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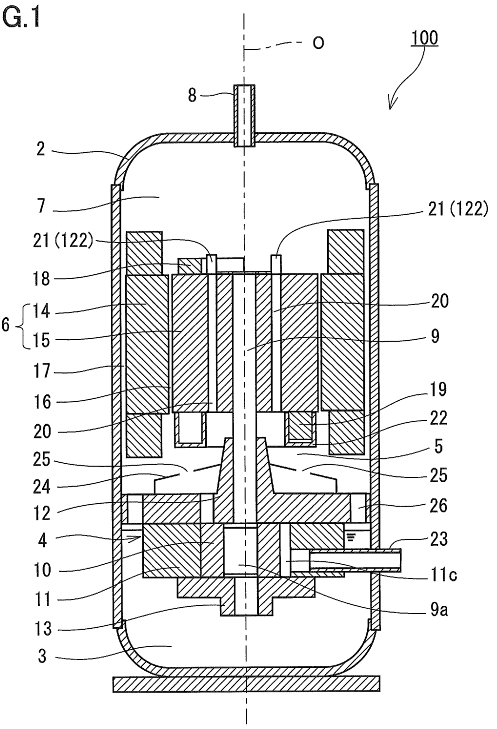
(54) HERMETICALLY SEALED COMPRESSOR

(57) A hermetic compressor (100) includes a closed casing (2), a compression mechanism (4), a motor (6), a discharge pipe (8), a first balance weight (18), a swirl flow generating portion (21), and a second balance weight (19). The motor (6) has a stator (14) and a rotor (15). A communication passage (20) is formed in the rotor (15) so as to introduce, into an upper space (7), a working fluid compressed in the compression mechanism (4) and discharged to a lower space (5) of the closed casing (2). A baffle plate (122) is provided as a discharge direction deflecting portion for causing the compressed working fluid to travel from the communication passage (20) to the upper space (7), while deflecting the working fluid in a direction inclined with respect to a direction parallel to a rotational axis O. The baffle plate (122) may be constituted by a part of the swirl flow generating portion (21).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a hermetic compressor, and more specifically to a technique for separating lubricating oil from a compressed working fluid.

BACKGROUND ART

[0002] A known conventional example of an oil separation mechanism usable in a hermetic compressor is Patent Literature 1. Fig. 25 shows an overview of a compressor described in Patent Literature 1. A motor including a rotor 211 and a stator 213 is disposed in a closed casing 203 of the compressor. A compression mechanism (not shown) is disposed below the motor. A refrigerant compressed in the compression mechanism is discharged into the internal space of the closed casing 203. An oil separation plate 237 that rotates together with the rotor 211 is provided at the end of the rotor 211. The oil separation plate 237 applies a centrifugal force to a multiphase flow of the compressed refrigerant and oil.

[0003] As shown in Fig. 26A and Fig. 26B, the oil separation plate 237 has an approximately disk shape. Projections 239 and recesses 245 are formed radially on the bottom surface of the oil separation plate 237. The projections 239 and the recesses 245 each extend continuously to the outer periphery of the oil separation plate 237. The flow of the refrigerant containing oil particles travels along the projections 239, is scattered by the centrifugal force from the end of each projection 239, and collides with the inner peripheral surface of the rotor 213. Thus, the oil is separated from the refrigerant. The refrigerant is discharged outside the closed casing 203 through a discharge pipe 235.

[0004] Patent Literature 2 discloses a method of causing a compressed refrigerant to pass through an insulator so as to promote the separation of oil from the refrigerant.

[0005] In the compressor described in Patent Literature 1 or 2, the separated oil returns to an oil reservoir in the bottom portion of the closed casing through a gap between the rotor and the stator or through a gap between the stator and the closed casing.

CITATION LIST

Patent Literature

[0006]

Patent Literature 1 JP 11(1999)-107967 A
Patent Literature 2 JP 2009-144581 A

SUMMARY OF INVENTION

Technical Problem

[0007] With the techniques disclosed in Patent Literatures 1 and 2, the oil can be efficiently separated from the refrigerant. However, no particular consideration is given to the return of the separated oil to the oil reservoir. For example, when a strong swirl flow is generated in a space below the motor, the oil separated in a space above the motor is hard to return to the oil reservoir. As a result, the oil, once separated from the refrigerant, is again mixed therewith, and discharged outside the compressor through the discharge pipe.

[0008] It is an object of the present invention to provide a hermetic compressor with less discharge of oil.

Solution to Problem

[0009] The present invention provides a hermetic compressor including: a closed casing having an oil reservoir in its bottom portion; a compression mechanism, disposed in the closed casing, for compressing a working fluid; a motor, disposed above the compression mechanism in the closed casing, for driving the compression mechanism, the motor having a rotor and a stator; an upper space, formed above the motor, as a part of an internal space of the closed casing; a lower space, formed between the motor and the compression mechanism, as a part of the internal space of the closed casing; a discharge pipe opening into the upper space, for discharging the compressed working fluid outside the hermetic compressor; a first balance weight protruding from an upper surface of the rotor toward the upper space; a swirl flow generating portion protruding from the upper surface of the rotor toward the upper space, the swirl flow generating portion being disposed at a position closer to a rotational axis of the motor than the first balance weight; a second balance weight protruding from a lower surface of the rotor toward the lower space; and a communication passage formed in the rotor so as to introduce, into the upper space, the working fluid compressed in the compression mechanism and discharged to the lower space. When a three-dimensional annular trajectory of the first balance weight formed around the rotational axis when the motor is driven is defined as a first trajectory, a plane obtained by cutting the first trajectory with a first plane parallel to the rotational axis and including the rotational axis is defined as a first cross section, a three-dimensional annular trajectory of the second balance weight formed around the rotational axis when the motor is driven is defined as a second trajectory, a plane obtained by cutting the second trajectory with a second plane parallel to the rotational axis and including the rotational axis is defined as a second cross section, a three-dimensional annular trajectory of the swirl flow generating portion formed around the rotational axis when the motor is driven is defined as a third trajectory, a plane obtained by cutting the third trajectory with a third plane parallel to the rotational axis and including the rotational axis is defined as a third cross section, an area of a micro-region included in a specific region on an arbitrary plane parallel to the rotational axis and including the rotational axis is defined as dA, a distance from the rotational axis to a centroid of the micro-region is defined as r, and a value M_A represented by the following equation (1) is defined as a second moment of area,

[0010] [Equation 1]

$$M_A = \int_A r^2 dA \cdots (1)$$

[0011] a sum of a second moment of area of the first cross section and a second moment of area of the third cross section is greater than a second moment of area of the second cross section. The hermetic compressor further includes a discharge direction deflecting portion for causing the compressed working fluid to travel from the communication passage to the upper space, while deflecting the working fluid in a direction inclined with respect to a direction parallel to the rotational axis.

Advantageous Effects of Invention

[0012] According to the present invention, the sum of the second moment of area of the first cross section and the second moment of area of the third cross section is greater than the second moment of area of the second cross section. That is, the swirl flow in the upper space is stronger and the swirl flow in the lower space is weaker. This promotes the effect of separating the oil from the working fluid by a centrifugal force in the upper space. Furthermore, the return of the oil from the upper space to the oil reservoir can be facilitated by increasing the swirl flow in the upper space and reducing the swirl flow in the lower space relatively. This can prevent lubrication failure from occurring in the compression mechanism due to a drop in the oil level. Moreover, since the stability of the oil level is enhanced by reducing the swirl flow in the lower space, splashing of the oil can also be reduced.

[0013] Furthermore, since the discharge direction deflecting portion is provided, the compressed working fluid travels from the communication passages to the upper space, while being deflected in a direction inclined with respect to a direction parallel to the rotational axis. This allows the swirl flow of the working fluid to be generated at a position closer to the outlet of the communication passage in the direction parallel to the rotational axis of the motor. As a result, the flow distance of the working fluid in the upper space can be increased, which can reduce the discharge of the oil from the compressor.

BRIEF DESCRIPTION OF DRAWINGS

[0014]

Fig. 1 is a cross-sectional view of a compressor according to an embodiment of the present invention.
Fig. 2 is a perspective view of a rotor and balance weights.
Fig. 3 is a perspective view of the rotor on which the balance weights and a swirl flow generating portion are provided.
Fig. 4 is a perspective view of the rotor on which another swirl flow generating portion is provided.
Fig. 5 is a perspective view of a swirl flow suppressing portion.
Fig. 6A is a perspective view showing the definitions of a first cross section and a second cross section.
Fig. 6B is a plan view showing the definitions of the first cross section and the second cross section.
Fig. 7A is a perspective view showing the definition of a third cross section.

Fig. 7B is a plan view showing the definition of the third cross section.

Fig. 8 is a schematic diagram showing the definition of a second moment of area.

Fig. 9 is a schematic diagram showing the flow of refrigerant and the flow of oil in the compressor.

Fig. 10 is a schematic diagram showing a pressure field of a model in which a rotor is placed in a cylindrical container.

Fig. 11 is a schematic diagram showing the flow of refrigerant and the flow of oil in a compressor without a swirl flow generating portion.

Fig. 12 is a schematic diagram showing a pressure difference between two openings of a flow path.

Fig. 13A is a perspective view of a rotor without a swirl flow generating portion.

Fig. 13B is a schematic diagram showing a refrigerant flow in the vicinity of an outlet of a communication passage formed in the rotor shown in Fig. 13A.

Fig. 14A is a perspective view of a rotor with a swirl flow generating portion incapable of deflecting a refrigerant flow.

Fig. 14B is a schematic diagram showing a refrigerant flow in the vicinity of an outlet of a communication passage formed in the rotor shown in Fig. 14A.

Fig. 15A is a perspective view of the rotor of the present embodiment.

Fig. 15B is a schematic diagram showing a refrigerant flow in the vicinity of an outlet of a communication passage formed in the rotor of Fig. 15A.

Fig. 16 is a schematic diagram showing a flow field in the upper space of the rotary compressor of the present embodiment.

Fig. 17 is a schematic diagram showing a flow field in the upper space of a rotary compressor provided with the swirl flow generating portion shown in Fig. 14A.

Fig. 18 is a graph showing the results of experiments conducted to ascertain the effect of the rotary compressor of the present embodiment.

Fig. 19 is a cross-sectional view of a compressor according to a first modification.

Fig. 20 is a perspective view of a swirl flow suppressing portion according to a second modification.

Fig. 21 is a cross-sectional view showing a preferred position of a discharge port.

Fig. 22 is a perspective view of a swirl flow suppressing portion according to a third modification.

Fig. 23 is a perspective view of a swirl flow generating portion according to a fourth modification.

Fig. 24 Ais a schematic cross-sectional view of a discharge direction deflecting portion according to a fifth modification.

Fig. 24B is a schematic cross-sectional view of a swirl flow generating portion and a discharge direction deflecting portion according to a sixth modification.

Fig. 25 is a cross-sectional view of a conventional hermetic compressor.

Fig. 26A is a bottom view of an oil separation plate provided in the conventional hermetic compressor.

Fig. 26B is a cross-sectional view of the oil separation plate shown in Fig. 26A, taken along the line B-B.

DESCRIPTION OF EMBODIMENTS

[0015] Hereinafter, the embodiments of the present invention will be described with reference to the drawings.

[0016] As shown in Fig. 1, a rotary compressor 100 of the present embodiment includes a closed casing 2, a compression mechanism 4, and a motor 6. The compression mechanism 4 and the motor 6 are disposed in one closed casing 2. That is, the rotary compressor 100 is configured as a hermetic compressor. In the closed casing 2, the motor 6 is located above the compression mechanism 4. The closed casing 2 has an oil reservoir 3 formed in its bottom portion. The compression mechanism 4 is immersed in oil (refrigerating machine oil) held in the oil reservoir 3. The compression mechanism 4 is coupled to the motor 6 by a shaft 9 so as to be driven by the motor 6. Alower space 5 and an upper space 7 are formed in the closed casing 2. The lower space 5 is a space formed between the compression mechanism 4 and the motor 6 in the axial direction of the shaft 9. The upper space 7 is a space formed above the motor 6. The longitudinal direction of the shaft 9 is parallel to the vertical direction. That is, the rotary compressor 100 is a vertical rotary compressor.

[0017] The compression mechanism 4 has an upper bearing 12, a piston 10, a cylinder 11, and a lower bearing 13. The piston 10 is fitted to an eccentric portion 9a of the shaft 9 within the cylinder 11. A compression chamber 11c having a crescent shape in plan view is formed between the outer peripheral surface of the piston 10 and the inner peripheral surface of the cylinder 11. A torque generated in the motor 6 is transmitted to the piston 10 by the shaft 9. As the piston 10 rotates within the cylinder 11, a refrigerant is compressed in the compression chamber 11c. The type of the refrigerant as a working fluid is not particularly limited. A fluorine-containing refrigerant such as R410A or a natural refrigerant such as carbon dioxide can be used.

[0018] The upper bearing 12 and the lower bearing 13 are mounted on the top and the bottom of the cylinder 11, respectively. The shaft 9 is rotatably supported by the upper bearing 12 and the lower bearing 13. A discharge muffler 24 having a discharge port 25 is provided on the top of the upper bearing 12. The compressed refrigerant travels from the compression mechanism 4 to the lower space 5 through the interior of the discharge muffler 24 and the discharge port 25. An oil passage 26 for returning the oil separated from the refrigerant in the lower space 5 or the upper space 7 to the oil reservoir 3 is formed along the outer periphery of the upper bearing 12.

[0019] A discharge pipe 8 for discharging the compressed refrigerant outside the closed casing 2 is provided in the top portion of the closed casing 2. A suction pipe 23 for introducing the refrigerant to be compressed into the compression mechanism 4 is provided in the side portion of the closed casing 2. The discharge pipe 8 penetrates the top portion of the closed casing 2 and opens into the upper space 7. The suction pipe 23 penetrates the side portion of the closed casing 2 and is inserted into the cylinder 11.

[0020] The motor 6 includes a stator 14 and a rotor 15. The stator 14 is fixed to the inner wall of the closed casing 2. The stator 14 has an annular shape when viewed in the axial direction, and the rotor 15 is disposed within the stator 14. The rotor 15 is fixed to the shaft 9. Therefore, the rotational axis of the motor 6 coincides with the rotational axis O of the shaft 9. A small gap 16 (air gap) is formed between the inner peripheral surface of the stator 14 and the outer peripheral surface of the rotor 15 in the radial direction. A plurality of slit-shaped flow paths 17 extending in a direction parallel to the rotational axis O are formed between the outer peripheral surface of the stator 14 and the inner peripheral surface of the closed casing 2.

[0021] The rotor 15 has a plurality of communication passages 20 communicating the lower space 5 and the upper space 7. The communication passages 20 are formed at equal angular intervals around the rotational axis O of the shaft 9, and each of them penetrates the rotor 15 in the direction parallel to the axial direction of the shaft 9. The refrigerant compressed in the compression mechanism 4 travels from the lower space 5 to the upper space 7 through the gap 16, the flow paths 17, or the communication passages 20. The oil separated from the refrigerant in the upper space 7 returns from the upper space 7 to the lower space 5 through the gap 16, the flow paths 17, or the communication passages 20. In the present embodiment, the rotor 15 has four communication passages 20, but the number of the communication passages 20 is not particularly limited.

