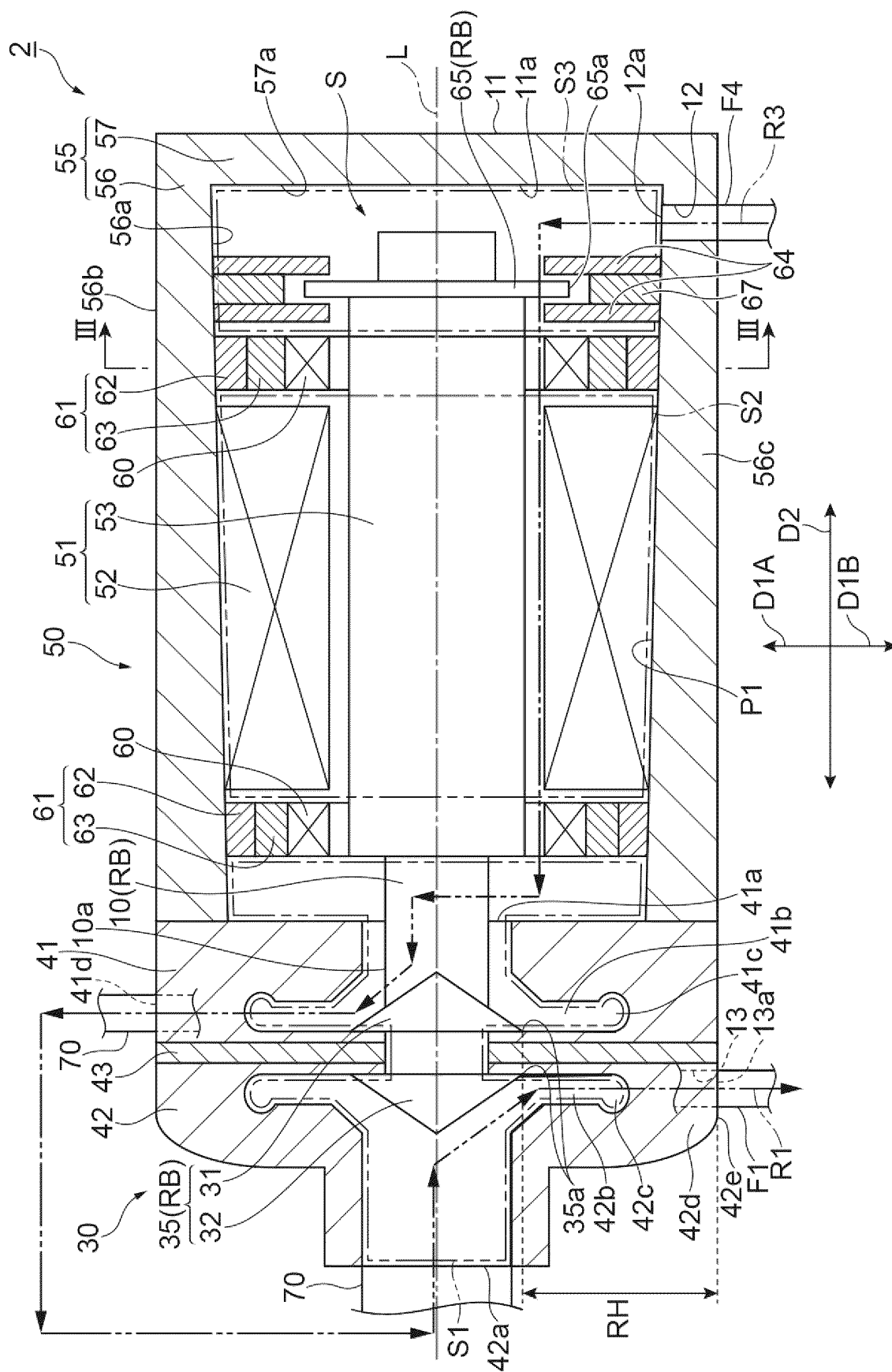


Fig.3

