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

(11) EP 4 177 465 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
22.01.2025 Bulletin 2025/04

(21) Application number: **22205764.8**

(22) Date of filing: **07.11.2022**

(51) International Patent Classification (IPC):
F04B 37/14 *(2006.01)* ***F04B 53/08*** *(2006.01)*
F04C 25/02 *(2006.01)* ***F04C 29/04*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04B 37/14; F04B 53/08; F04C 25/02; F04C 29/04

(54) VACUUM PUMP APPARATUS

VAKUUMPUMPENVORRICHTUNG

APPAREIL DE POMPE À VIDE

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

(30) Priority: **09.11.2021 JP 2021182249**

(43) Date of publication of application:
10.05.2023 Bulletin 2023/19

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Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a vacuum pump apparatus, and more particularly to a vacuum pump apparatus suitable for use in exhausting a process gas used in manufacturing of semiconductor devices, liquid crystals, LEDs, solar cells, or the like.

Description of the Related Art:

[0002] In process of manufacturing semiconductor devices, liquid crystal panels, LEDs, solar cells, etc., a process gas is introduced into a process chamber to perform a certain type of process, such as etching process or CVD process. The process gas that has been introduced into the process chamber is exhausted by a vacuum pump apparatus. Generally, the vacuum pump apparatus used in these manufacturing processes that require high cleanliness is so-called dry vacuum pump apparatus that does not use oil in gas flow passages. One typical example of such a dry vacuum pump apparatus is a positive-displacement vacuum pump apparatus having a pair of pump rotors in a rotor chamber which are rotated in opposite directions to deliver the gas.

[0003] The process gas may contain by-product having high sublimation temperature. When a temperature in the rotor chamber of the vacuum pump apparatus is low, the by-product may be solidified in the rotor chamber and may be deposited on the pump rotors and an inner surface of a pump casing. The solidified by-product may prevent the rotation of the pump rotors, causing the pump rotors to slow down and, in the worst case, causing shutdown of the vacuum pump apparatus. Therefore, in order to prevent solidification of the by-product, a heater is provided on an outer surface of the pump casing to heat the rotor chamber.

[0004] On the other hand, it is necessary to cool an electric motor that drives the pump rotors and gears that are fixed to rotation shafts of the pump rotors. Therefore, the vacuum pump apparatus described above usually includes a cooling system for cooling the electric motor and the gears. The cooling system is configured to cool the electric motor and the gears by, for example, circulating a cooling liquid through a cooling pipe provided in a motor housing accommodating the electric motor and a cooling pipe provided in a gear housing accommodating the gears. Such a cooling system can prevent overheating of the electric motor and the gears and can therefore achieve stable operation of the vacuum pump apparatus.

[0005] Examples of such vacuum pumps are shown in e.g. in JP 2003 035290 A, and JP 2021 063 503 A. Furthermore, WO 2020 255 300 A1 discloses a vacuum pump according to the preamble of claim 1.

[0006] The heater attached to the pump casing in the Japanese documents is sandwiched between side covers. Therefore, when the heater is to be replaced due to the end of its service life, etc., the vacuum pump apparatus should be disassembled, and as a result, the heater cannot be easily replaced.

SUMMARY OF THE INVENTION

[0007] Therefore, the present invention provides a vacuum pump apparatus capable of maintaining a high temperature in a rotor chamber of a pump casing and capable of allowing a heater to be easily attached and removed. In accordance with the invention, a vacuum pump apparatus as set forth in the claims is provided.

[0008] In an embodiment, there is provided a vacuum pump apparatus comprising: a pump casing having a rotor chamber therein; a pump rotor arranged in the rotor chamber; a rotation shaft to which the pump rotor is fixed; an electric motor coupled to the rotation shaft; a side cover forming an end surface of the rotor chamber; a housing structure located outwardly of the side cover in an axial direction of the rotation shaft; and a cartridge heater disposed in the side cover or in the pump casing and removably attached to the side cover or the pump casing, wherein the cartridge heater has a heater and a heater casing covering at least a part of the heater, and the heater casing has a slit extending from one end to other end thereof.

[0009] In an embodiment, the heater casing is made of a material having a higher coefficient of linear expansion than that of a material constituting an outer shell of the heater.

[0010] In an embodiment, the heater casing is made of one of aluminum alloy, aluminum, copper, and magnesium.

[0011] In an embodiment, the side cover or the pump casing has a hole which is open in an outer surface of the side cover or the pump casing, the hole extending linearly, and the cartridge heater has a rod shape and is arranged in the hole.

[0012] In an embodiment, the vacuum pump apparatus further comprises: a fixing mechanism configured to removably fix the cartridge heater to the side cover or the pump casing.

[0013] According to the present invention, an inside of the rotor chamber can be maintained at a high temperature by attaching the cartridge heater in the side cover or in the pump casing.

[0014] The slit formed in the heater casing can absorb thermal expansion of the heater and the heater casing. As a result, deformation of the cartridge heater due to deformation of the heater over time can be prevented, and the cartridge heater can be easily removed from the side cover or the pump casing.