[0022] As shown in Fig. 2, the rotor 15 has, as constituent elements of the rotor 15, a stack of steel plates 28, end plates 27 disposed on the top and the bottom of the stack of steel plates 28 to clamp the steel plates 28 therebetween and fix them together, and rivets (not shown). In order to prevent whirling of the rotor 15 during its rotation, a first balance weight 18 and a second balance weight 19 are provided on the top and the bottom of the rotor 15, respectively. The balance weights 18 and 19 each have an arcuate shape, and surround the communication passages 20 in plan view. The second balance weight 19 is disposed symmetrically to the first balance weight 18 with respect to the rotational axis O of the shaft 9. That is, the second balance weight 19 is disposed at a position 180 degrees opposite to the position of the first balance weight 18 with respect to the rotational direction of the shaft 9.

[0023] The second balance weight 19 is heavier than the first balance weight. The second balance weight 19 is located closer to the supporting point of the shaft 9 (the upper bearing 12 and the lower bearing 13) than the first balance weight 18. Therefore, the effect of preventing the whirling motion can be enhanced by making the second balance weight 19 relatively heavy.

[0024] As shown in Fig. 1 and Fig. 3, a swirl flow generating portion 21 is provided on the top of the rotor 15 to increase a swirl flow in the upper space 7. The swirl flow generating portion 21 protrudes from the upper surface of the rotor 15 toward the upper space 7 and is disposed at a position closer to the rotational axis O than the first balance weight 18. Specifically, the swirl flow generating portion 21 includes a supporting ring 121 and baffle plates 122. The supporting ring 121 is a plate-like member, and is located closer to the rotational axis O than the communication passages 20 on the upper surface of the rotor 15. The baffle plates 122 have a flat plate shape and are formed integrally with the supporting ring 121 on the outer periphery of the supporting ring 121. Four baffle plates 122 are provided at equal angular intervals along the circumferential direction of the supporting ring 121. Each of the baffle plates 122 protrudes obliquely from the upper surface of the rotor 15 toward the upper space 7 (i.e., in a direction inclined with respect to a direction parallel to the rotational axis O of the motor 6). In the present embodiment, the swirl flow generating portion 21 has the same number of baffle plates 122 as the communication passages 20. The protruding direction of each baffle plate 122 is set to, for example, 30 to 60 degrees, and typically 45 degrees, with respect to the direction perpendicular to the rotational axis O (i.e., a horizontal direction (= 0 degrees).

[0025] The baffle plate 122 is provided at the outlet of the communication passage 20. Specifically, the baffle plate 122 is located in the rotational direction of the rotor 15 from the outlet of the communication passage 20. An image obtained by projecting the baffle plate 122 onto the upper surface of the rotor 15 overlaps the outlet of the communication passage 20. That is, the communication passage 20 is partially or entirely covered by the baffle plate 122. By the function of the baffle plate 122, the compressed refrigerant travels from the communication passage 20 to the upper space 7, while being deflected in the direction inclined with respect to the direction parallel to the rotational axis O. As described above, the baffle plate 122 serves as a discharge direction deflecting portion for deflecting the discharge direction of the refrigerant. In the present embodiment, in order to suppress an increase in the number of components, the swirl flow generating portion 21 is also used as a discharge direction deflecting portion (baffle plate 122).

[0026] In the present embodiment, the baffle plates 122 each are configured to direct the compressed refrigerant in a rotational direction opposite to that of the rotor 15 (hereinafter referred to as a "opposite rotational direction"). This configuration can prevent the refrigerant in the upper space 7 and the refrigerant discharged from the communication passages 20 from colliding with each other at right angles. Therefore, the refrigerant discharged from the communication passages 20 can travel smoothly to the upper space 7. This means that the pressure loss at the outlet of the communication passage 20 is less likely to increase.

[0027] The swirl flow generating portion 21 may have the baffle plate 122 at a position where it does not cover the outlet of the communication passage 20. The baffle plate 122 provided at such a position also has a function of increasing the swirl flow in the upper space 7, but does not have a function of deflecting the discharge direction of the refrigerant. Therefore, the flow distance of the refrigerant in the upper space 7 cannot be increased.

[0028] In order to further reduce the number of components, the baffle plate 122 may be formed as a part of the end plate 27. Specifically, as shown in Fig. 4, the baffle plate 122 can be formed by cutting and raising a part of the end plate 27 at a position covering the communication passage 20. In a configuration shown in Fig. 4, the baffle plate 122 thus cut and raised serves as a swirl flow generating portion and a discharge direction deflecting portion. The shape of the discharge direction deflecting portion is not limited to a plate shape as long as it has a function of deflecting the discharge direction of the refrigerant.

[0029] As shown in Fig. 1 and Fig. 5, a swirl flow suppressing portion 22 is provided beneath the rotor 15 to reduce the swirl flow in the lower space 5. Specifically, the swirl flow suppressing portion 22 is constituted by an annular cover 22 that completely covers the second balance weight 19. When the second balance weight 19 is covered by the cover 22 to suppress the swirl flow in the lower space 5, the pressure at the opening of the flow path 17 on the lower space 5 side drops. Thereby, the oil separated in the upper space 7 can be returned smoothly to the lower space 5 and the oil reservoir 3 through the flow path 17. Furthermore, since the stability of the oil level is enhanced by suppressing the swirl flow in the lower space 5, splashing of oil in the oil reservoir 3 can be reduced.

[0030] In the present embodiment, the first balance weight 18, the second balance weight 19, the swirl flow generating portion 21 and the swirl flow suppressing portion 22 are designed to increase the swirl flow in the upper space 7 and reduce the swirl flow in the lower space 5. One of the factors in the generation of swirl flows in the lower space 5 and the upper space 7 is that the refrigerant filled in the lower space 5 and the upper space 7 is subjected to the displacement action of the first balance weight 18, the second balance weight 19, and the swirl flow generating portion 21.

[0031] As shown in Fig. 6A and Fig. 6B, a three-dimensional annular trajectory of the first balance weight 18 formed around the rotational axis O when the motor 6 is driven is defined as a first trajectory, and a plane obtained by cutting the first trajectory with a first plane parallel to the rotational axis O and including the rotational axis O is defined as a first cross section 33.

[0032] The first cross section 33 can also be defined as follows. A plane that is a part of the surface of the first balance weight 18 and applies displacement action to the refrigerant when the motor 6 is driven is defined as a first displacement surface 18p, and an image obtained by projecting the first displacement surface 18p onto the first plane parallel to the rotational axis O and including the rotational axis O is defined as a first projected image. The first projected image can have various shapes and areas because the first plane can be determined without limitation, but herein the first plane is determined so that the area of the first projected image has a maximum value. In this case, the first projected image coincides with the first cross section 33.

[0033] For the second balance weight 19, a second cross section 34, a second displacement surface 19p, a second plane, and a second projected image can be defined according to the same criteria as applied to the first balance weight 18.

[0034] Furthermore, for the swirl flow generating portion 21, a third cross section 35, a third displacement surface, a third plane, and a third projected image can be defined according to the same criteria as applied to the first balance weight 18. Specifically, as shown in Fig. 7A and Fig. 7B, a three-dimensional annular trajectory of the swirl flow generating portion 21 formed around the rotational axis O when the motor 6 is driven is defined as a third trajectory, and a plane obtained by cutting the third trajectory with a third plane parallel to the rotational axis O and including the rotational axis O is defined as a third cross section 35. In the present embodiment, four baffle plates 122 for applying displacement action to the refrigerant are provided. Therefore, the third cross section 35 is composed of four cross sections having the same shape.

[0035] The third cross section 35 also can be defined as follows. A plane that is a part of the surface of the swirl flow generating portion 21 and applies displacement action to the refrigerant when the motor 6 is driven is defined as a third displacement surface 21p, and an image obtained by projecting the third displacement surface 21p onto the third plane parallel to the rotational axis O and including the rotational axis O is defined as a third projected image. In the present embodiment, the surface of the baffle plate 122 forms the third displacement surface 21p. The third projected image can have various shapes and areas because the third plane can be determined without limitation, but herein the third plane is determined so that the area of the third projected image has a maximum value. In this case, the third projected image coincides with the third cross section 35.

[0036] Next, as shown in Fig. 8, the area of a micro-region 136 included in a specific region 135 on an arbitrary plane parallel to the rotational axis O and including the rotational axis O is defined as dA, the distance from the rotational axis O to the centroid of the micro-region 136 is defined as r, the length of the micro-region 136 in a radial direction is defined as dr, the height of the micro-region 136 in a direction parallel to the rotational axis O is defined as dh, and the value M_A represented by the following equation (1) is defined as a second moment of area. In Fig. 8, the micro-region 136 is rectangular.

[0037] [Equation 2]

$$M_A = \int r^2 dA = \iint r^2 dh dr \quad \cdots (1)$$

[0038] Furthermore, the second moment of area of the first cross section 33 is defined as a 1st second moment of area M_{A1}. Likewise, the second moment of area of the second cross section 34 is defined as a 2nd second moment of area M_{A2}. Likewise, the second moment of area of the third cross section 35 is defined as a 3rd second moment of area M_{A3}. The 1st to 3rd second moments of area can be calculated using Equation (1) for the first cross section 33, the second cross section 34, and the third cross section 35, respectively. The first balance weight 18, the second balance weight 19, and the swirl flow generating portion 21 are designed so that the relationship among these 1st to 3rd second moments of area satisfies the following equation (2). This makes it possible to make the swirl flow in the upper space 7 stronger and the swirl flow in the lower space 5 weaker. The "second moment of area of the first cross section 33" means a second moment of area calculated using Equation (1) for the first cross section 33. This also applies to the second cross section 34 and the third cross section 35.

[0039]

$$M_{A1} + M_{A3} > M_{A2} \ldots (2)$$

[0040] In the present embodiment, the swirl flow generating portion 21 has a plurality of baffle plates 122. Therefore, the second term in the left-hand side of Equation (2) is represented as a sum of a plurality of 3rd second moments of area of the plurality of baffle plates 122. In the case where a plurality of first balance weights 18 are provided, the first term in the left-hand side of Equation (2) is represented as a sum of a plurality of 1st second moments of area of the plurality of first balance weights 18. Likewise, in the case where a plurality of second balance weights 19 are provided, the right-hand side of Equation (2) is represented as a sum of a plurality of 2nd second moments of area of the plurality of second balance weights 19.

[0041] In the present embodiment, the second balance weight 19 is covered by a cover 22 to reduce the area of the second displacement surface 19p of the second balance weight 19. The second displacement surface 19p displaces the refrigerant. The area of the second displacement surface 19p is substantially zero, if the presence of screws or the like for fixing the cover 22 to the rotor 15 is ignored. Therefore, the right-hand side of Equation (2) is zero and thus the relationship of Equation (2) is satisfied.

[0042] The 1st second moment of area M_{A1} is equal to the second moment of area of the first projected image on the first plane, when the first plane is determined so that the area of the first projected image has a maximum value. Likewise, the 2nd second moment of area M_{A2} is equal to the second moment of area of the second projected image on the second plane, when the second plane is determined so that the area of the second projected image has a maximum value. The 3rd second moment of area M_{A3} is equal to the second moment of area of the third projected image on the third plane, when the third plane is determined so that the area of the third projected image has a maximum value.

[0043] Next, the flows of the refrigerant and the oil in the closed casing 2 are described with reference to Fig. 9. In Fig. 9, the flow of the refrigerant in the lower space 5, the flow of the refrigerant in the upper space 7, and the flow of the oil returning from the upper space 7 to the oil reservoir 3 are indicated by an arrow 38a, an arrow 38b, and a dashed arrow 39, respectively. The oil held in the oil reservoir 3 is used for lubrication and sealing of the sliding parts of the compression mechanism 4. The compressed refrigerant containing oil particles (oil mist) is discharged from the compression mechanism 4 to the lower space 5 in a high-temperature and high-pressure state. In the lower space 5, a swirl flow field is formed by the rotation of the rotor 15, but the intensity of the flow is reduced by the function of the cover 22, compared to that in the upper space 7. The refrigerant discharged into the lower space 5 is introduced from the lower space 5 to the upper space 7 through the communication passages 20. The refrigerant discharged into the upper space 7 is deflected in the swirling direction and the outer peripheral direction by centrifugal forces generated by the baffle plates 122 serving also as the swirl flow generating portion 21 and the first balance weight 18 as well as a flow deflecting action performed by the baffle plates 122 serving also as the swirl flow generating portion 21. Since the refrigerant travels in the upper space 7 while swirling, the oil particles are separated from the refrigerant by the centrifugal forces during travelling. Then, the refrigerant is discharged outside the closed casing 2 through the discharge pipe 8. The oil separated by the centrifugal forces in the upper space 7 adheres to the inner peripheral surface of the stator 14 or the inner wall of the closed casing 2. Then, the oil returns to the oil reservoir 3 through the air gap 16 or the flow path 17.

[0044] Next, the actions of the swirl flow generating portion (baffle plate 122) and the swirl flow suppressing portion (cover 22) are described in detail.

[0045] First, a flow field generated by a swirl flow is described. A model is assumed, in which a rotor 37a is placed in a cylindrical container 37 and the rotor 37a is rotating about the central axis O_1 of the cylindrical container 37, as shown in Fig. 10. In the cylindrical container 37, a pressure field 37b is generated with a low pressure near the central axis O_1 and a high pressure near the inner peripheral surface of the cylindrical container 37. This is the result of the effect of directing the flow radially outwardly by the centrifugal force of the flow itself and the effect of converting kinetic energy produced by swirling into pressure energy near the inner peripheral surface of the cylindrical container 37.

[0046] If the intensity of swirling increases, a pressure field 37c indicated by a dashed line is generated. That is, the increase in the intensity of swirling increases the centrifugal force of the swirl flow itself. Therefore, the pressure field 37c tends to have an even lower pressure near the central axis O_1 of the cylindrical container 37. On the other hand, kinetic energy produced by swirling with the inclusion of additional kinetic energy is converted into pressure energy near the inner peripheral surface of the cylindrical container 37. Therefore, the pressure field 37c tends to have an even higher pressure near the inner peripheral surface of the cylindrical container 37.

[0047] In order to increase the swirl flow without changing the rotational speed of the rotor 37a, it is necessary to increase the displacement area of the rotor 37a and thus increase the momentum added to the fluid. On the contrary, if the displacement area of the rotor 37a is reduced, the swirl flow is suppressed.

[0048] In the present embodiment, from the viewpoint of preventing whirling, the second balance weight 19 is heavier than the first balance weight 18. Typically, the balance weights 18 and 19 are made of a metal such as brass. In the case where the balance weights 18 and 19 are made of the same material, the volume of the second balance weight 19 must be greater than that of the first balance weight 18 to make the second balance weight 19 heavier than the first balance weight 18. In the case where the volume of the second balance weight 19 is greater than that of the first balance weight 18 and the cover 22 is not provided, the area of the displacement surface 19p of the second balance weight 19 exceeds the area of the displacement surface 18 of the first balance weight 18.

[0049] Next, the flows of refrigerant and oil in a rotary compressor without a swirl flow generating portion and a swirl flow suppressing portion are described with reference to Fig. 11. A rotary compressor 100g shown in Fig. 11 does not have components corresponding to the swirl flow generating portion (baffle plate 122) and the swirl flow suppressing portion (cover 22) in the rotary compressor 100 of the present embodiment. Except for these components, the configuration of the rotary compressor 100g is the same as that of the rotary compressor 100 of the present embodiment. That is, a first balance weight 18g and a second balance weight 19g are each fixed to a rotor 15g and rotate with the rotor 15g. The second balance weight 19g has a larger displacement area than the first balance weight 18g. Therefore, the swirl flow formed by the second balance weight 19g in a lower space 5g is stronger than that formed by the first balance weight 18g in an upper space 7g.