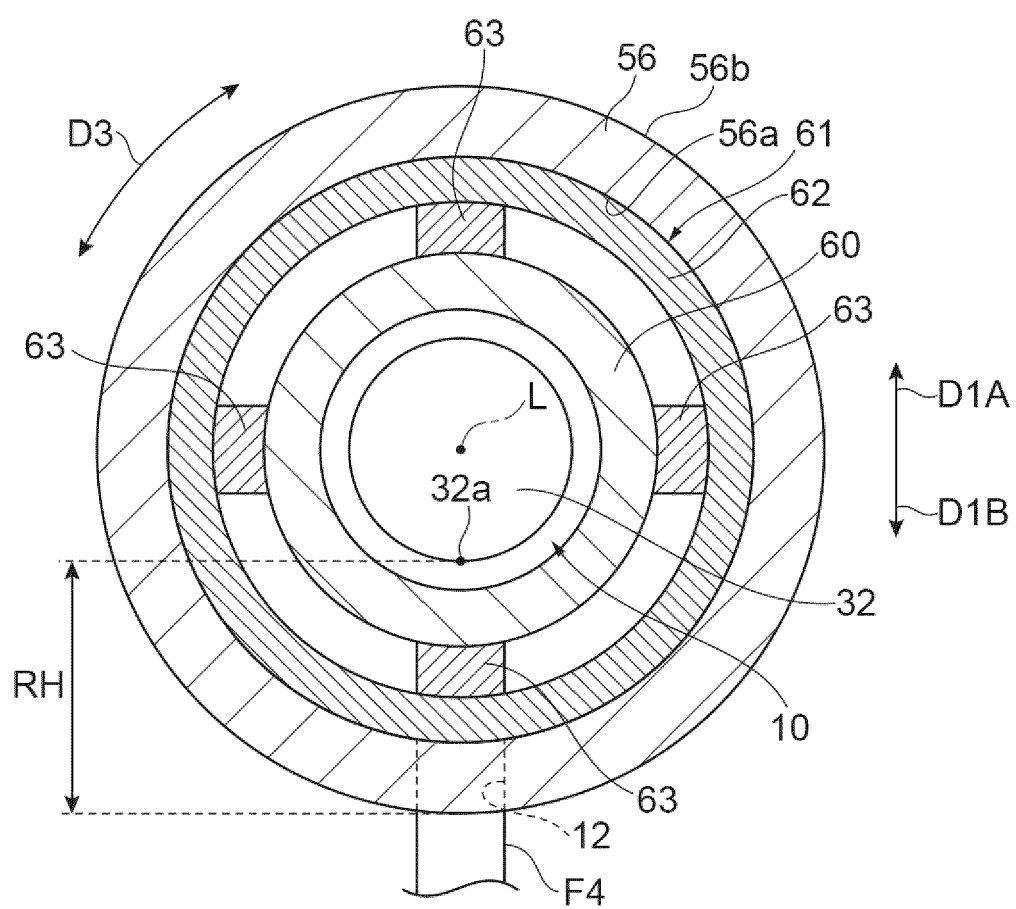
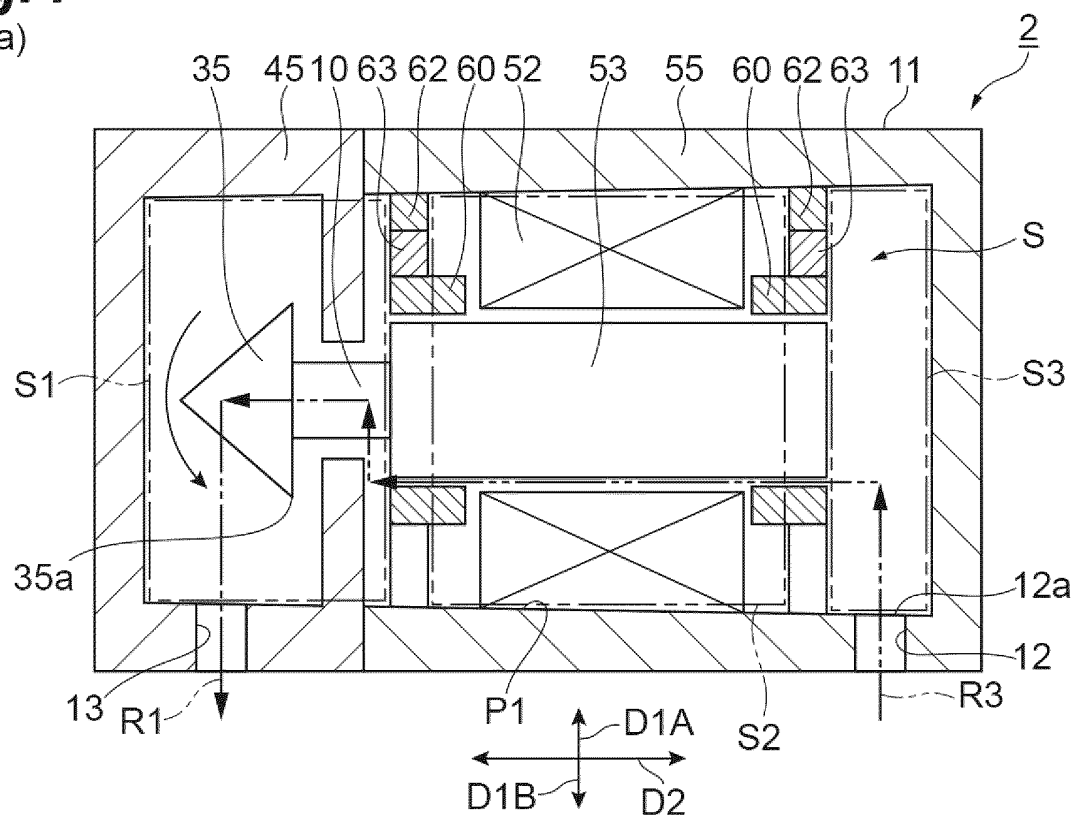