[0015] The heater casing is made of a material having a higher coefficient of linear expansion than that of a material constituting the outer shell of the heater, so that a gap between the side cover or the pump casing and the heater can be filled by thermal expansion of the heater casing. Therefore, heat can be efficiently transferred from the cartridge heater to the side cover or the pump casing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a cross-sectional view showing an embodiment of a vacuum pump apparatus;
FIG. 2 is a side view of a side cover according to the embodiment shown in FIG. 1;
FIG. 3 is a cross-sectional view taken along a line A-A of FIG. 2;
FIG. 4 is a perspective view of a cartridge heater;
FIG.5 is a cross-sectional view taken along a line B-B of FIG. 4;
FIG.6 is an enlarged cross-sectional view of the cartridge heater inserted into a hole;
FIG.7 is an enlarged cross-sectional view of the cartridge heater during heating;
FIG. 8 is a cross-sectional view showing another embodiment of the vacuum pump apparatus;
FIG. 9 is a cross-sectional view taken along a line C-C of FIG. 8;
FIG. 10 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus;
FIG. 11 is a side view of a side cover according to the embodiment shown in FIG. 10;
FIG. 12 is a diagram as viewed from a direction indicated by an arrow D in FIG. 11; and
FIG. 13 is a perspective view of the side cover shown in FIG. 11.

DESCRIPTION OF EMBODIMENTS

[0017] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[0018] FIG. 1 is a cross-sectional view showing an embodiment of a vacuum pump apparatus. The vacuum pump apparatus of the embodiment described below is a positive-displacement vacuum pump apparatus. In particular, the vacuum pump apparatus shown in FIG. 1 is a so-called dry vacuum pump apparatus that does not use oil in its flow passages for a gas. Since a vaporized oil does not flow to an upstream side, the dry vacuum pump apparatus can be suitably used for a semiconductor-device manufacturing apparatus that requires high cleanliness.

[0019] As shown in FIG. 1, the vacuum pump apparatus includes a pump casing 2 having a rotor chamber 1 therein, pump rotors 5 arranged in the rotor chamber 1, rotation shafts 7 to which the pump rotors 5 are fixed, and electric motor 8 coupled to the rotation shafts 7. Each pump rotor 5 and each rotation shaft 7 may be an integral structure. Although only one pump rotor 5 and only one rotation shaft 7 are depicted in FIG. 1, a pair of pump rotors 5 are arranged in the rotor chamber 1, and are secured to a pair of rotation shafts 7, respectively. The electric motor 8 is coupled to one of the pair of rotation shafts 7. In one embodiment, a pair of electric motors 8 may be coupled to the pair of rotation shafts 7, respectively.

[0020] The pump rotors 5 of the present embodiment are Roots-type pump rotors, while the type of the pump rotors 5 is not limited to the present embodiment. In one embodiment, the pump rotors 5 may be screw-type pump rotors. Further, although the pump rotors 5 of the present embodiment are single-stage pump rotors, in one embodiment the pump rotors 5 may be multistage pump rotors.

[0021] The vacuum pump apparatus further includes side covers 10A and 10B located outwardly of the pump casing 2 in an axial direction of the rotation shafts 7. The side covers 10A and 10B are provided on both sides of the pump casing 2 and are coupled to the pump casing 2. In the present embodiment, the side covers 10A and 10B are fixed to end surfaces of the pump casing 2 by not-shown screws.

[0022] The rotor chamber 1 is formed by an inner surface of the pump casing 2 and inner surfaces of the side covers 10A and 10B. The pump casing 2 has an intake port 2a and an exhaust port 2b. The intake port 2a is coupled to a chamber (not shown) filled with gas to be delivered. In one example, the intake port 2a may be coupled to a process chamber of a semiconductor-device manufacturing apparatus, and the vacuum pump apparatus may be used for exhausting a process gas that has been introduced into the process chamber.

[0023] The vacuum pump apparatus further includes a motor housing 14 and a gear housing 16 which are housing structures located outwardly of the side covers 10A and 10B in the axial direction of the rotation shafts 7. The side cover 10A is located between the pump casing 2 and the motor housing 14, and the side cover 10B is located between the pump casing 2 and the gear housing 16.

[0024] Each rotation shaft 7 is rotatably supported by a bearing 17 held by the side cover 10A and a bearing 18 held by the side cover 10B. The motor housing 14 accommodates a motor rotor 8A and a motor stator 8B of the electric motor 8 therein. The motor housing 14 and the gear housing 16 are examples of the housing structure, and the housing structures are not limited to this embodiment. For example, the housing structure may be a bearing housing that holds a bearing.

[0025] Inside the gear housing 16, a pair of gears 20 that mesh with each other are arranged. In FIG. 1, only one gear 20 is depicted. The electric motor 8 is rotated by a not-shown motor driver, and one rotation shaft 7 to which the electric motor 8 is coupled rotates the other rotation shaft 7 to which the electric motor 8 is not coupled in an opposite direction via the gears 20.

[0026] In one embodiment, a pair of electric motors 8, which are coupled to the pair of rotation shafts 7, respectively, may be provided. The pair of electric motors 8 are synchronously rotated in opposite directions by a not-shown motor driver, so that the pair of rotation shafts 7 and the pair of pump rotors 5 are synchronously rotated in opposite directions. In this case, the role of the gears 20 is to prevent loss of the synchronous rotation of the pump rotors 5 due to a sudden external cause.

[0027] When the pump rotors 5 are rotated by the electric motor 8, a gas is sucked into the pump casing 2 through the intake port 2a. The gas is transferred from the intake port 2a to the exhaust port 2b by the rotating pump rotor 5.

[0028] A cooling channel 21 is provided in the motor housing 14. Similarly, a cooling channel 22 is provided in the gear housing 16. The cooling channel 21 extends through an entire circumferential wall of the motor housing 14, and the cooling channel 22 extends through an entire circumferential wall of the gear housing 16. The cooling channel 21 and the cooling channel 22 are coupled to a not-shown cooling-liquid supply source. Cooling liquid is supplied from the cooling-liquid supply source to the cooling channel 21 and the cooling channel 22. The cooling liquid flowing through the cooling channel 21 cools the motor housing 14, so that the electric motor 8 and the bearings 17 arranged in the motor housing 14 can be cooled. The cooling liquid flowing through the cooling channel 22 cools the gear housing 16, so that the gears 20 and the bearings 18 arranged in the gear housing 16 can be cooled.