[0050] In this case, as indicated by a dashed line 140b in Fig. 12, a significant increase in pressure occurs in the opening of the flow path 17g on the lower space 5g side, on the basis of the theory described with reference to Fig. 10. As a result, as indicated by an arrow 138 in Fig. 11, the refrigerant is more likely to flow from the lower space 5g to the upper space 7g through the flow path 17g.

[0051] On the other hand, the oil separated by a centrifugal force in the upper space 7g reaches the inner wall of the closed casing 2g in the upper space 7g, and then returns to an oil reservoir 3g by its own weight through the flow path 17g. However, if the pressure in the opening of the flow path 17g on the lower space 5g side is excessively higher than that in the opening of the flow path 17g on the upper space 7g side, such a high pressure makes it difficult for the oil to return smoothly through the flow path 17g. That is, since the refrigerant travels from the lower space 5g to the upper space 7g mainly through the flow path 17g, the flow of the oil from the upper space 7g to the lower space 5g (indicated by a dashed arrow 139) is impeded. As a result, the oil is likely to accumulate near the inner wall of the closed casing 2g in the upper space 7g. The accumulated oil is again mixed with the refrigerant and discharged with the refrigerant outside the closed casing 2g.

[0052] In contrast, in the rotary compressor 100 of the present embodiment, the swirl flow in the upper space 7 is increased by the function of the swirl flow generating portion 21 while the swirl flow in the loser space 5 is suppressed by the function of the swirl flow suppressing portion 22. Therefore, as indicated by a solid line 140a in Fig. 12, the pressure in the opening of the flow path 17 on the upper space 7 side is higher than that in the opening of the flow path 17 on the lower space 5 side, or the difference between the pressure in the opening of the flow path 17 on the upper space 7 side and that in the opening of the flow path 17 on the lower space 5 side is relatively small.

[0053] Furthermore, as described with reference to Fig. 10, the pressure near the center of the rotor 15 decreases when the swirl flow is increased, while it increases when the swirl flow is suppressed. When the swirl flow generating portion 21 is provided in the upper space 7 and the swirl flow suppressing portion 22 is provided in the lower space 5, the pressure near the center of the rotor 15 becomes lower in the upper space 7 and higher in the lower space 5. As a result, the amount of refrigerant flowing from the lower space 5 to the upper space 7 through the communication passage 20 increases, and the refrigerant can be prevented from flowing from the upper space 7 to the lower space 5 through the flow path 17, or the amount of refrigerant flowing from the lower space 5 to the upper space 7 through the flow path 17 decreases significantly. When the amount of refrigerant flowing from the compression mechanism 4 to the discharge pipe 8 through the flow path 17 decreases, the oil can be returned from the upper space 7 to the oil reservoir 3 smoothly through the flow path 17.

[0054] Next, consideration is given to a second moment of area.

[0055] Generally, the intensity of a swirl flow applied to a flow field is determined by a swirl momentum Kr represented by the following equation (3). In Equation (3), p is the density of a fluid, V is the rotational speed of a rotor, ω is the angular velocity of the rotor, r is the turning radius of a displacement portion (displacement surface) of the rotor, and A is the projected area of the displacement portion (displacement surface) of the rotor.

[0056] [Equation 3]

$$Kr = \rho V^2 A = \rho (r\omega)^2 A \quad \cdot\cdot\cdot \quad (3)$$

[0057] In Equation (3), assuming that the rotational speed V of the rotor is far below 0.3 times the sound velocity in a refrigerant flow, the refrigerant can be regarded as an incompressible fluid. In this case, the density p is constant. Furthermore, the angular velocity ω also is constant under the same operating conditions. As a result, the swirl momentum Kr that contributes to the intensity of the swirl flow applied to the flow field is proportional to a value obtained by multiplying the square of the turning radius r by the projected area A. The value obtained by multiplying the square of the turning radius r by the projected area A corresponds to the second moment of area described above. That is, the second moment of area represents the intensity of swirling applied to the refrigerant flow. The smaller the second moment of area, the smaller the intensity of swirling given to the refrigerant flow. Therefore, when a strong swirl flow must be generated in the upper space 7, the second moments of area of the first balance weight 18 and the swirl flow generating portion 21 must be increased. When a swirl flow in the lower space 5 must be suppressed, the second moment of area of the second balance weight 19 must be decreased using the swirl flow suppressing portion 22.

[0058] Next, the effect obtained by covering the outlet of the communication passage 20 with the baffle plate 122 (discharge direction deflecting portion) of the swirl flow generating portion 21 is described.

[0059] First, an example where nothing but a balance weight 18g is provided on the top of a rotor 15g (in the compressor 100g shown in Fig. 11), as shown in Fig. 13A and Fig. 13B, is described. In Fig. 13B, the rotational direction of the rotor 15g is considered as a static system. Probably, a refrigerant flow 42g discharged from a communication passage 20g to an upper space 7g collides with a refrigerant flow 41g in the upper space 7g at an almost right angle. In this case, a large pressure loss may occur. When a large pressure loss occurs at the outlet of the communication passage 20g, the flow rate of the refrigerant flowing upward through the communication passage 20g decreases relatively, while the flow rate of the refrigerant flowing through the air gap 16g or the flow path 17g increases relatively. As described above, when the refrigerant flow rate in the flow path 17g increases, the amount of oil discharged from the compressor 100g also increases.

[0060] Next, an example where baffle plates 21g are disposed at the outlets of the communication passages 20g, as shown in Fig. 14A and Fig. 14B, is described. Each of the baffle plates 21g is located in the rotational direction of the rotor 15g with respect to the outlet of the communication passage 20g. The baffle plate 21g extends straight in a direction parallel to the rotational axis O, and thus does not cover the outlet of the communication passage 20g. Such a baffle plate 21g can prevent the refrigerant flow 42g from colliding with the refrigerant flow 41g at a right angle. This means that the pressure loss at the outlet of the communication passage 20 can be reduced. It should be noted that the baffle plate 21g has no ability to deflect the refrigerant flow. Therefore, as shown in Fig. 17, the refrigerant tends to flow upward in the vertical direction.

[0061] Next, the present embodiment in which baffle plates 122 are disposed to cover the outlets of the communication passages 20, as shown in Fig. 15A and Fig. 15B, is described. Since a refrigerant flow 42 discharged from the communication passage 20 to the upper space 7 is subjected to the deflecting action of the baffle plate 122, the refrigerant is discharged in the opposite rotational direction of the rotor 15. That is, the refrigerant travels from the communication passages 20 to the upper space 7, while being deflected in a direction inclined with respect to the direction parallel to the rotational axis O. Then, as shown in Fig. 16, a swirl flow begins to be formed at a position relatively close to the upper surface of the rotor 15. As a result, the flow distance (time) of the refrigerant in the upper space 7 increases, which can promote the centrifugal separation of oil.

[0062] The baffle plate 122 may completely cover the outlet of the communication passage 20 in plan view, or may partially cover it. That is, a projected image obtained by projecting the baffle plate 122 onto the upper surface of the rotor 15 may contain the opening area of the communication passage 20, or the projected image of the baffle plate 122 may overlap the opening area. For example, experimental results under high load conditions (a high rotational speed and a high pressure ratio) show that an excellent effect is obtained when the baffle plate 122 covers about 85% of the opening area.

[0063] Fig. 18 is a graph showing the results of experiments conducted to ascertain the effect of the rotary compressor 100 of the present embodiment. The vertical axis represents the amount of discharged oil. The experiments were conducted under high load conditions, and the amount of oil discharged with the refrigerant through the discharge pipe was measured. The amount of the discharged oil was evaluated by sampling the refrigerant at the outlet of a condenser in a refrigeration cycle. "Embodiment" shows the measurement result in the rotary compressor described with reference to Fig. 1, etc. "Comparative Example" shows the measurement result in a rotary compressor in which the swirl flow generating portion 21 and the swirl flow suppressing portion 22 (cover) of the rotary compressor of the embodiment are removed. "First Modification" shows the measurement result in a rotary compressor according to a first modification described later. The amount of oil discharged from the rotary compressor of the present embodiment was small, i.e., "0.44", when the amount of oil discharged from the rotary compressor of Comparative Example was "1". The amount of oil discharged from the rotary compressor of the first modification described later was even smaller, i.e., "0.1".

(First Modification)

[0064] As shown in Fig. 19, in a rotary compressor 101 according to the first modification, the inlet of the discharge pipe 8 is located near the upper surface of the rotor 15. More specifically, the lower end of the discharge pipe 8 is located below the upper end of the stator 14 in the direction parallel to the rotational axis O of the shaft 9 (i.e., the vertical direction). The rotational axis O of the shaft 9 passes through the inlet of the discharge pipe 8. More specifically, the rotational axis O of the shaft 9 coincides with the center of the inlet of the discharge pipe 8.

[0065] A refrigerant is discharged from the communication passage 20 to the upper space 7, and then travels, while swirling and being deflected, toward the inner wall of the closed casing 2 by the centrifugal force and the action of the baffle plates 122. Then, the refrigerant goes downward along the outer peripheral surface of the discharge pipe 8 while swirling and enters the discharge pipe 8. Since the flow distance (time) of the refrigerant flow in the upper space 7 can be increased, the separation of oil can further be promoted. Furthermore, since the refrigerant forms a downflow immediately before it enters the discharge pipe 8, the oil separation by the weight of the refrigerant itself also can be promoted. As a result, as shown in Fig. 18, the amount of discharged oil can further be reduced.

(Second Modification)

[0066] In a modification shown in Fig. 20, a space filling member 22b is used instead of the cover 22 as a swirl flow suppressing portion. The space filling member 22b has a smaller specific gravity than the second balance weight 19, and is provided along the rotational trajectory of the second balance weight 19. That is, the space filling member 22b is disposed symmetrically to the second balance weight 19 with respect to a plane including the rotational axis O, and fills the space along the trajectory of the second balance weight 19. The area of the displacement surface of the second balance weight 19 can be reduced by the space filling member 22b, like the cover 22 described with reference to Fig. 1, etc.

[0067] Preferably, the space filling member 22b is made of a material having voids into which the refrigerant containing oil particles can penetrate. Typically, the space filling member 22b can be made of a material having voids, such as foamed materials, metal fiber woven materials, and steel wool. Since these materials are relatively light in weight, the function of the second balance weight 19 as a balance weight is less likely to be impaired.

[0068] The shape of the space filling member 22b is not particularly limited as long as the area of the displacement surface of the second balance weight 19 can be reduced. In the modification shown in Fig. 20, the shape of the space filling member 22b is determined so that the area of the displacement surface of the second balance weight 19 is substantially zero. The area of the displacement surface of the space filling member 22b also is zero. That is, a combination of the second balance weight 19 and the space filling member 22b forms an annular shape.

[0069] The refrigerant flow around the second balance weight 19 contains oil particles. The space filling member 22b is fixed to the rotor 15, and rotates with the rotor 15. Therefore, a shear flow is formed between the space filling member 22b and the refrigerant flow. In the case where the space filling member 22b is made of a material having voids such as a foamed material, oil particles enter the foamed material due to turbulence in the refrigerant flow, etc. Thereby, the space filling member 22b serves as an oil mist trap.

[0070] As shown in Fig. 21, a discharge port 25 for discharging the refrigerant compressed in the compression mechanism 4 to the lower space 5 may be formed at a position where it overlaps the second balance weight 19 and the space filling member 22b, that is, a position where the discharge port 25 overlaps the rotational trajectory of the second balance weight 19, in the direction parallel to the rotational axis O (i.e., in the vertical direction). In still other words, when the discharge port 25, the second balance weight 19, and the space filling member 22b are projected on a plane perpendicular to the rotational axis O, the projected image of the discharge port 25 may overlap the projected image of the second balance weight 19 and/or the projected image of the space filling member 22b. In this configuration, the refrigerant discharged to the lower space 5 through the discharge port 25 can collide directly with the space filling member 22b. As a result, the amount of oil particles entering the voids in the space filling member 22b increase, and the oil separation effect of the space filling member 22b can be sufficiently obtained.

(Third Modification)

[0071] As shown in Fig. 22, a cover 22c as a swirl flow suppressing portion may be formed integrally with the end plate for clamping and fixing the stack of steel plates 28 constituting the rotor 15. Thereby, the number of components can be reduced. The cover 22c has an annular shape in plan view. In the cover 22c, a plurality of through-holes 44 are each formed at a position corresponding to the inlet of the communication passage 20. The refrigerant can move from the lower space 5 to the communication passages 20 through the through-holes 44 and the interior of the cover 22c.

(Fourth Modification)

[0072] A swirl flow generating portion 146 shown in Fig. 23 has an end plate 27 and a first balance weight 18 integrated with the end plate 27. That is, the end plate 27 and the first balance weight 18 are formed as a single component by a casting method or the like. This can reduce the number of components and simplify the assembly process of the compressor.

[0073] The end plate 27 is caulked and fixed to the stack of steel plates 28 to form the rotor 15. The communication passages 20 of the rotor 15 are covered by roof portions 46 provided on the end plate 27. The roof portion 46 constitutes a discharge direction deflecting portion. One roof portion 46 is provided for one communication passage 20. The roof portion 46 has walls above the outlet of the communication passage 20, downstream thereof in the rotational direction of the rotor 15, on the radially inner peripheral side, and on the radially outer peripheral side. In other words, the roof portion 46 has the shape of a small box with an opening only in the opposite rotational direction of the rotor 15. The refrigerant is discharged from the communication passage 20 in the opposite rotational direction of the rotor 15 by the function of the roof portions 46.

(Fifth Modification)

[0074] As shown in Fig. 24A, in the present modification, an outlet part 48 of the communication passage 20 extends in a direction inclined with respect to the direction parallel to the rotational axis O of the motor 6. By the function of the outlet part 48, the compressed refrigerant travels from the communication passage 20 to the upper space 7, while being deflected in a direction that is opposite to the rotational direction of the rotor 15 and is inclined with respect to the direction parallel to the rotational axis O. That is, the discharge direction deflecting portion is constituted by the outlet part 48. Also in this modification, a refrigerant flow 42 from the communication passage 20 does not collide with a refrigerant flow 41 at a right angle in the upper space 7. Therefore, an increase in the pressure loss at the outlet of the communication passage 20 can be prevented.

[0075] Fig. 24A does not indicate a swirl flow generating portion for increasing a swirl flow. However, the swirl flow generating portion (for example, the baffle plate 122 shown in Fig. 3) may be provided at a position where it does not cover the outlet of the communication passage 20.

(Sixth Modification)

[0076] In a modification shown in Fig. 24B, a baffle plate 122 protruding obliquely from the upper surface of the rotor 15 so as to extend in the same direction as the outlet part 48 is provided as a swirl flow generating portion. An image obtained by projecting the baffle plate 122 onto the upper surface of the rotor 15 overlaps the outlet of the communication passage 20. This means that in this modification, both the outlet part 48 and the baffle plate 122 have the function as a discharge direction deflecting portion. This configuration ensures that a refrigerant flow from the communication passage 20 is directed toward the opposite rotational direction of the rotor 15. This configuration has the potential to further reduce the pressure loss that occurs when the refrigerant flow 42 is deflected.