Fig.4

(a)



(b)

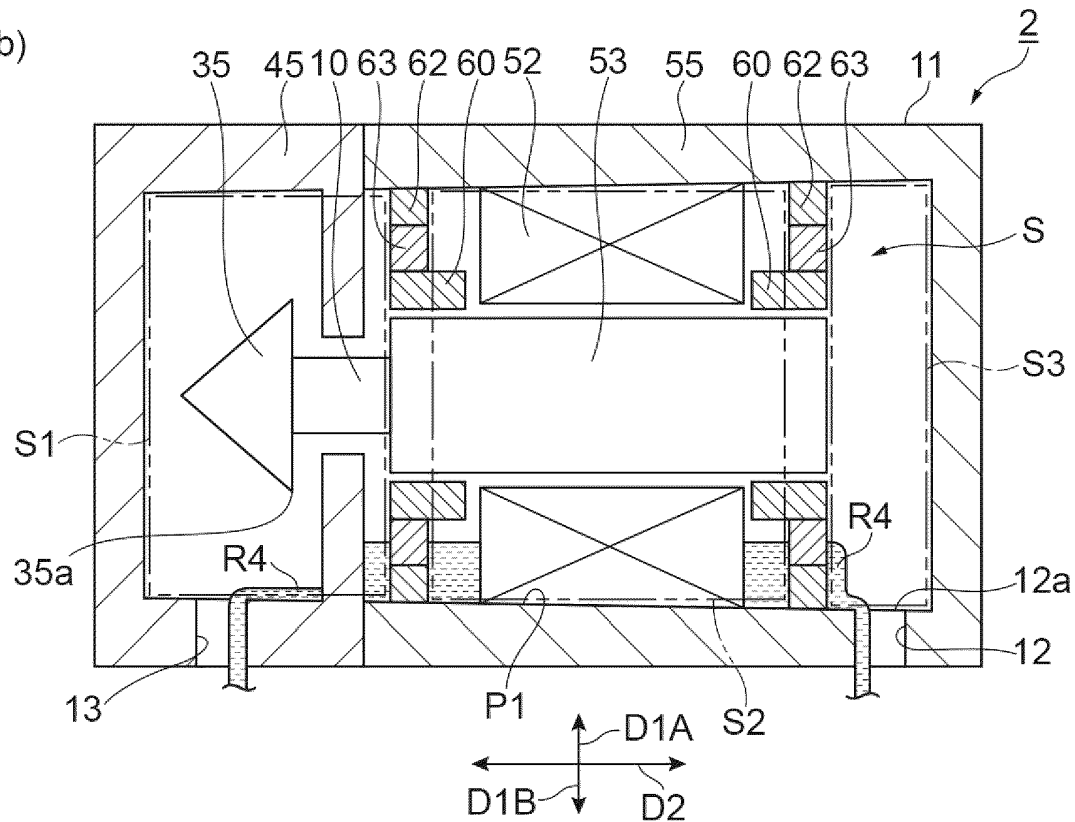


Fig.5