[0029] Some of the process gases to be handled by the vacuum pump apparatus include by-product that is solidified as the temperature decreases. During the operation of the vacuum pump apparatus, the process gas is compressed in the process of being transferred from the intake port 2a to the exhaust port 2b by the pump rotors 5. Therefore, an inside of the rotor chamber 1 becomes hot due to the heat of compression of the process gas. The side cover 10A is configured to reduce heat transfer from the pump casing 2 to the motor housing 14, and the side cover 10B is configured to reduce heat transfer from the pump casing 2 to the gear housing 16. Therefore, the side covers 10A and 10B can maintain the inside of the rotor chamber 1 at a high temperature. In particular, the side covers 10A and 10B can maintain the inside of the rotor chamber 1 at a high temperature while the motor housing 14 and the gear housing 16 is cooled with the cooling liquid flowing through the cooling channels 21 and 22.

[0030] In the present embodiment, the pump casing 2 and the side covers 10A and 10B forming the rotor chamber 1 are made of cast iron. In one embodiment, the side covers 10A and 10B may be made of a material having a lower thermal conductivity than that of the cast iron.

[0031] The vacuum pump apparatus further includes cartridge heaters 70A and 70B disposed in the side covers 10A and 10B, respectively. The cartridge heaters 70A and 70B are removably attached to the side covers 10A and 10B, respectively. Details of configurations of the cartridge heaters 70A and 70B will be described later.

[0032] Since the side covers 10A and 10B have basically the same configuration, and the cartridge heaters 70A and 70B have basically the same configuration, the side cover 10A and the cartridge heater 70A will be described below. FIG. 2 is a side view of the side cover 10A according to the embodiment shown in FIG. 1. FIG. 3 is a cross-sectional view taken along a line A-A of FIG. 2. The side cover 10A has through-holes 27 through which the rotation shafts 7 extend. The through-holes 27 communicate with the rotor chamber 1.

[0033] The side cover 10A has an inner wall portion 31 forming an end surface 31a of the rotor chamber 1, an outer wall portion 32 located outwardly of the inner wall portion 31 in the axial direction of the rotation shafts 7, and a plurality of spacers 34 sandwiched between the inner wall portion 31 and the outer wall portion 32. The inner wall portion 31 and the outer wall portion 32 are located away from each other by the spacers 34. The inner wall portion 31 is coupled to the pump casing 2 (see FIG. 1), and the outer wall portion 32 is coupled to the motor housing 14. The outer wall portion 32 has recesses (not shown) in which the bearings 17 are accommodated. A heat insulating material may be disposed between the outer wall portion 32 and the motor housing 14.

[0034] The inner wall portion 31 of the side cover 10A has holes 31b opened in an outer surface of the side cover 10A (more specifically, an outer surface of the inner wall portion 31). The holes 31b extend linearly. Each cartridge heater 70A has a rod shape extending linearly, and is arranged in each hole 31b. The vacuum pump apparatus of this embodiment allows the cartridge heaters 70A to be locally mounted by providing the holes 31b at desired positions where the cartridge heaters 70A are to be attached.

[0035] In this embodiment, two cartridge heaters 70A are arranged so as to sandwich the rotation shafts 7 (see FIG. 1). In one embodiment, only one cartridge heater 70A may be provided, or three or more cartridge heaters 70A may be provided. In this embodiment, the inner wall portion 31 and the outer wall portion 32 are separated, while in one embodiment, the inner wall portion 31 and the outer wall portion 32 may be integrally formed without providing the spacers 34. Further, in one embodiment, the hole 31b may be formed in an outer surface of an existing side cover of the vacuum pump apparatus, and the cartridge heater 70A may be inserted into the hole 31b.

[0036] With the cartridge heaters 70A inserted into the holes 31b, the cartridge heaters 70A are fixed to the side cover 10A by screws 45, respectively, which are fixing mechanisms. More specifically, the inner wall portion 31 of the side cover 10A has screw holes 46 communicating with the holes 31b. When each screw 45 is screwed into each screw hole 46, a distal end of each screw 45 presses the cartridge heater 70A in the hole 31b against the inner wall portion 31, so that positions of the cartridge heaters 70A are fixed. When each of the screws 45 is loosened, the cartridge heaters 70A can be removed from the holes

31b. Since the holes 31b are open in the outer surface of the side cover 10A, the cartridge heaters 70A can be removed from the side cover 10A without disassembling the vacuum pump apparatus. Therefore, if a malfunction of the cartridge heater 70A occurs, the cartridge heater 70A can be easily replaced with a new cartridge heater.

[0037] Next, the configuration of the cartridge heater 70A will be described. FIG. 4 is a perspective view of the cartridge heater 70A. FIG. 5 is a cross-sectional view taken along a line B-B of FIG. 4. The cartridge heater 70A has a heater 71 and a heater casing 72 covering at least a part of the heater 71. The heater 71 has a heating element 71a and an outer shell 71b surrounding the heating element 71a. The outer shell 71b is made of metal and has a function of transferring heat generated by the heating element 71a while protecting the heating element 71a. The cartridge heater 70A is a heating device in which the heater 71 is inserted inside the heater casing 72. A type of the heater 71 is not particularly limited, while a sheathed heater, which is a kind of electric heater, can be used for the heater 71. The heater 71 is a rod-shaped heater extending linearly.