[0077] The configurations of the first to sixth modifications can be arbitrarily combined in the rotary compressor 100 shown in Fig. 1, without departing from the spirit and scope of the present invention. Furthermore, the present invention is not limited to a rotary compressor, and can be applied to other hermetic compressors.

INDUSTRIAL APPLICABILITY

[0078] The hermetic compressor of the present invention is suitably applicable to refrigeration cycle apparatuses used for air conditioners, water heaters, etc. Since the flow of oil into a condenser and an evaporator of a refrigeration cycle apparatus can be reduced, the heat exchange efficiency of the condenser and the evaporator can be improved.

Claims

1. A hermetic compressor comprising:

   a closed casing having an oil reservoir in its bottom portion;
   a compression mechanism, disposed in the closed casing, for compressing a working fluid;
   a motor, disposed above the compression mechanism in the closed casing, for driving the compression mechanism, the motor having a rotor and a stator;
   an upper space, formed above the motor, as a part of an internal space of the closed casing;
   a lower space, formed between the motor and the compression mechanism, as a part of the internal space of the closed casing;
   a discharge pipe opening into the upper space, for discharging the compressed working fluid outside the hermetic compressor;
   a first balance weight protruding from an upper surface of the rotor toward the upper space;
   a swirl flow generating portion protruding from the upper surface of the rotor toward the upper space, the swirl flow generating portion being disposed at a position closer to a rotational axis of the motor than the first balance weight;
   a second balance weight protruding from a lower surface of the rotor toward the lower space; and
   a communication passage formed in the rotor so as to introduce, into the upper space, the working fluid compressed in the compression mechanism and discharged to the lower space, wherein
   when a three-dimensional annular trajectory of the first balance weight formed around the rotational axis when the motor is driven is defined as a first trajectory, a plane obtained by cutting the first trajectory with a first plane parallel to the rotational axis and including the rotational axis is defined as a first cross section, a three-dimensional annular trajectory of the second balance weight formed around the rotational axis when the motor is driven is defined as a second trajectory, a plane obtained by cutting the second trajectory with a second plane parallel to the rotational axis and including the rotational axis is defined as a second cross section, a three-dimensional annular trajectory of the swirl flow generating portion formed around the rotational axis when the motor is driven is defined as a third trajectory a plane obtained by cutting the third trajectory with a third plane parallel to the rotational axis and including the rotational axis is defined as a third cross section, an area of a micro-region included in a specific region on an arbitrary plane parallel to the rotational axis and including the rotational axis is defined as dA, a distance from the rotational axis to a centroid of the micro-region is defined as r, and a value M_A represented by the following equation (1) is defined as a second moment of area, [Equation 1]

   $$M_A = \int_A r^2 dA \cdots (1)$$

   a sum of a second moment of area of the first cross section and a second moment of area of the third cross section is greater than a second moment of area of the second cross section, and
   the hermetic compressor further comprises a discharge direction deflecting portion for causing the compressed working fluid to travel from the communication passage to the upper space, while deflecting the working fluid in a direction inclined with respect to a direction parallel to the rotational axis.

2. The hermetic compressor according to claim 1, wherein the swirl flow generating portion is also used as the discharge direction deflecting portion.

3. The hermetic compressor according to claim 1 or 2, wherein the discharge direction deflecting portion is configured to direct the compressed working fluid in a direction opposite to a rotational direction of the rotor.

4. The hermetic compressor according to claim 2, wherein the swirl flow generating portion includes, as the discharge direction deflecting portion, a baffle plate protruding from the upper surface of the rotor toward the upper space, and an image obtained by projecting the baffle plate onto the upper surface of the rotor overlaps an outlet of the communication passage.

5. The hermetic compressor according to claim 1, wherein an outlet part of the communication passage extends in the direction inclined with respect to the direction parallel to the rotational axis so that the compressed working fluid travels from the communication passage to the upper space, while being deflected in a direction that is opposite to a rotational direction of the rotor and is inclined with respect to the direction parallel to the rotational axis, and the discharge direction deflecting portion is constituted by the outlet part.

6. The hermetic compressor according to claim 5, wherein the swirl flow generating portion includes a baffle plate protruding obliquely from the upper surface of the rotor so as to extend in the same direction as the outlet part, and an image obtained by projecting the baffle plate onto the upper surface of the rotor overlaps an outlet of the communication passage.

7. The hermetic compressor according to any one of claims 1 to 6, further comprising a swirl flow suppressing portion for reducing an area of a displacement surface of the second balance weight, the displacement surface displacing the working fluid.

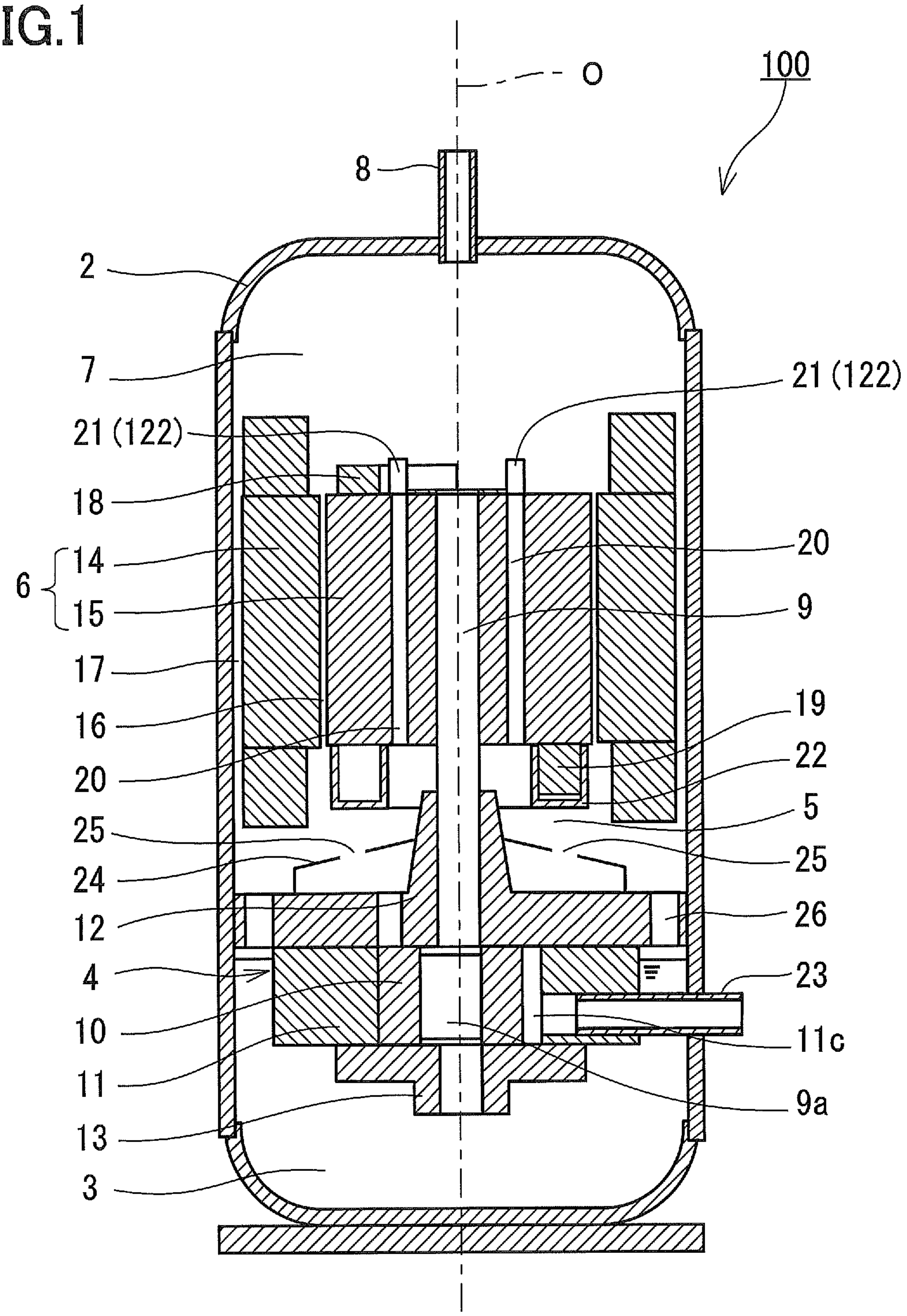
8. The hermetic compressor according to claim 7, wherein the swirl flow suppressing portion is constituted by a cover that covers the second balance weight so that the area of the displacement surface of the second balance weight is zero, the displacement surface displacing the working fluid.

9. The hermetic compressor according to claim 8, wherein the cover is formed integrally with an end plate for clamping and fixing constituent elements of the rotor.

10. The hermetic compressor according to claim 7, wherein the swirl flow suppressing portion is provided along a rotational trajectory of the second balance weight, and the swirl flow suppressing portion has a smaller specific gravity than the second balance weight.

11. The hermetic compressor according to claim 10, wherein the swirl flow suppressing portion is made of a material having voids into which the working fluid containing oil particles can penetrate.

FIG.1


O
100
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7
21 (122)
21 (122)
18
6
14
15
17
16
20
25
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4
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11
13
3
20
9
19
22
5
25
26
23
11c
9a