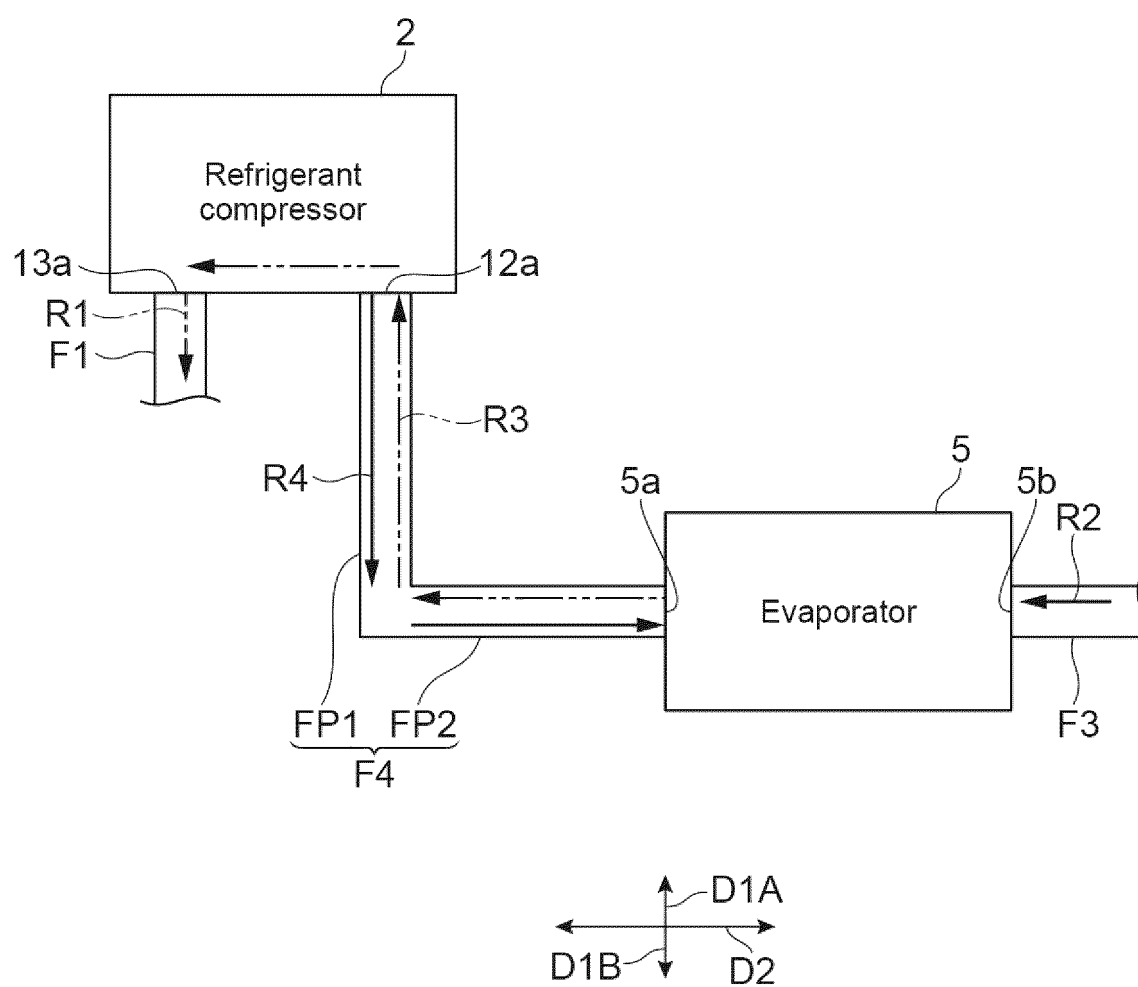
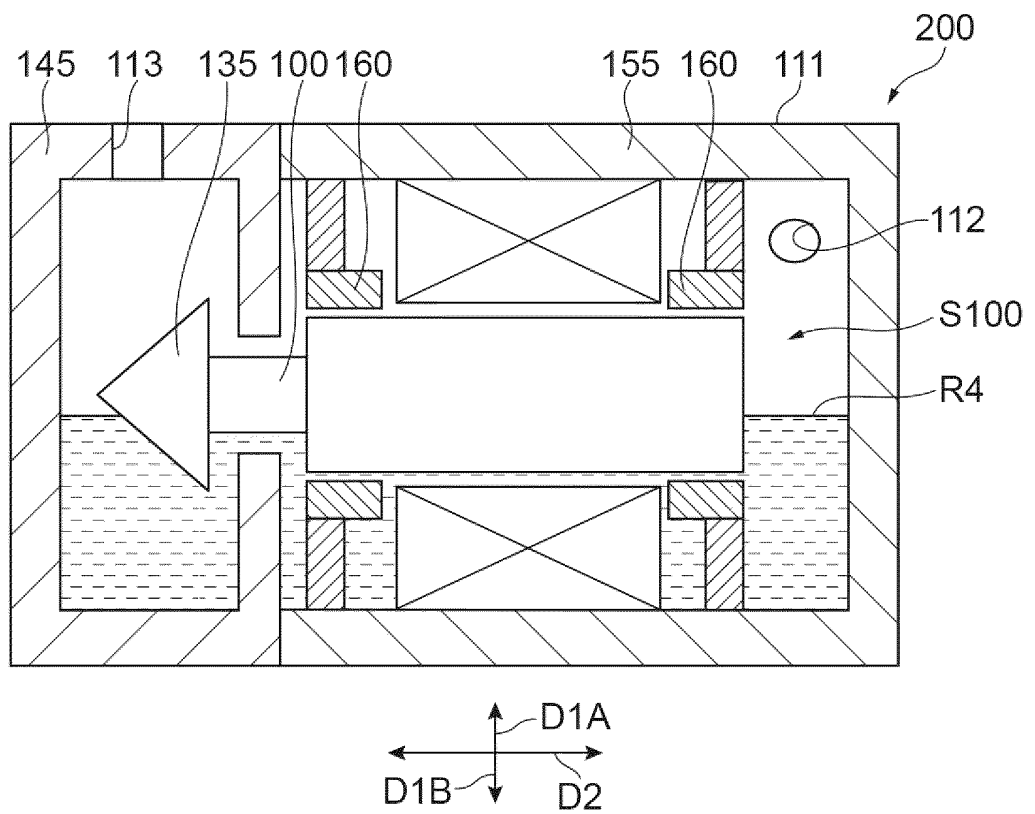


Fig.6

(a)



(b)