[0038] The heater casing 72 is open at both ends thereof and has a cylindrical shape forming a columnar space therein. The heater casing 72 has a slit 72a extending from one end to other end thereof. The slit 72a extends over an entire length of the heater casing 72. A cross section of the heater casing 72 has an annular shape opened at the slit 72a having a width s1. In this embodiment, the entire length of the heater casing 72 is the same as an entire length of the heater 71, and the heater casing 72 covers the entire heater 71. In one embodiment, the entire length of heater casing 72 may be longer than the entire length of heater 71.

[0039] FIG.6 is an enlarged cross-sectional view of the cartridge heater 70A inserted into the hole 31b. As shown in FIG. 6B, before the heater 71 generates heat, an inner diameter φ1 of the hole 31b of the side cover 10A is larger than an outer diameter φ2 of the heater casing 72. Therefore, a gap is formed between the side cover 10A (more specifically, an inner wall forming the hole 31b) and the heater casing 72 when the cartridge heater 70A has been inserted into the hole 31b. Before the heater 71 generates the heat, an inner diameter φ3 of the heater casing 72 is larger than an outer diameter φ4 of the heater 71. Therefore, a gap is formed between the heater 71 and the heater casing 72 before the heater 71 generates the heat.

[0040] In this embodiment, the outer shell 71b of the heater 71 is made of stainless steel. The stainless steel has a higher coefficient of linear expansion than that of cast iron constituting the pump casing 2 and the side covers 10A and 10B. The heater casing 72 is made of a material having a higher coefficient of linear expansion than that of the outer shell 71b of the heater 71. More specifically, the heater casing 72 is made of metal having a higher coefficient of linear expansion than that of the outer shell 71b of the heater 71. Examples of the metal having a higher coefficient of linear expansion than that of the stainless steel constituting the outer shell 71b of the heater 71 include aluminum alloy, aluminum, copper, magnesium, etc.

[0041] When the heater 71 generates the heat, the heat is transferred through the heater casing 72 and transferred from the side cover 10A to the rotor chamber 1 (see FIG. 1), so that the rotor chamber 1 can be heated. As a result, the inside of the rotor chamber 1 can be maintained at a high temperature, and solidification of by-product contained in the process gas can be prevented.

[0042] The heater 71 may be heated up to about 600°C, which causes the heater 71 itself to thermally expand. When the heater 71 is repeatedly heated over a long period of operations, the entire heater 71 may be deformed. As a result, there is a problem that the heater 71 cannot be removed from the side cover 10A, and the heater 71 cannot be easily replaced when a malfunction of the cartridge heaters 70A occurs. If the inner diameter φ1 of the hole 31b of the inner wall portion 31 is enlarged in consideration of the deformation of the heater 71, the heat cannot be efficiently transferred from the heater 71 to the side cover 10A. As a result, power consumption of the heater 71 may increase, and operating cost may increase.

[0043] FIG. 7 is an enlarged cross-sectional view of the cartridge heater 70A during heating. According to the present embodiment, the cartridge heater 70A includes the heater casing 72 covering the heater 71. Therefore, when the heater 71 generates the heat, the heater 71 and the heater casing 72 thermally expand. As a result, the gap between the heater 71 and the heater casing 72 becomes smaller. More specifically, the inner diameter φ3 of the heater casing 72 becomes equal to the outer diameter φ4 of the heater 71. The heater casing 72 having the slit 72a can absorb the deformation of the heater 71 over time. Therefore, deformation of the entire cartridge heater 70A due to the deformation of the heater 71 over time can be prevented, so that the cartridge heater 70A can be easily removed from the side cover 10A.

[0044] The heater casing 72, which is made of the material having a higher coefficient of linear expansion than that of the outer shell 71b of the heater 71, thermally expands more greatly than the heater 71. The heater casing 72 expands until the heater casing 72 contacts the inner wall forming the hole 31b of the side cover 10A. More specifically, the outer diameter φ2 of the heater casing 72 becomes equal to the inner diameter φ1 of the hole 31b. Thus, the thermally-expanding heater casing 72 can fill the gap between the side cover 10A (more specifically, the inner wall forming the hole 31b) and the heater 71. Therefore, the heat can be transferred efficiently from the cartridge heater 70A to the side cover 10A.

[0045] As can be seen from comparison between FIGS. 6 and 7, the thermal expansion of the heater casing 72 after contacting the hole 31b is absorbed by the slit 72a of the heater casing 72. More specifically, the thermal expansion of the heater casing 72 is restricted by the hole

31b, while the heater casing 72 expands in a direction in which the slit 72a narrows. As a result, stress generated in the heater casing 72 is reduced, so that the deformation and breakage of the heater casing 72 are prevented.

[0046] When the heat generation of the heater 71 is stopped and the temperatures of the heater 71 and the heater casing 72 are lowered, the heater 71 and the heater casing 72 contract. As a result, the gap is formed again between the side cover 10A (more specifically, the inner wall forming the hole 31b) and the heater casing 72. Therefore, the cartridge heater 70A can be easily attached to and removed from the side cover 10A.

[0047] FIG. 8 is a cross-sectional view showing another embodiment of the vacuum pump apparatus. FIG. 9 is a cross-sectional view taken along a line C-C of FIG. 8. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiment described with reference to FIGS. 1 to 7, and duplicated descriptions will be omitted. The vacuum pump apparatus shown in FIG. 8 has cartridge heaters 70 disposed in the pump casing 2. The cartridge heaters 70 are removably attached to the pump casing 2. Details of the configuration of each of the cartridge heaters 70 are the same as those of the configuration of the cartridge heater 70A described with reference to FIGS. 4 and 5.