FIG.2

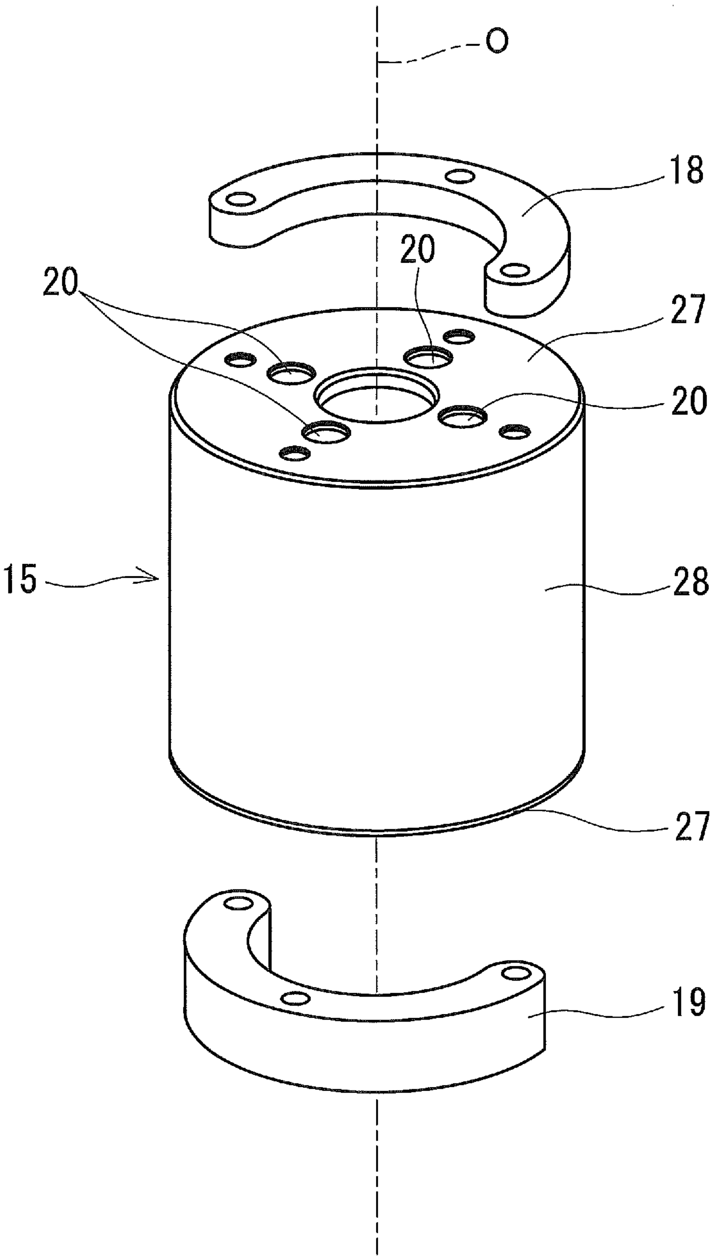


FIG.3

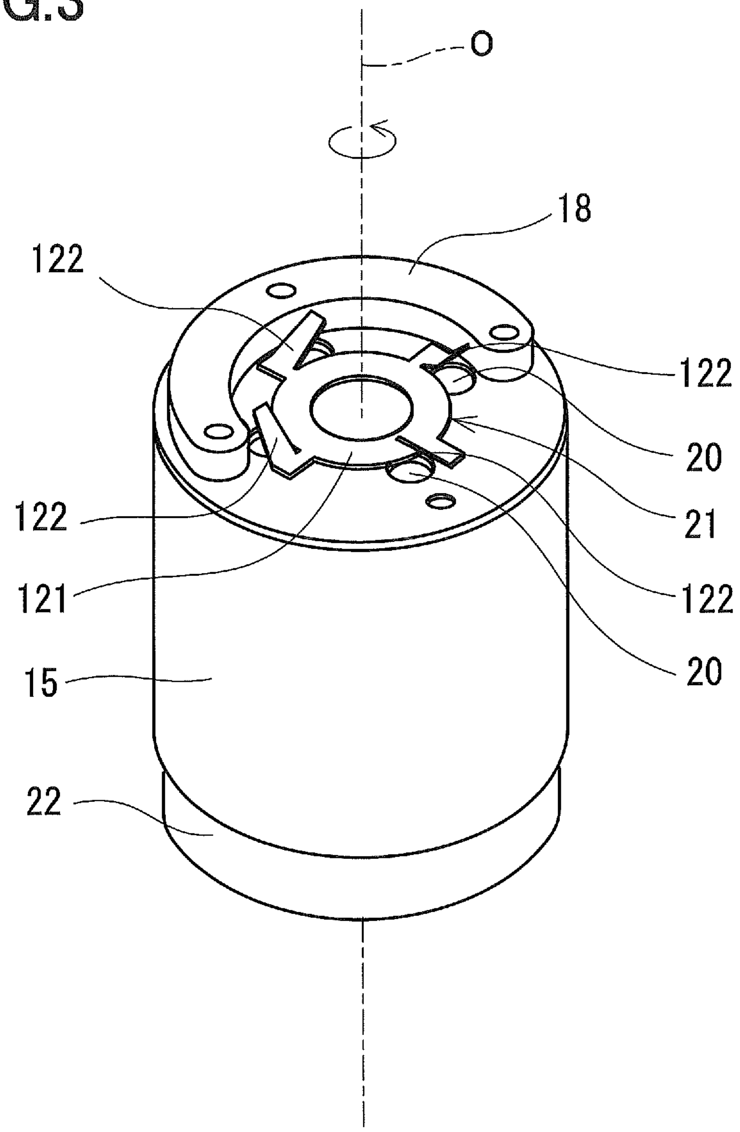


FIG.4

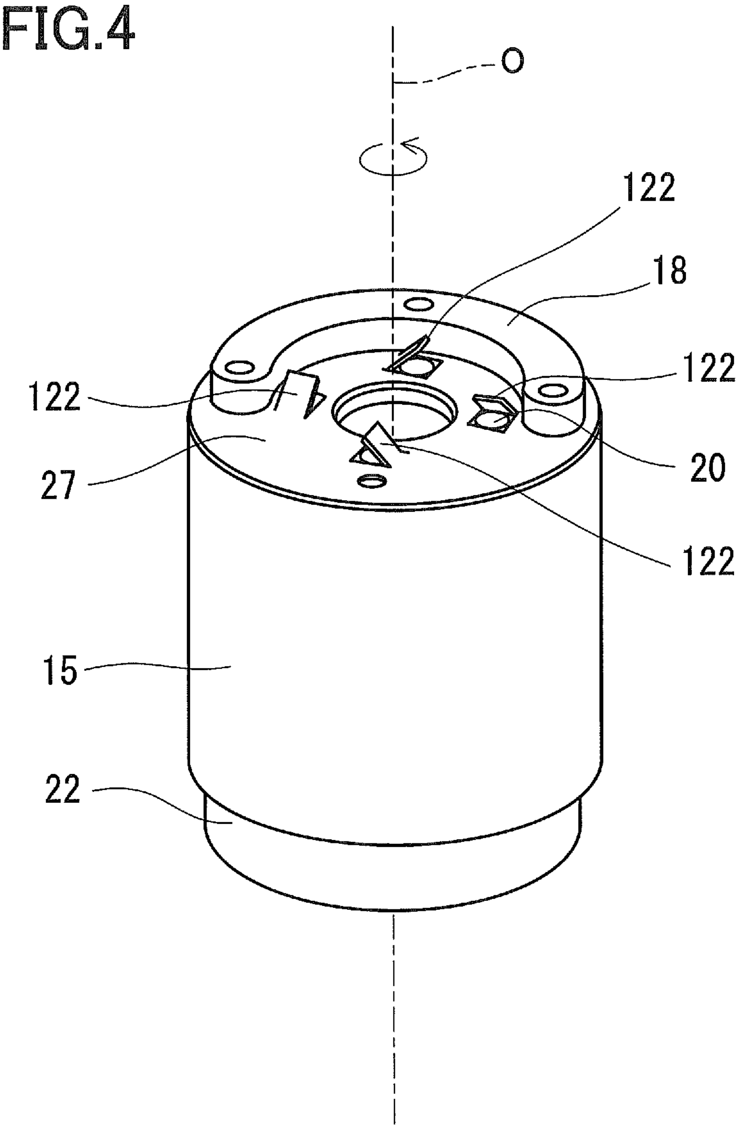


FIG.5

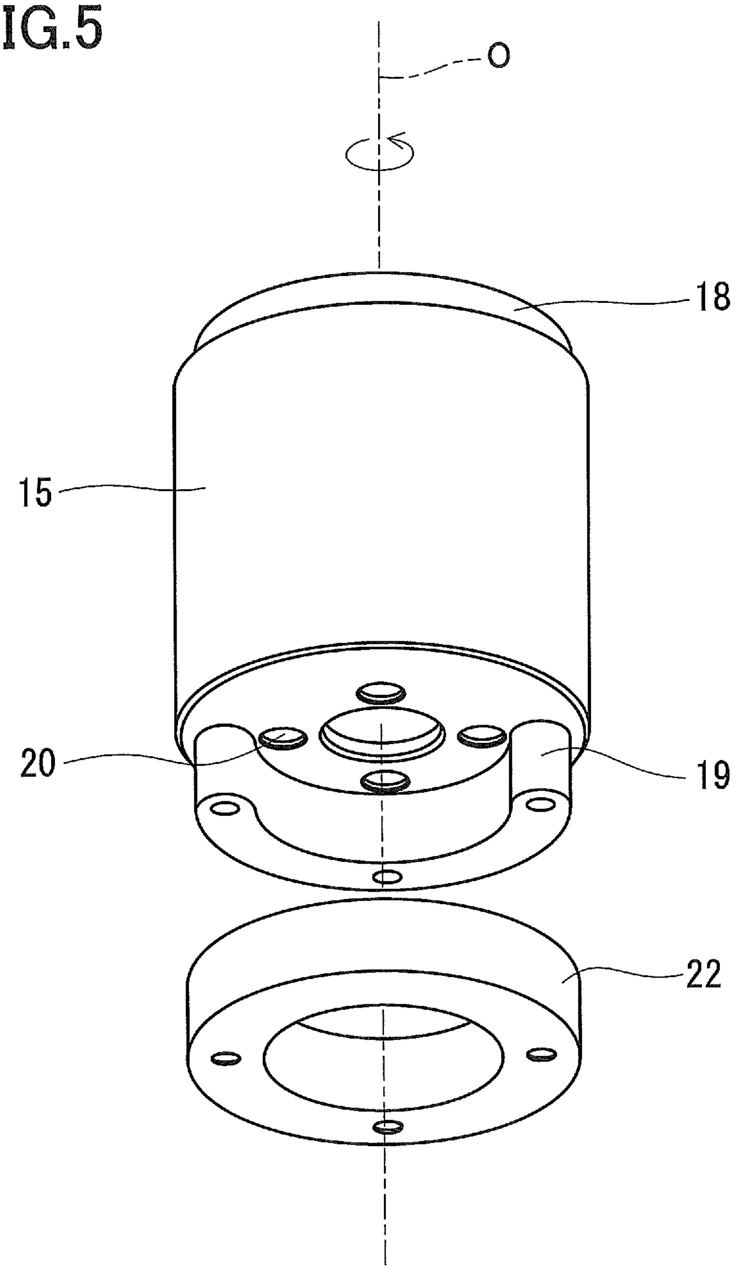


FIG.6A

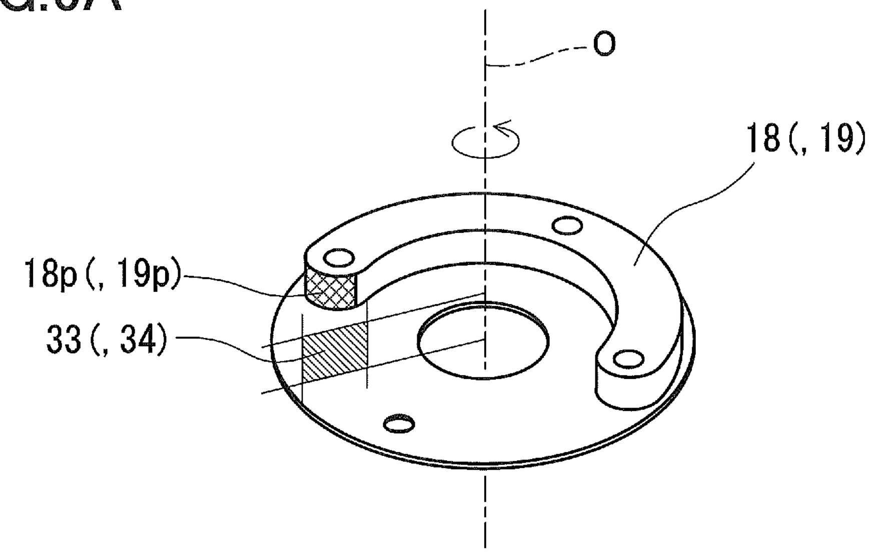


FIG.6B

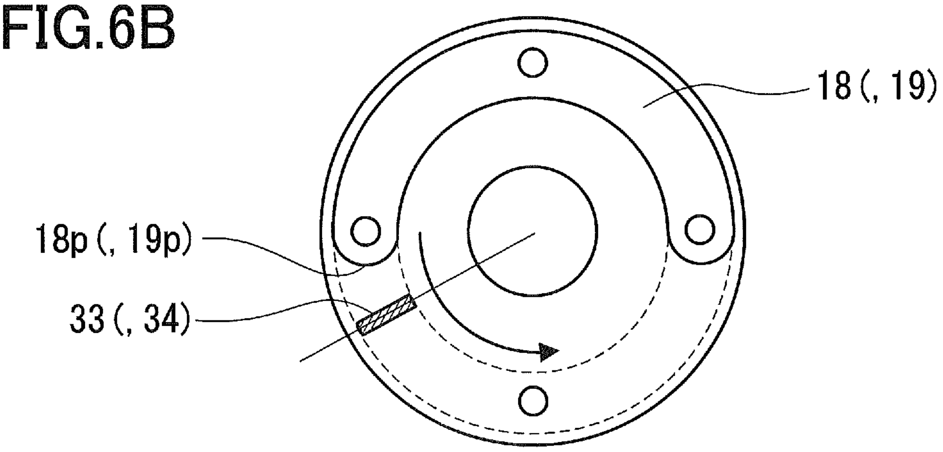
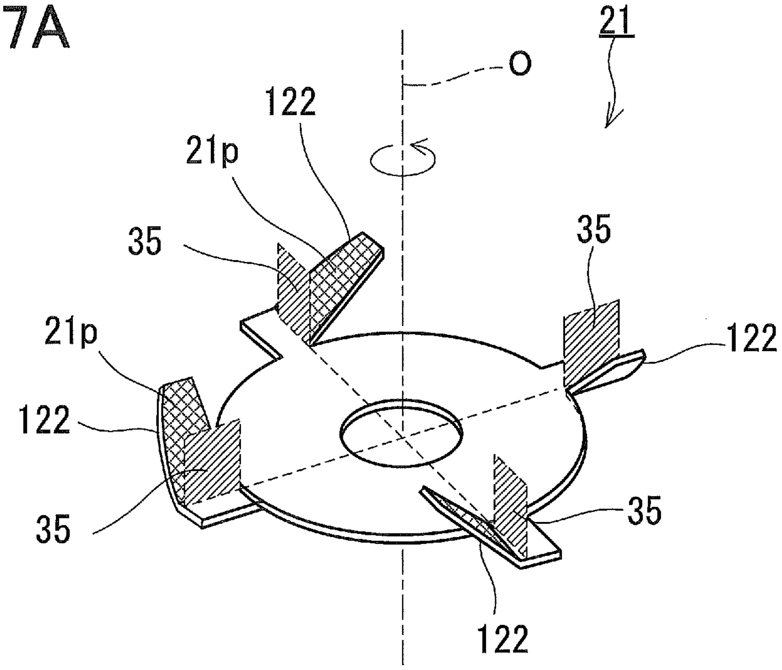


FIG.7A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21p
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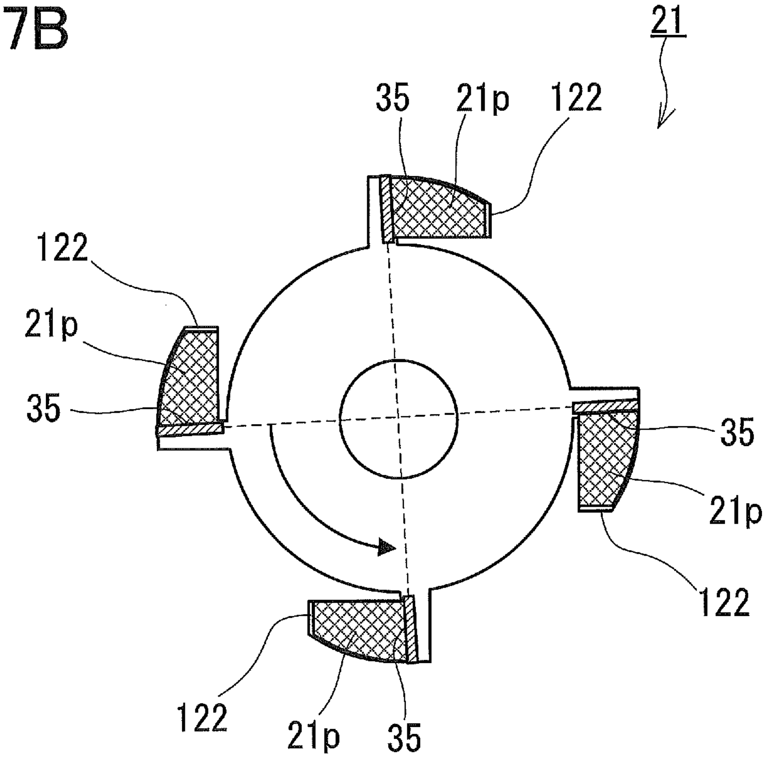
35
122

FIG.7B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21p
35

FIG.8

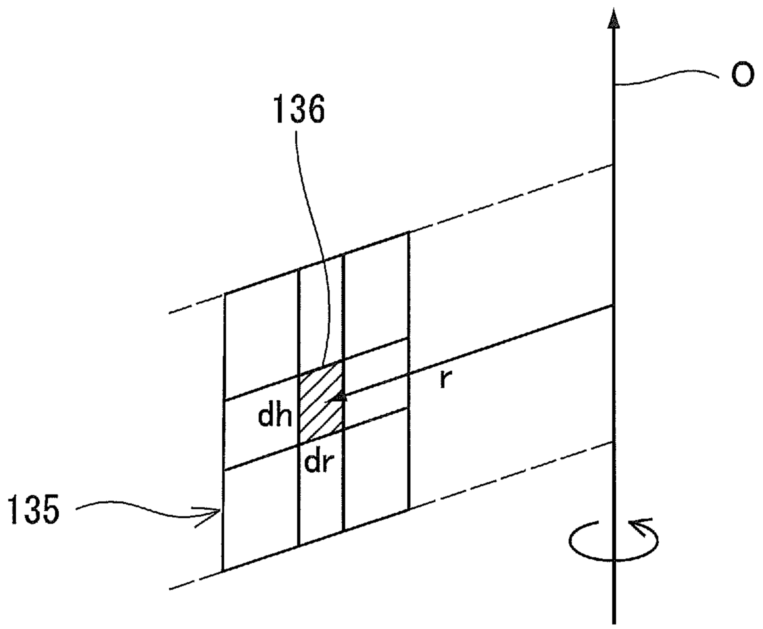
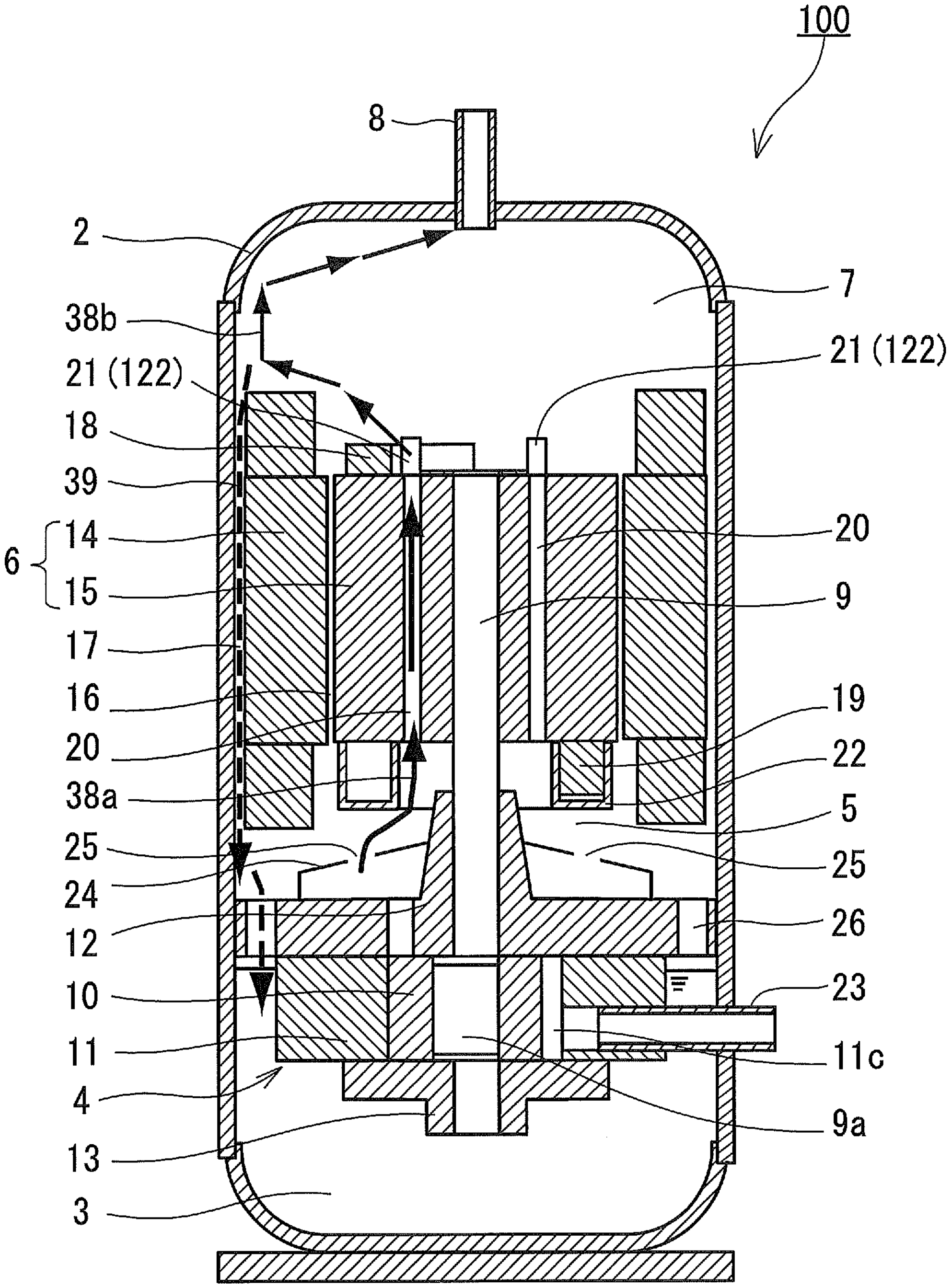