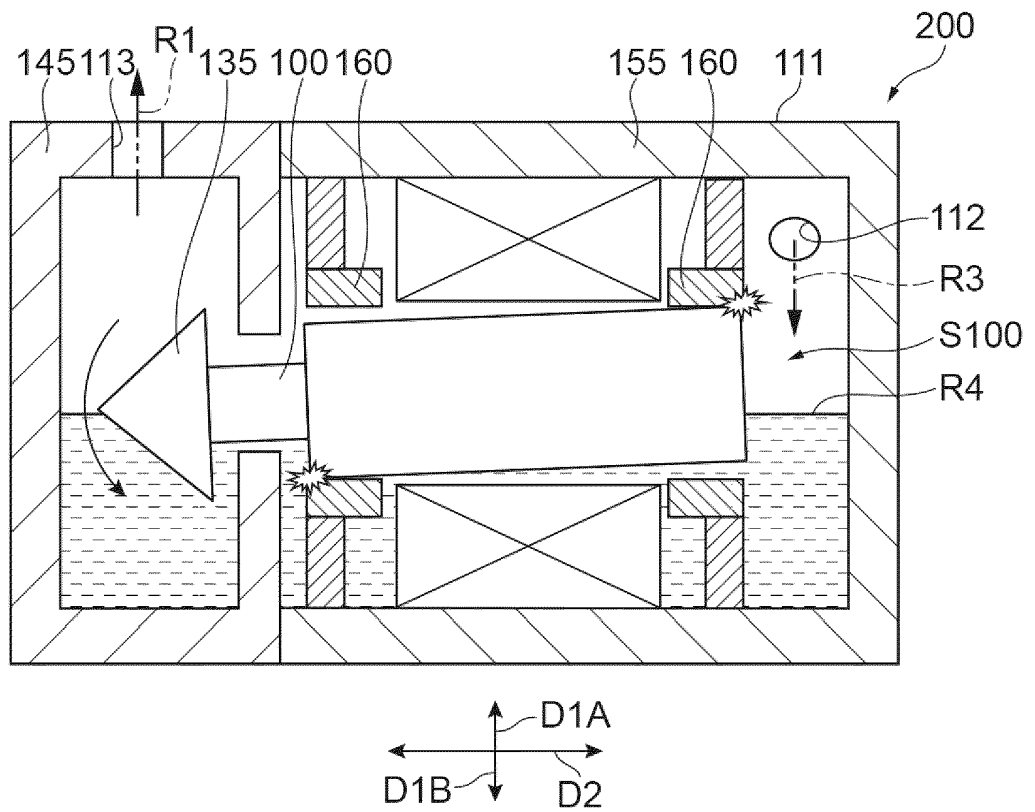