[0048] The cartridge heaters 70 are arranged at both sides of the intake port 2a and at both sides of the exhaust port 2b of the pump casing 2. As shown in FIG. 9, the pump casing 2 has holes 2c opened in an outer surface of the pump casing 2. The holes 2c extend linearly. Each cartridge heater 70 has a rod shape extending linearly, and is arranged in each hole 2c. The vacuum pump apparatus of this embodiment allows the cartridge heaters 70 to be locally mounted by providing the holes 31c at desired positions where the cartridge heaters 70 are to be attached. In this embodiment, four cartridge heaters 70 are arranged so as to sandwich the intake port 2a and the exhaust port 2b of the pump casing 2. In one embodiment, three or less, or five or more cartridge heaters 70 may be provided.

[0049] With the cartridge heaters 70 inserted into the holes 2c, the cartridge heaters 70 are fixed to the pump casing 2 by screws 45, respectively, which are fixing mechanisms. More specifically, the pump casing 2 has screw holes 46 communicating with the holes 2c. When each screw 45 is screwed into each screw hole 46, a distal end of each screw 45 presses the cartridge heater 70 in the hole 2c against the pump casing 2, so that positions of the cartridge heaters 70 are fixed. When each of the screws 45 is loosened, the cartridge heaters 70 can be removed from the holes 2c. Since the holes 2c are open in the outer surface of the pump casing 2, the cartridge heaters 70 can be removed from the pump casing 2 without disassembling the vacuum pump apparatus. Therefore, if a malfunction of the cartridge heater 70 occurs, the cartridge heater 70 can be easily replaced with a new cartridge heater.

[0050] A relationship between an inner diameter of the hole 2c of the pump casing 2, an outer diameter and an inner diameter of the heater casing 72 of the cartridge heater 70, and an outer diameter of the heater 71 of the present embodiment is the same as the relationship of the inner diameter $\varphi 1$ of the hole 31b of the side cover 10A, the outer diameter $\varphi 2$ and the inner diameter $\varphi 3$ of the heater casing 72 of the cartridge heater 70A, and the outer diameter $\varphi 4$ of the heater 71 described with reference to FIGS. 6 and 7, and duplicated descriptions are omitted.

[0051] When the heater 71 generates the heat, the heat is transferred through the heater casing 72 and transferred from the pump casing 2 to the rotor chamber 1 (see FIG. 8), so that the rotor chamber 1 can be heated. As a result, the inside of the rotor chamber 1 can be maintained at a high temperature, and solidification of by-product contained in the process gas can be prevented.

[0052] According to the present embodiment, the cartridge heater 70 includes the heater casing 72 covering the heater 71. Therefore, when the heater 71 generates the heat, the heater 71 and the heater casing 72 thermally expand. As a result, the gap between the heater 71 and the heater casing 72 becomes smaller. More specifically, the inner diameter of the heater casing 72 becomes equal to the outer diameter of the heater 71. The heater casing 72 having the slit 72a can absorb the deformation of the heater 71 over time. Therefore, deformation of the entire cartridge heater 70 due to the deformation of the heater 71 over time can be prevented, so that the cartridge heater 70 can be easily removed from the pump casing 2.

[0053] The heater casing 72, which is made of the material having a higher coefficient of linear expansion than that of the outer shell 71b of the heater 71, thermally expands more greatly than the heater 71. The heater casing 72 expands until the heater casing 72 contacts an inner wall forming the hole 2c of the pump casing 2. More specifically, the outer diameter of the heater casing 72 becomes equal to the inner diameter of the hole 2c. Thus, the thermally-expanding heater casing 72 can fill the gap between the pump casing 2 (more specifically, the inner wall forming the hole 2c) and the heater 71. Therefore, the heat can be transferred efficiently from the cartridge heater 70 to the pump casing 2.

[0054] When the heat generation of the heater 71 is stopped and the temperatures of the heater 71 and the heater casing 72 are lowered, the heater 71 and the heater casing 72 contract, so that the gap is formed again between the pump casing 2 (more specifically, the inner wall forming the hole 2c) and the heater casing 72. Therefore, the cartridge heater 70 can be easily attached to and removed from the pump casing 2.

[0055] In one embodiment, the vacuum pump apparatus may further include the cartridge heaters 70A and 70B in the side covers 10A and 10B as well as the embodiments described with reference to FIGS. 1 to 7, in addition to the cartridge heaters 70 in the pump casing 2 described above.

[0056] FIG. 10 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus. FIG. 11 is a side view of a side cover according to the embodiment shown in FIG. 10. FIG. 12 is a diagram as viewed from a direction indicated by an arrow D in FIG. 11. FIG. 13 is a perspective view of the side cover 10A shown in FIG. 11. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiment described with reference to FIGS. 1 to 7, and duplicated description will be omitted. Side covers 10A and 10B of the vacuum pump apparatus shown in FIG. 10 further include narrow portions 33 and heater housings 35. The cartridge heaters 70A and 70B are removably attached to the heater housings 35 of the side covers 10A and 10B, respectively. Details of the configurations of the cartridge heaters 70A and 70B are the same as those of the configurations of the cartridge heater 70A described with reference to FIGS. 4 and 5.

[0057] The side cover 10A of this embodiment has an inner wall portion 31 forming an end surface 31a of the rotor chamber 1, an outer wall portion 32 located outwardly of the inner wall portion 31 in the axial direction of the rotation shafts 7, and the narrow portion 33 located between the inner wall portion 31 and the outer wall portion 32. The inner wall portion 31 is coupled to the pump casing 2 and the outer wall portion 32 is coupled to the motor housing 14. The outer wall portion 32 has recesses 32a in which the bearings 17 are accommodated. A heat insulating material may be disposed between the outer wall portion 32 and the motor housing 14.