FIG.9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9a
13
3

FIG.10

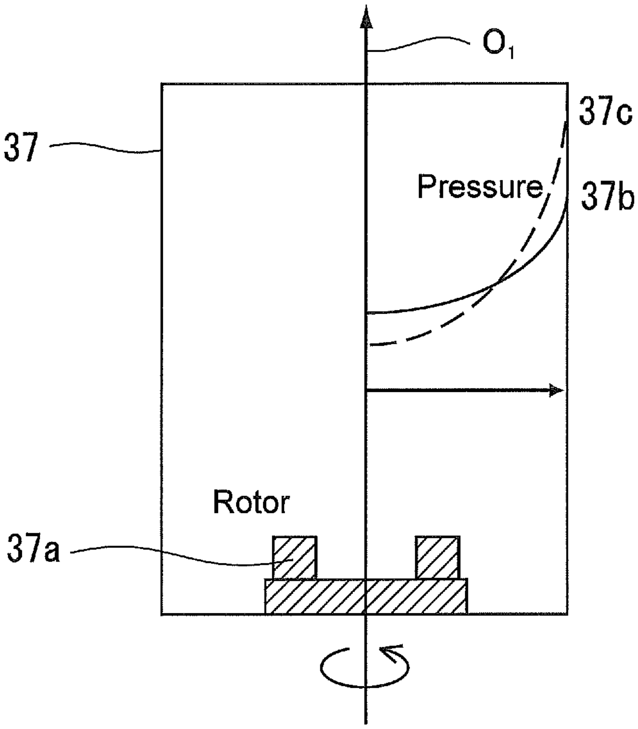


FIG.11

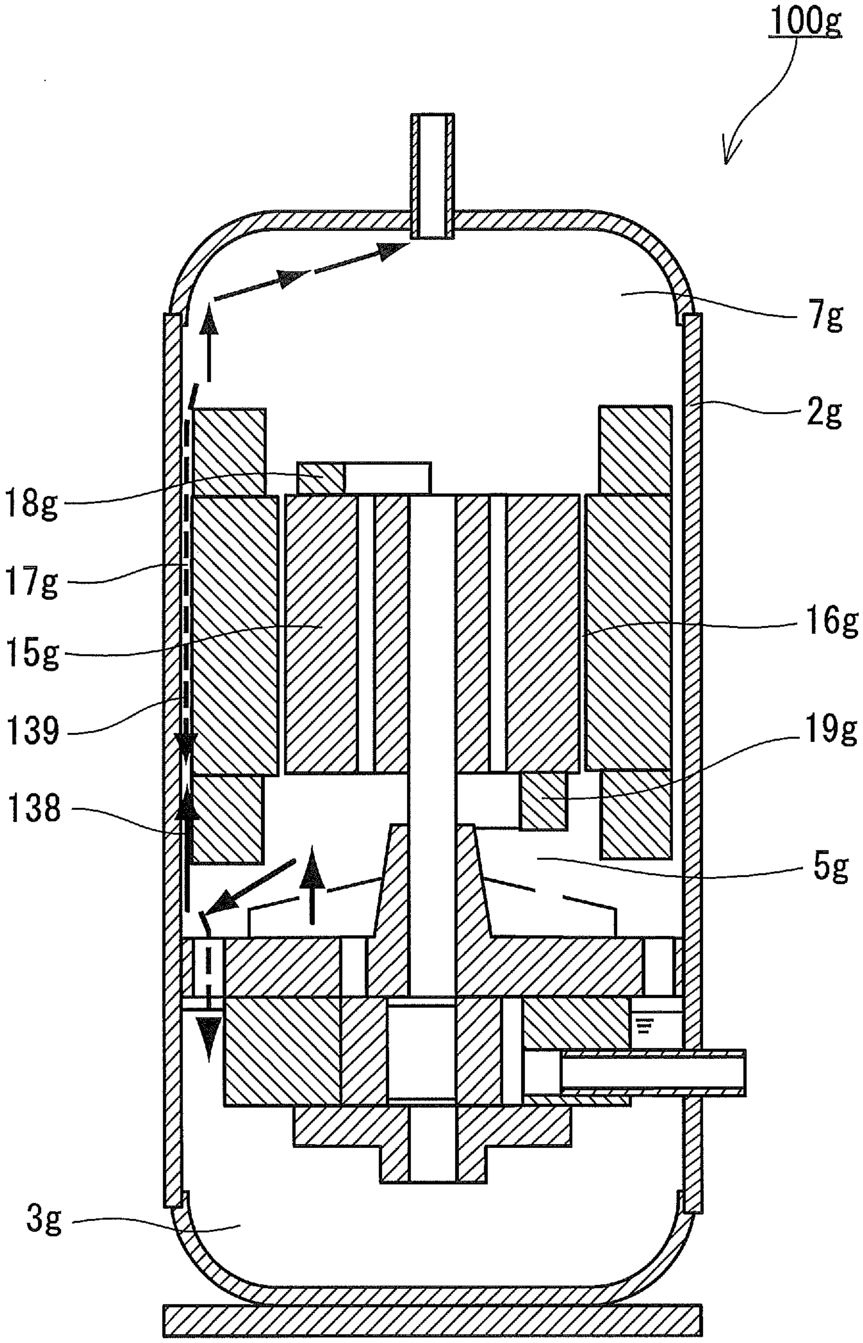


FIG.12

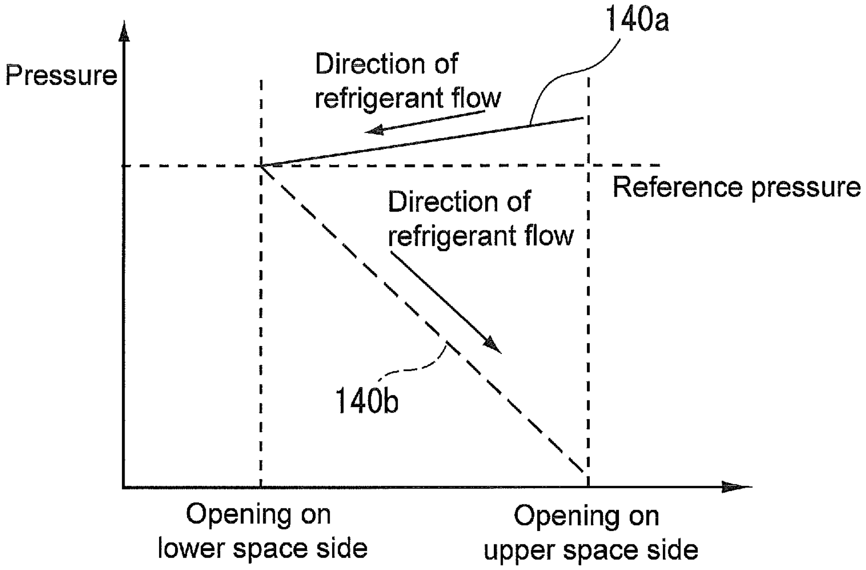


FIG.13A

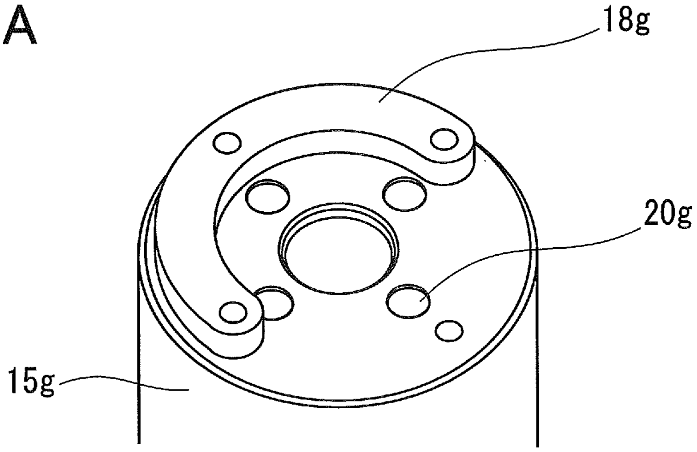


FIG.13B

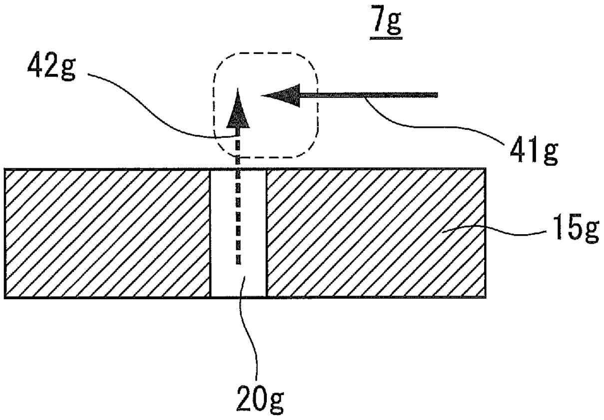


FIG.14A

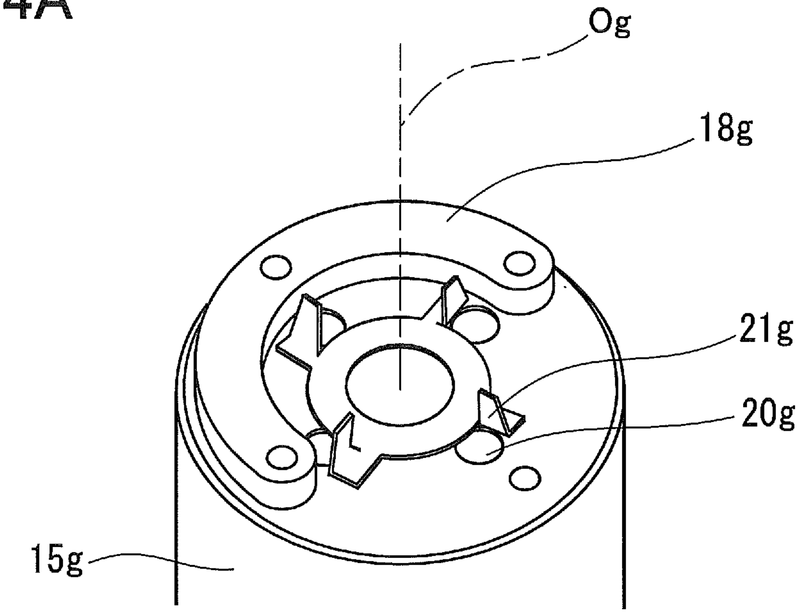


FIG.14B

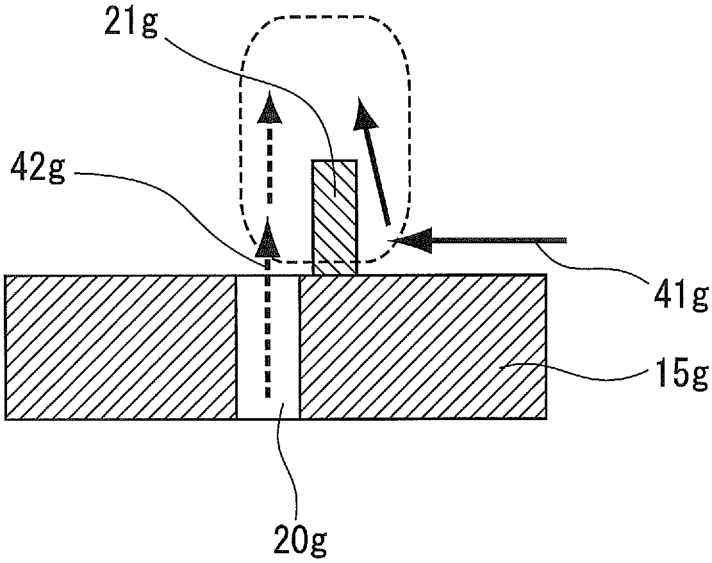


FIG.15A

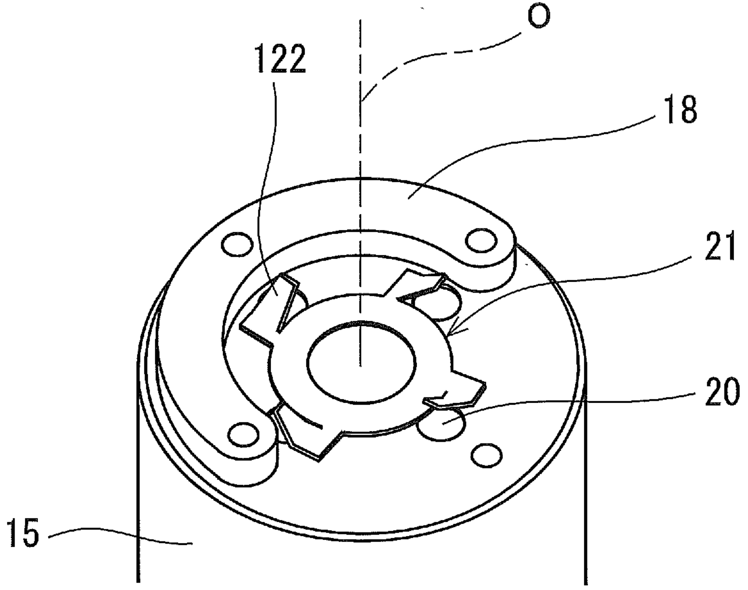


FIG.15B