Fig. 7

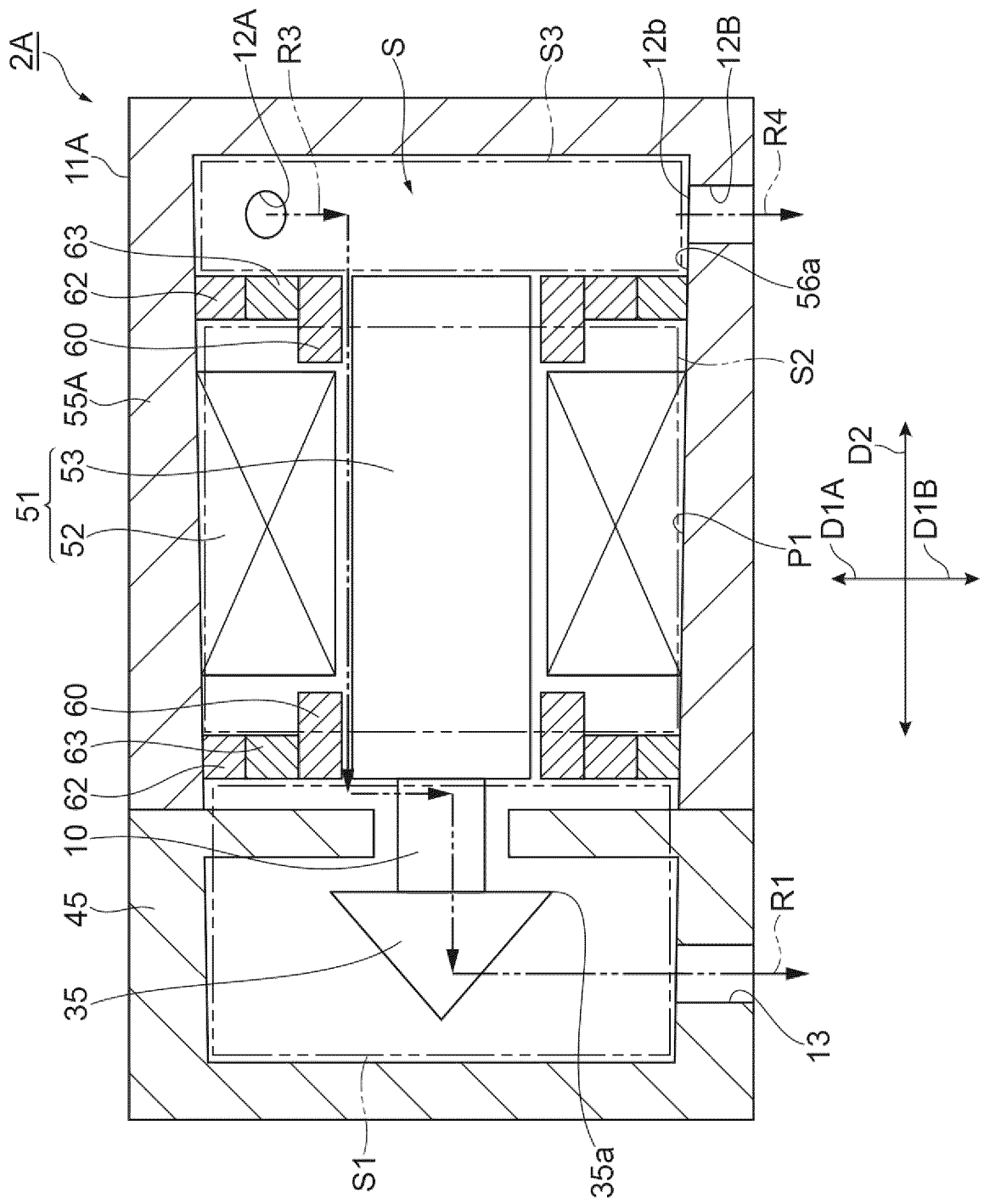