[0058] The inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are an integral structure. In this embodiment, the inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are an integrally molded casting. Since the side cover 10A includes the integral structure, it is not necessary to produce multiple members separately and assemble these multiple members. As a result, manufacturing cost can be reduced.

[0059] The narrow portion 33 has an outer peripheral length shorter than outer peripheral lengths of the inner wall portion 31 and the outer wall portion 32. Specifically, the narrow portion 33 has a cross-sectional area smaller than cross-sectional areas of the inner wall portion 31 and the outer wall portion 32. The inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are made of the same material, while the cross-sectional area of the narrow portion 33 is smaller than the cross-sectional areas of the inner wall portion 31 and the outer wall portion 32. Therefore, the heat is less likely to be transferred from the inner wall portion 31 through the narrow portion 33 to the outer wall portion 32. Although descriptions are omitted, the side cover 10B also basically has the same configuration as the side cover 10A. Since the side covers 10A and 10B having such narrow portions 33 have high heat insulating performances, the interior of the rotor chamber 1 can be maintained at a high temperature. Furthermore, cooling of the pump casing 2 by the cooling liquid flowing through the cooling channel 21 and the cooling channel 22 can be prevented.

[0060] The side cover 10A has two heater housings 35 having holes 35a, respectively. The two heater housings 35, the inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are an integral structure. Each hole 35a is open in an outer surface of the side cover 10A (more specifically, an outer surface of the heater housing 35), and the cartridge heater 70A is arranged in the hole 35a. In this embodiment, two cartridge heaters 70A are arranged so as to sandwich the rotation shafts 7. In one embodiment, only one cartridge heater 70A may be provided, or three or more cartridge heaters 70A may be provided.

[0061] The holes 35a extend linearly, and the cartridge heaters 70A are rod-shaped heaters extending linearly. With the cartridge heaters 70A inserted into the holes 35a, the cartridge heaters 70A are fixed to the side cover 10A by screws 45, respectively, which are fixing mechanisms. More specifically, the heater housing 35 has screw holes 46 communicating with the holes 35a. When each screw 45 is screwed into each screw hole 46, a distal end of each screw 45 presses the cartridge heater 70A in the hole 35a against the heater housing 35, so that positions of the cartridge heaters 70A are fixed. When each of the screws 45 is loosened, the cartridge heaters 70A can be removed from the holes 35a. Since the holes 35a are open in the outer surface of the side cover 10A, the cartridge heaters 70A can be removed from the side covers 10A without disassembling the vacuum pump apparatus. Therefore, if the cartridge heater 70A breaks down, the cartridge heater 70A can be easily replaced with a new cartridge heater.

[0062] A relationship between an inner diameter of the hole 35a of the heater housing 35, an outer diameter and an inner diameter of the heater casing 72 of the cartridge heater 70A, and an outer diameter of the heater 71 of the present embodiment is the same as the relationship of the inner diameter φ1 of the hole 31b of the side cover 10A, the outer diameter φ2 and the inner diameter φ3 of the heater casing 72 of the cartridge heater 70A, and the outer diameter φ4 of the heater 71 described with reference to FIGS. 6 and 7, and duplicated descriptions are omitted.

[0063] When the heater 71 generates the heat, the heat is transferred through the heater casing 72 and transferred from the heater housings 35 and the inner wall portion 31 to the rotor chamber 1 (see FIG. 10), so that the rotor chamber 1 can be heated. As a result, the inside of the rotor chamber 1 can be maintained at a high temperature, and solidification of by-product contained in the process gas can be prevented. In particular, since the heater housings 35 and the inner wall portion 31 are integrally formed, heat conduction efficiency from the cartridge heaters 70A to the inner wall portion 31 is improved.

[0064] As shown in FIG. 13, at least a part of each heater housing 35 is separated from the outer wall portion 32. Although not shown, the entire heater housings 35 may be located away from the outer wall portion 32. With such a configuration, the heat generated by the heaters 71 and transferred through the heater casings 72 is less likely to be transferred to the outer wall portion 32. Therefore, this configuration can prevent heating of the motor housing 14 (see FIG. 10), which is a housing structure coupled to the outer wall portion 32, while the cartridge heaters 70A heats the rotor chamber 1.

[0065] According to the present embodiment, the cartridge heater 70A includes the heater casing 72 covering the heater 71. Therefore, when the heater 71 generates the heat, the heater 71 and the heater casing 72 thermally expand. As a result, the gap between the heater 71 and the heater casing 72 becomes smaller. More specifically, the inner diameter of the heater casing 72 becomes equal to the outer diameter of the heater 71. The heater casing 72 having the slit 72a can absorb the deformation of the heater 71 over time. Therefore, deformation of the entire cartridge heater 70A due to the deformation of the heater 71 over time can be prevented, so that the cartridge heater 70A can be easily removed from the heater housing 35.

[0066] The heater casing 72, which is made of the material having a higher coefficient of linear expansion than that of the outer shell 71b of the heater 71, thermally expands more greatly than the heater 71. The heater casing 72 expands until the heater casing 72 contacts the inner wall forming the hole 35a of the heater housing 35. More specifically, the outer diameter of the heater casing 72 becomes equal to the inner diameter of the hole 35a. Thus, the thermally-expanding heater casing 72 can fill the gap between the heater housing 35 (more specifically, the inner wall forming the hole 35a) and the heater 71. Therefore, the heat can be transferred efficiently from the cartridge heater 70A to the heater housing 35.

[0067] When the heat generation of the heater 71 is stopped and the temperatures of the heater 71 and the heater casing 72 are lowered, the heater 71 and the heater casing 72 contract, so that the gap is formed again between the heater housing 35 (more specifically, the inner wall forming the hole 35a) and the heater casing 72. Therefore, the cartridge heater 70A can be easily attached to and removed from the heater housing 35.