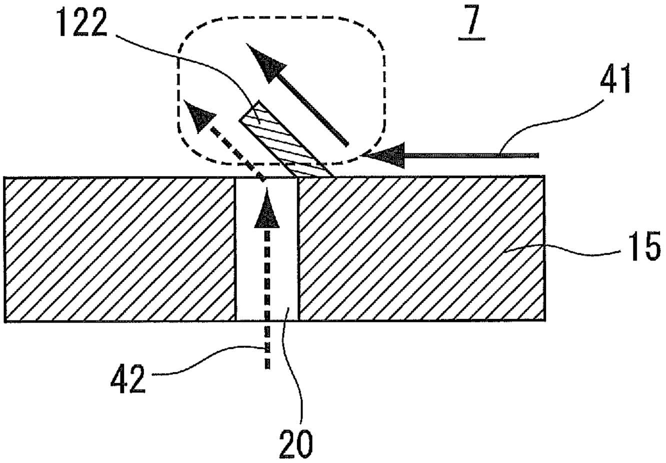
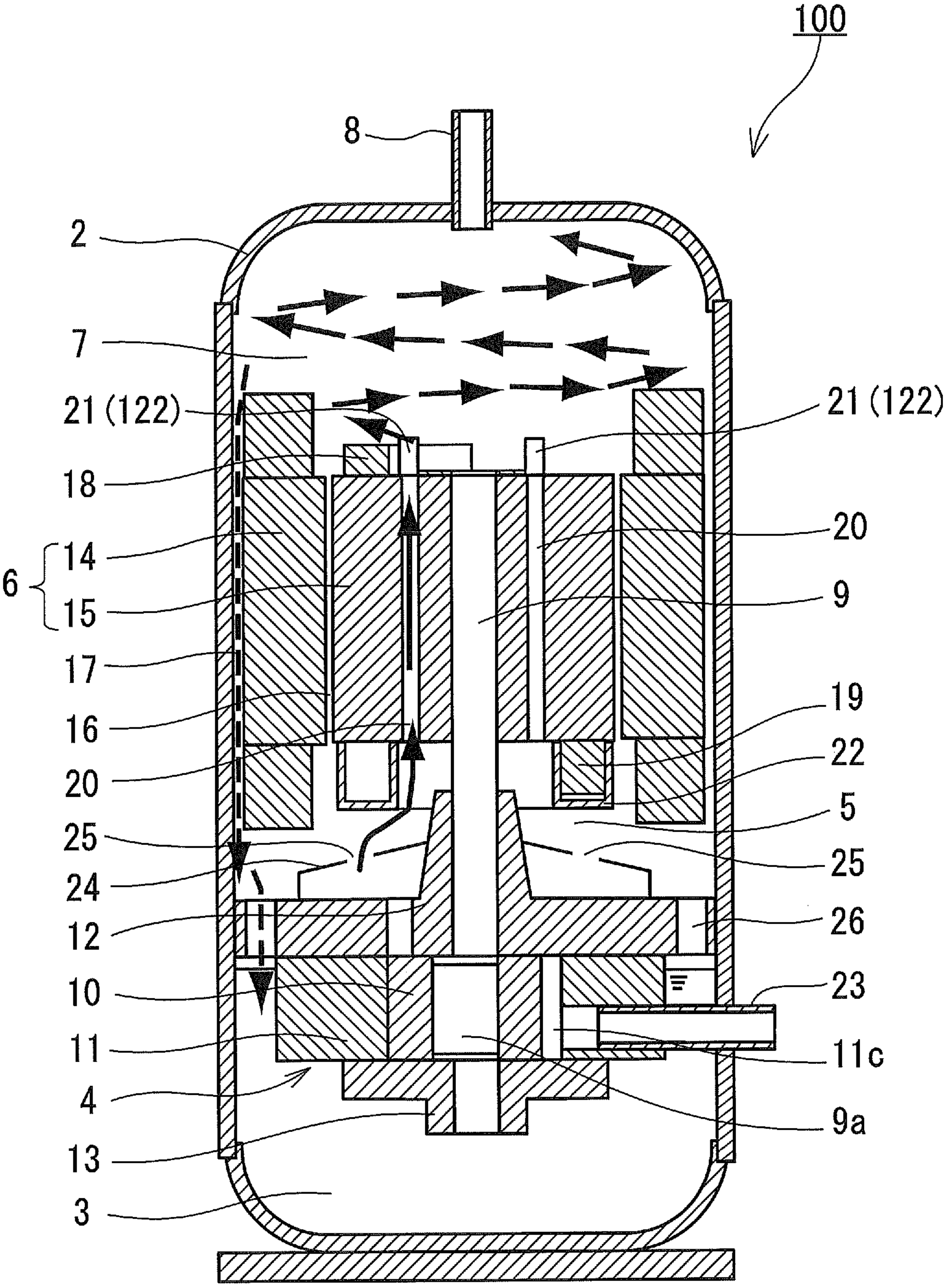


FIG.16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21 (122)
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26
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11c
9a

FIG.17

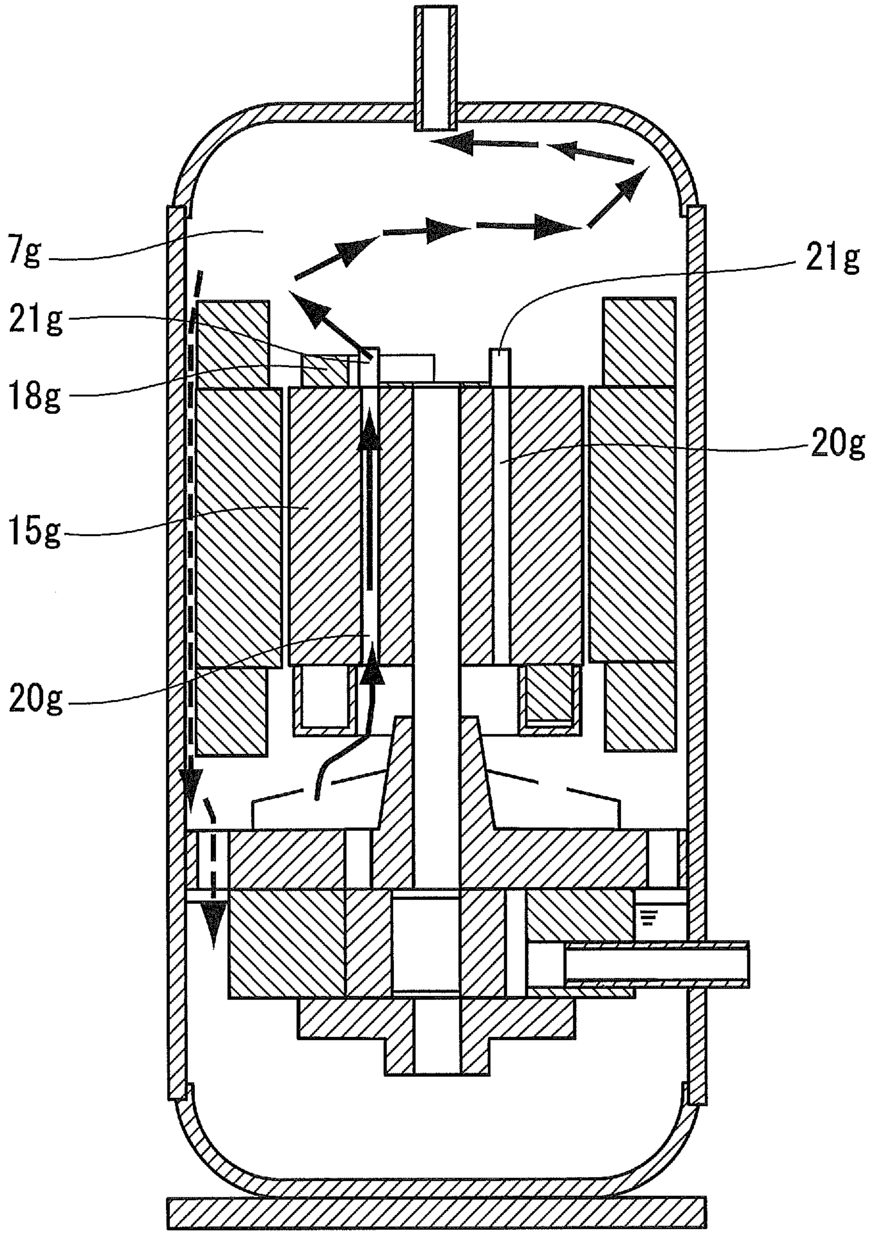

FIG.18


Amount of discharged oil
1.0
0.44
0.1
Comparative Example
Embodiment
First Modification

FIG.19

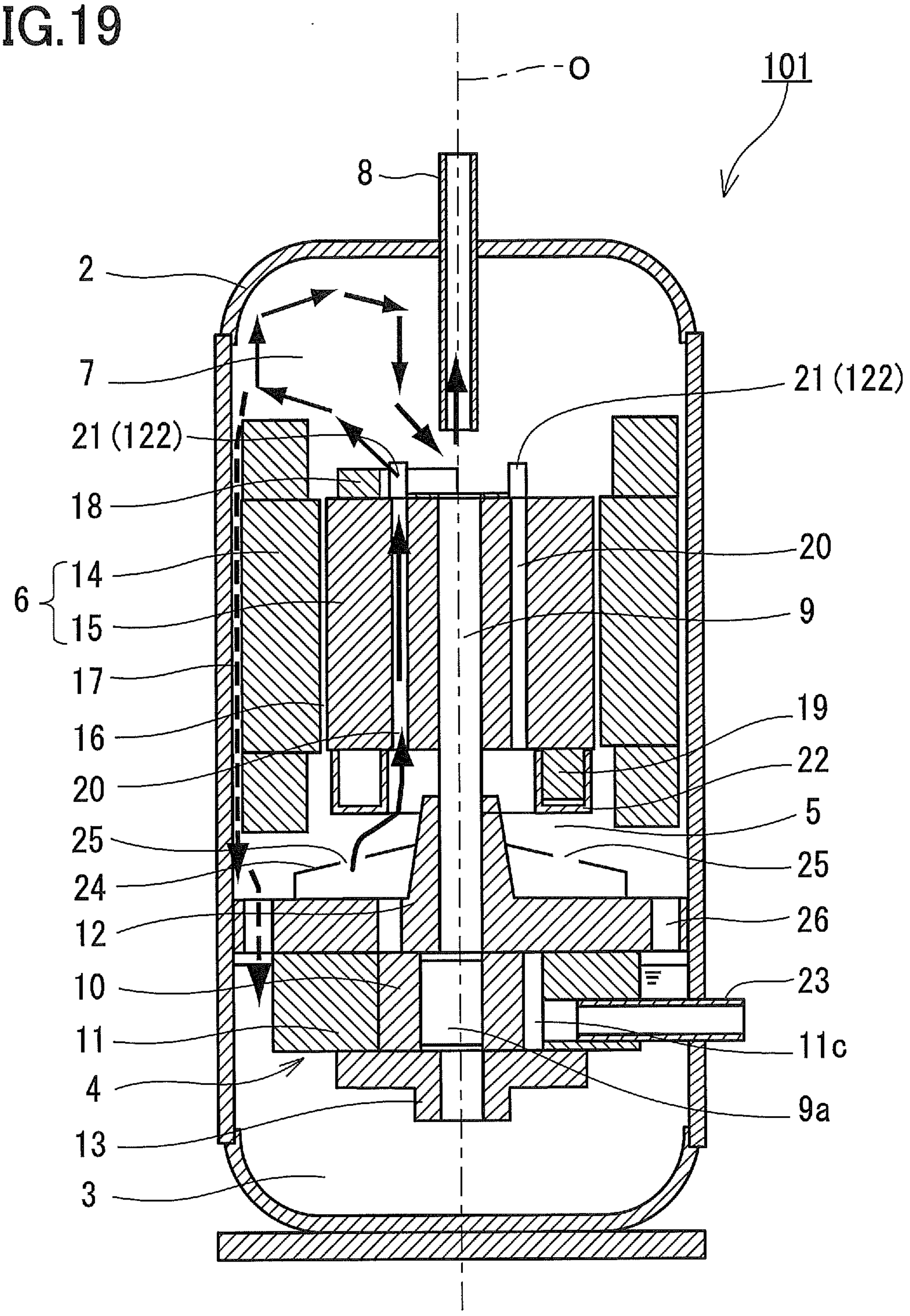
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FIG.20