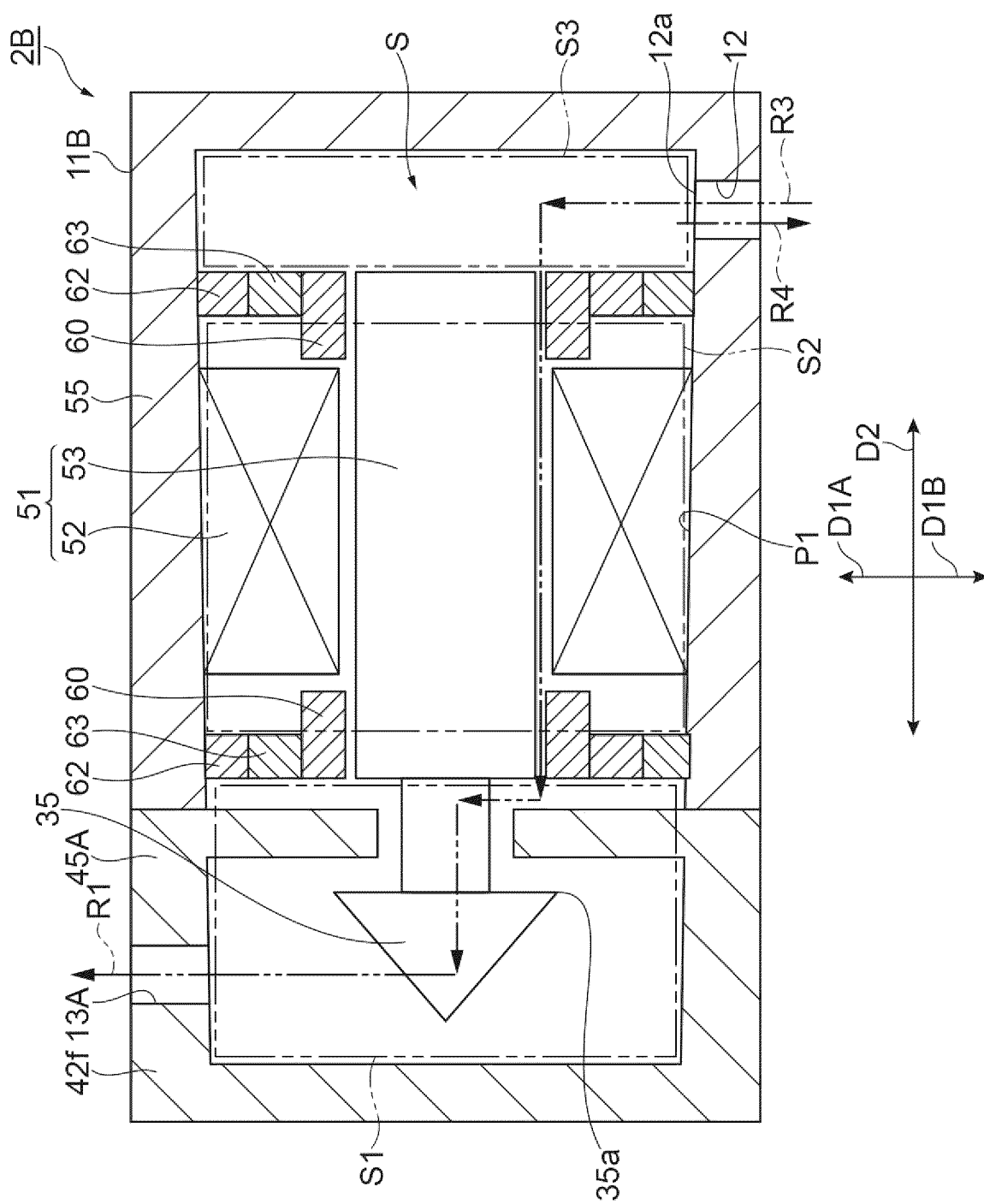