[0068] As shown in FIG. 10, the cartridge heaters 70B are also disposed in the side cover 10B. The descriptions with reference to FIGS. 11 to 13 can also be applied to the side cover 10B and the cartridge heaters 70B disposed therein, and duplicated descriptions are omitted.

[0069] In one embodiment, the vacuum pump apparatus may further include the cartridge heaters 70 in the pump casing 2 as well as the embodiments described with reference to FIGS. 8 and 9, in addition to the cartridge heaters 70A and 70B in the side covers 10A and 10B described above.

[0070] The previous description of embodiments is provided to enable a person skilled in the art to make and use the present invention. Moreover, various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles and specific examples defined herein may be applied to other embodiments. Therefore, the present invention is not intended to be limited to the embodiments described herein but is to be accorded the widest scope as defined by limitation of the claims.

Claims

1. A vacuum pump apparatus comprising:

a pump casing (2) having a rotor chamber (1) therein;
a pump rotor (5) arranged in the rotor chamber (1);
a rotation shaft (7) to which the pump rotor (5) is fixed;
an electric motor (8) coupled to the rotation shaft (7);
a side cover (10A, 10B) forming an end surface of the rotor chamber (1); and
a housing structure (14, 16) located outwardly of the side cover (10A, 10B) in an axial direction of the rotation shaft (7);
a cartridge heater (70A, 70B; 70) disposed in the side cover (10A, 10B) or in the pump casing (2) and removably attached to the side cover (10A, 10B) or the pump casing (2),
wherein the cartridge heater (70A, 70B; 70) has a heater (71), **characterized in that** the cartridge heater has a heater casing (72) covering at least a part of the heater (71), and
the heater casing (72) has a slit (72a) extending from one end to the other end thereof.

2. The vacuum pump apparatus according to claim 1, wherein the heater casing (72) is made of a material having a higher coefficient of linear expansion than that of a material constituting an outer shell (71b) of the heater (71).

3. The vacuum pump apparatus according to claim 2, wherein the heater casing (72) is made of one of aluminum alloy, aluminum, copper, and magnesium.

4. The vacuum pump apparatus according to any one of claims 1 to 3, wherein

the side cover (10A, 10B) or the pump casing (2) has a hole which is open in an outer surface of the side cover (10A, 10B) or the pump casing (2), the hole extending linearly, and
the cartridge heater (70A, 70B; 70) has a rod shape and is arranged in the hole.

5. The vacuum pump apparatus according to any one of claims 1 to 4, further comprising a fixing mechanism (45) configured to removably fix the cartridge heater (70A, 70B; 70) to the side cover (10A, 10B) or the pump casing (2).

Patentansprüche

1. Vakuumpumpenvorrichtung, umfassend:

ein Pumpengehäuse (2) mit einer Rotorkammer (1) darin;
einen Pumpenrotor (5), der in der Rotorkammer (1) angeordnet ist;
eine Drehwelle (7), an welcher der Pumpenrotor (5) befestigt ist;
einen Elektromotor (8), der mit der Drehwelle (7) gekoppelt ist;
eine Seitenabdeckung (10A, 10B), die eine Endfläche der Rotorkammer (1) bildet; und
eine Gehäusestruktur (14, 16), die außerhalb der Seitenabdeckung (10A, 10B) in einer axialen Richtung der Drehwelle (7) angeordnet ist;
eine Patronenheizung (70A, 70B; 70), die in der Seitenabdeckung (10A, 10B) oder in dem Pumpengehäuse (2) angeordnet ist und abnehmbar an der Seitenabdeckung (10A, 10B) oder dem Pumpengehäuse (2) angebracht ist,
wobei die Patronenheizung (70A, 70B; 70) eine Heizung (71) aufweist, **dadurch gekennzeichnet, dass** die Patronenheizung (70A, 70B; 70) ein Heizungsgehäuse (72) aufweist, das mindestens einen Teil der Heizung (71) abdeckt, und
das Heizungsgehäuse (72) einen Schlitz (72a) aufweist, der sich von einem Ende zu dem anderen Ende davon erstreckt.

2. Vakuumpumpenvorrichtung nach Anspruch 1, wobei das Heizungsgehäuse (72) aus einem Material hergestellt ist, das einen höheren linearen Ausdehnungskoeffizienten aufweist als der eines Materials, das eine Außenhülle (71b) der Heizung (71) bildet.

3. Vakuumpumpenvorrichtung nach Anspruch 2, wobei das Heizungsgehäuse (72) aus einer Aluminiumlegierung, Aluminium, Kupfer oder Magnesium hergestellt ist.

4. Vakuumpumpenvorrichtung nach einem der Ansprüche 1 bis 3, wobei

die Seitenabdeckung (10A, 10B) oder das Pumpengehäuse (2) ein Loch aufweist, das in einer Außenfläche der Seitenabdeckung (10A, 10B) oder des Pumpengehäuses (2) offen ist, wobei sich das Loch linear erstreckt, und
die Patronenheizung (70A, 70B; 70) eine Stabform aufweist und in dem Loch angeordnet ist.

5. Vakuumpumpenvorrichtung nach einem der Ansprüche 1 bis 4, ferner umfassend einen Befestigungsmechanismus (45), der konfiguriert ist, um die Patronenheizung (70A, 70B; 70) abnehmbar an der Seitenabdeckung (10A, 10B) oder dem Pumpengehäuse (2) zu befestigen.