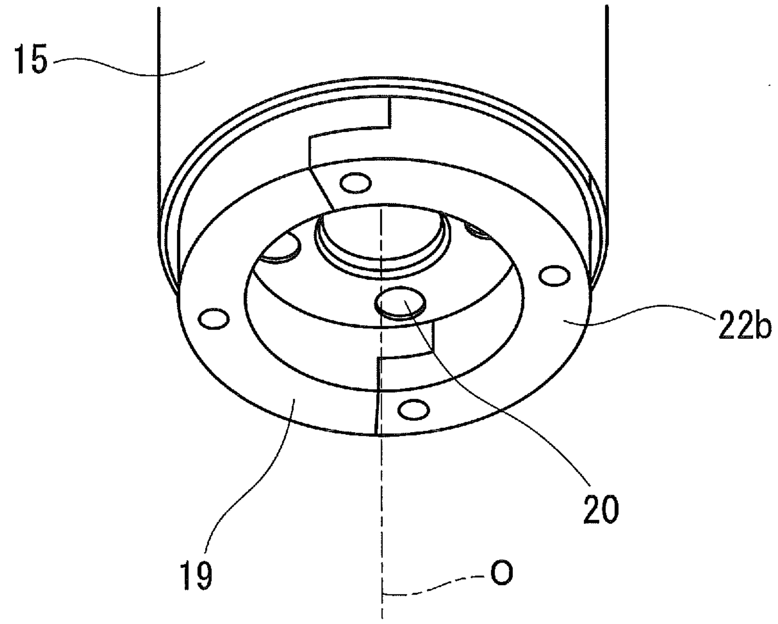

FIG.21

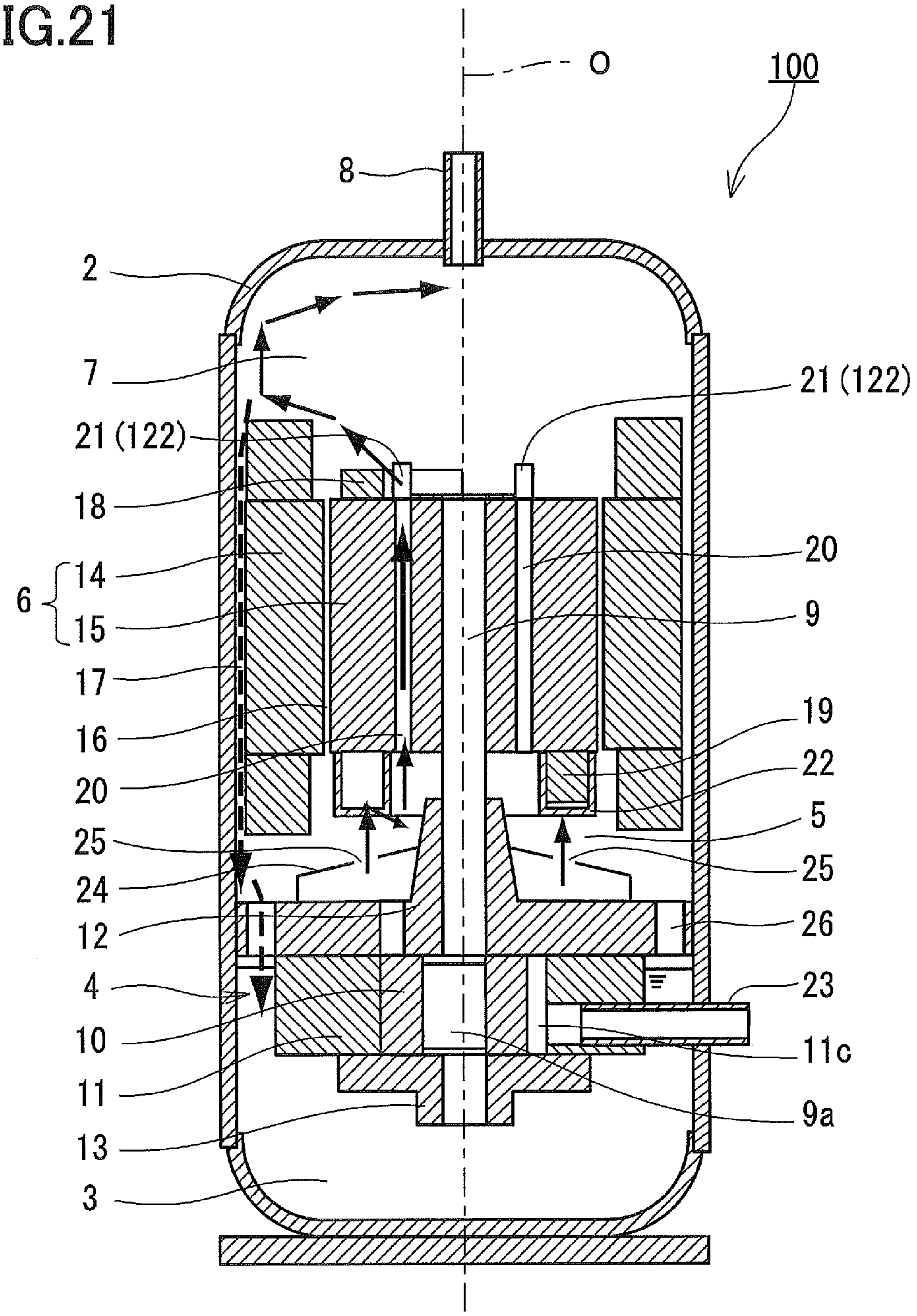
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FIG.22

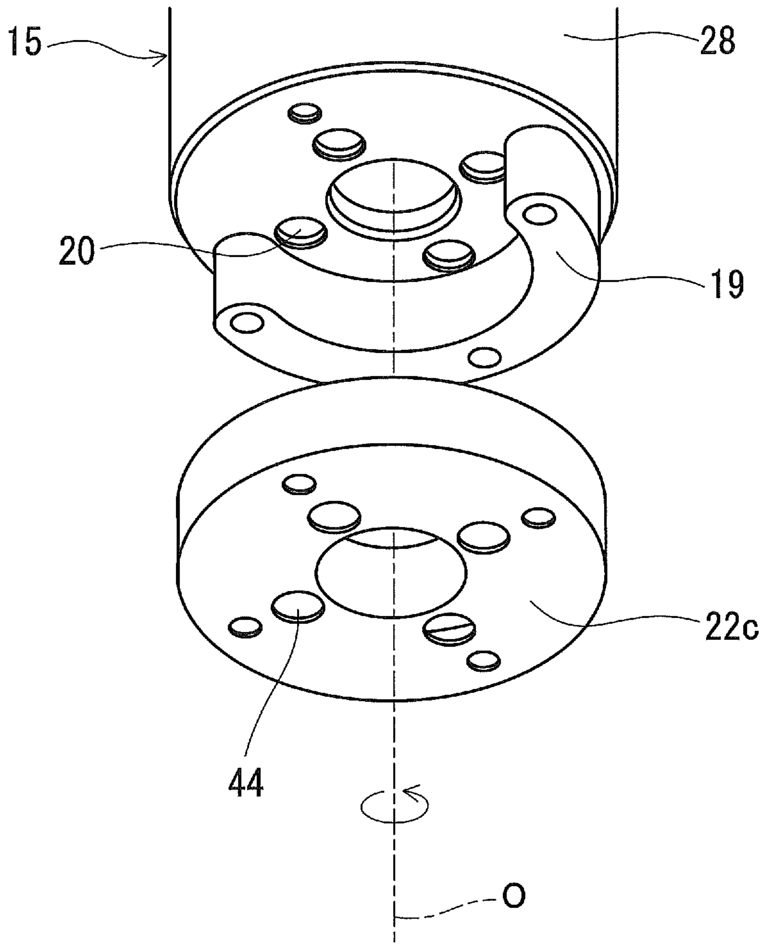


FIG.23

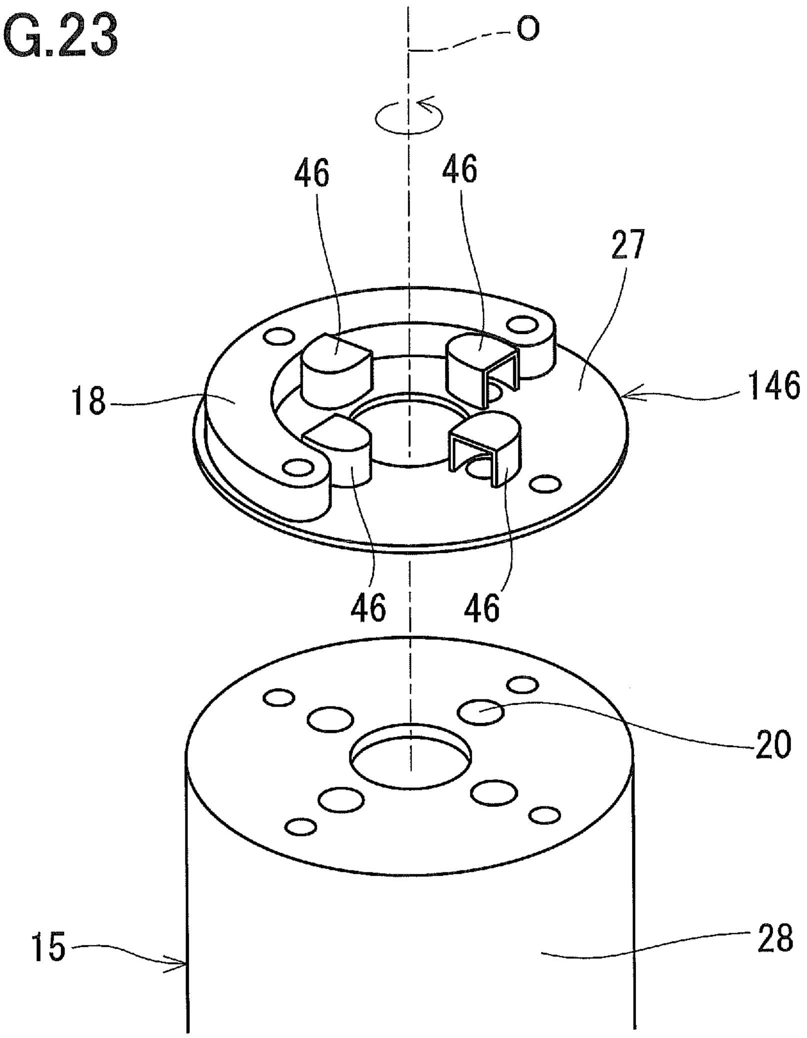


FIG.24A

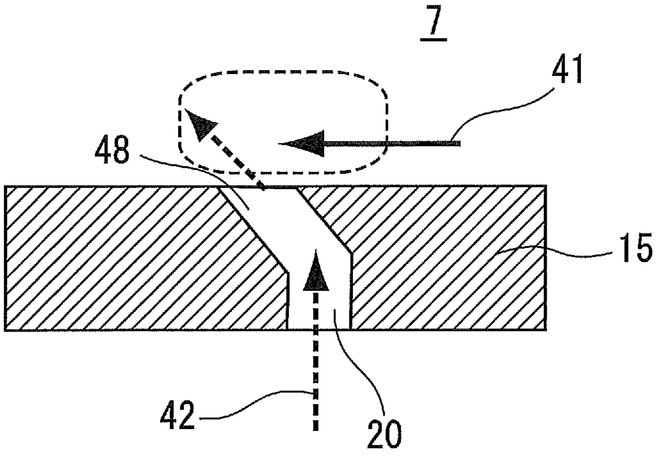


FIG.24B

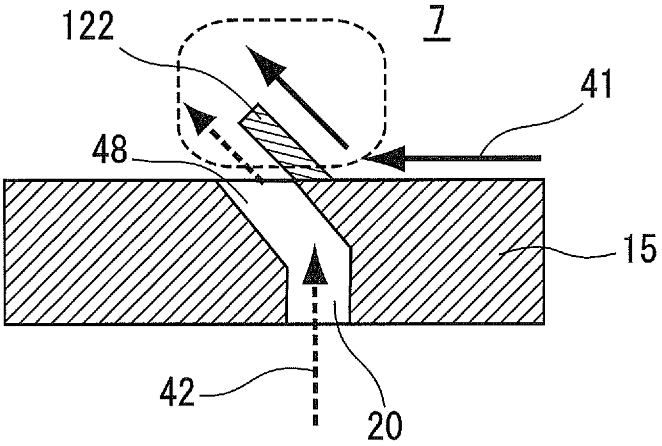


FIG.25

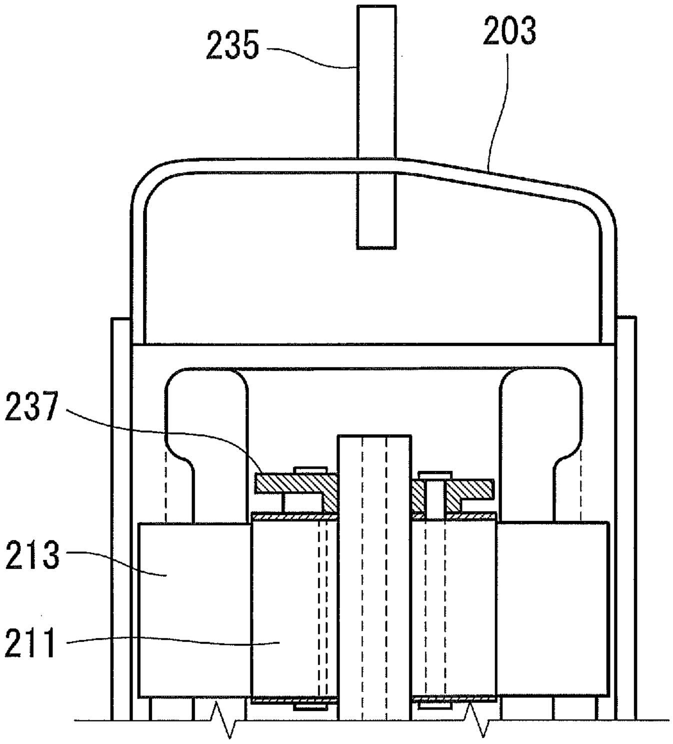


FIG.26A

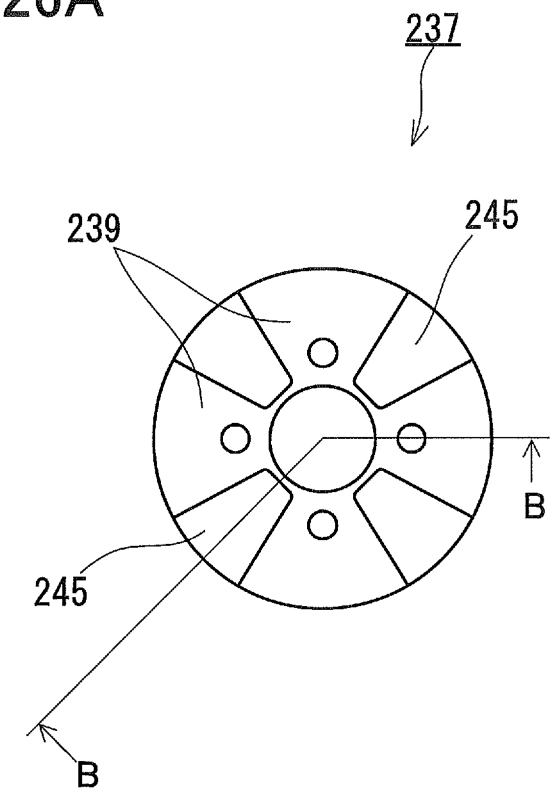
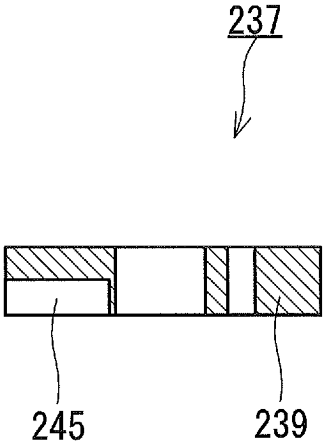


FIG.26B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/004543

A. CLASSIFICATION OF SUBJECT MATTER
F04B39/04(2006.01)i, *F04C29/02*(2006.01)i

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)
F04B39/04, F04C29/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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 A	JP 2005-351122 A (Matsushita Electric Industrial Co., Ltd.), 22 December 2005 (22.12.2005), paragraphs [0019] to [0022]; fig. 1 to 5 (Family: none)	1,2,7-9 3-6,10,11
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 180061/1983(Laid-open No. 88095/1985) (Hitachi, Ltd.), 17 June 1985 (17.06.1985), fig. 1 to 2 (Family: none)	1,2,7-9 3-6,10,11

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

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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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

Date of the actual completion of the international search 08 September, 2011 (08.09.11)	Date of mailing of the international search report 20 September, 2011 (20.09.11)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/004543

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 73425/1971(Laid-open No. 30407/1973) (Tokyo Shibaura Electric Co., Ltd.), 13 April 1973 (13.04.1973), fig. 2 to 3 (Family: none)	1,2,7-11
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 158185/1983(Laid-open No. 66890/1985) (Mitsubishi Heavy Industries, Ltd.), 11 May 1985 (11.05.1985), specification, page 4, line 19 to page 5, line 3; fig. 4 to 6 (Family: none)	1,2,7,10,11 3-6,8,9
A	JP 2002-327693 A (Mitsubishi Electric Corp.), 15 November 2002 (15.11.2002), fig. 9 (Family: none)	1-11
A	JP 2010-114953 A (Daikin Industries, Ltd.), 20 May 2010 (20.05.2010), fig. 7 (Family: none)	1-11
A	JP 62-168976 A (Hitachi, Ltd.), 25 July 1987 (25.07.1987), specification, page 2, upper right column, lines 10 to 13; all drawings (Family: none)	1-11
A	JP 63-215893 A (Matsushita Electric Industrial Co., Ltd.), 08 September 1988 (08.09.1988), fig. 1 to 2 (Family: none)	1-11
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 157137/1987(Laid-open No. 61486/1989) (Mitsubishi Electric Corp.), 19 April 1989 (19.04.1989), fig. 1 to 2 (Family: none)	3,4,6
P,A	JP 2010-261393 A (Toshiba Carrier Corp.), 18 November 2010 (18.11.2010), fig. 1 to 2, 10 (Family: none)	3,4,6

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 11107967 A **[0006]**
- JP 2009144581 A **[0006]**