Fig. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/008623

A. CLASSIFICATION OF SUBJECT MATTER

F04B 39/12(2006.01)i; **F04C 29/12**(2006.01)i; **F04D 17/12**(2006.01)i; **F04D 29/058**(2006.01)i
FI: F04B39/12 101G; F04C29/12 D; F04D17/12; F04D29/058

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)

F04B39/12; F04C29/12; F04D17/12; F04D29/058

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.
X	JP 11-230098 A (LG ELECTRONICS INC) 24 August 1999 (1999-08-24) paragraphs [0024], [0039], fig. 1	1-2, 4-5, 7
A		3, 6
X	JP 2016-33348 A (MITSUBISHI HEAVY IND LTD) 10 March 2016 (2016-03-10) paragraphs [0025], [0038], [0045], fig. 2-3	1, 4-7
A		2-3
A	JP 2000-240596 A (DAIKIN IND LTD) 05 September 2000 (2000-09-05) paragraphs [0031], [0034]-[0035], [0038], fig. 1	1-7
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 79520/1989 (Laid-open No. 19498/1991) (TOKYO ELECTRIC POWER CO INC) 26 February 1991 (1991-02-26), specification, p. 5, lines 1 to last line, fig. 1	1-7
A	US 2021/0285691 A1 (HONEYWELL INTERNATIONAL INC.) 16 September 2021 (2021-09-16) paragraphs [0069]-[0070], [0089], fig. 3	1-7

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

* Special categories of cited documents:	"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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"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

10 May 2023

Date of mailing of the international search report

23 May 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
Japan

Authorized officer

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2023/008623

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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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