Revendications

1. Appareil de pompe à vide comprenant :

un carter de pompe (2) ayant une chambre de rotor (1) dans celui-ci ;
un rotor de pompe (5) agencé dans la chambre de rotor (1) ;
un arbre de rotation (7) auquel le rotor de pompe (5) est fixé ;
un moteur électrique (8) couplé à l'arbre de rotation (7) ;
un couvercle latéral (10A, 10B) formant une surface d'extrémité de la chambre de rotor (1) ; et
une structure de logement (14, 16) située vers l'extérieur du couvercle latéral (10A, 10B) dans une direction axiale de l'arbre de rotation (7) ;
un élément chauffant de cartouche (70A, 70B ; 70) disposé dans le couvercle latéral (10A, 10B) ou dans le carter de pompe (2) et fixé de manière amovible au couvercle latéral (10A, 10B) ou au carter de pompe (2),
dans lequel l'élément chauffant de cartouche (70A, 70B ; 70) a un élément chauffant (71), **caractérisé en ce que** l'élément chauffant de cartouche (70A, 70B ; 70) a un boîtier d'élément chauffant (72) recouvrant au moins une partie de l'élément chauffant (71), et
le boîtier d'élément chauffant (72) a une fente (72a) s'étendant d'une extrémité à l'autre extrémité de celui-ci.

2. Appareil de pompe à vide selon la revendication 1, dans lequel le boîtier d'élément chauffant (72) est constitué d'un matériau ayant un coefficient de dilatation linéaire supérieur à celui d'un matériau constituant une coque externe (71b) de l'élément chauffant (71).

3. Appareil de pompe à vide selon la revendication 2, dans lequel le boîtier d'élément chauffant (72) est constitué d'un parmi un alliage d'aluminium, de l'aluminium, du cuivre et du magnésium.

4. Appareil de pompe à vide selon l'une quelconque des revendications 1 à 3, dans lequel

le couvercle latéral (10A, 10B) ou le carter de pompe (2) a un trou qui est ouvert dans une

surface externe du couvercle latéral (10A, 10B) ou du carter de pompe (2), le trou s'étendant de manière linéaire, et
l'élément chauffant de cartouche (70A, 70B ; 70) a une forme de tige et est agencé dans le trou.

5. Appareil de pompe à vide selon l'une quelconque des revendications 1 à 4, comprenant en outre un mécanisme de fixation (45) configuré pour fixer de manière amovible l'élément chauffant de cartouche (70A, 70B ; 70) au couvercle latéral (10A, 10B) ou au carter de pompe (2).

FIG. 1

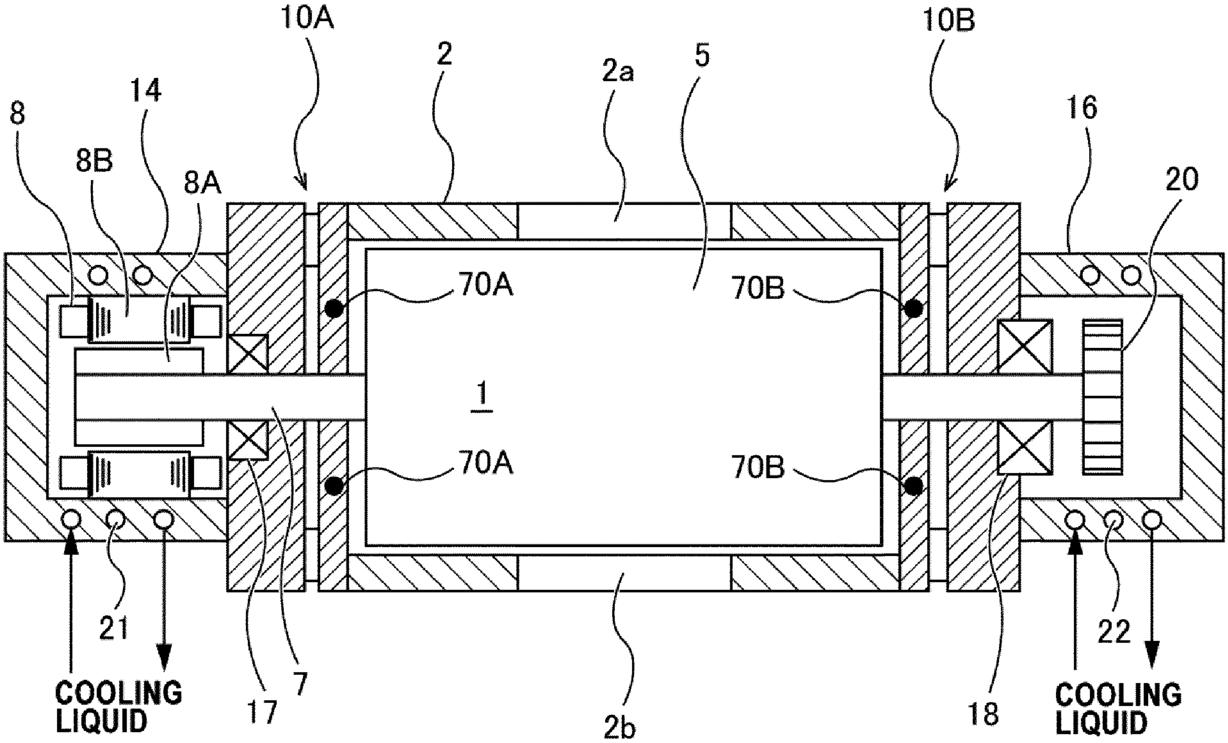

10A
2
2a
5
10B
8
14
8B
8A
16
20
70A
70B
1
70A
70B
21
COOLING LIQUID
17
7
2b
18
22
COOLING LIQUID

FIG. 2

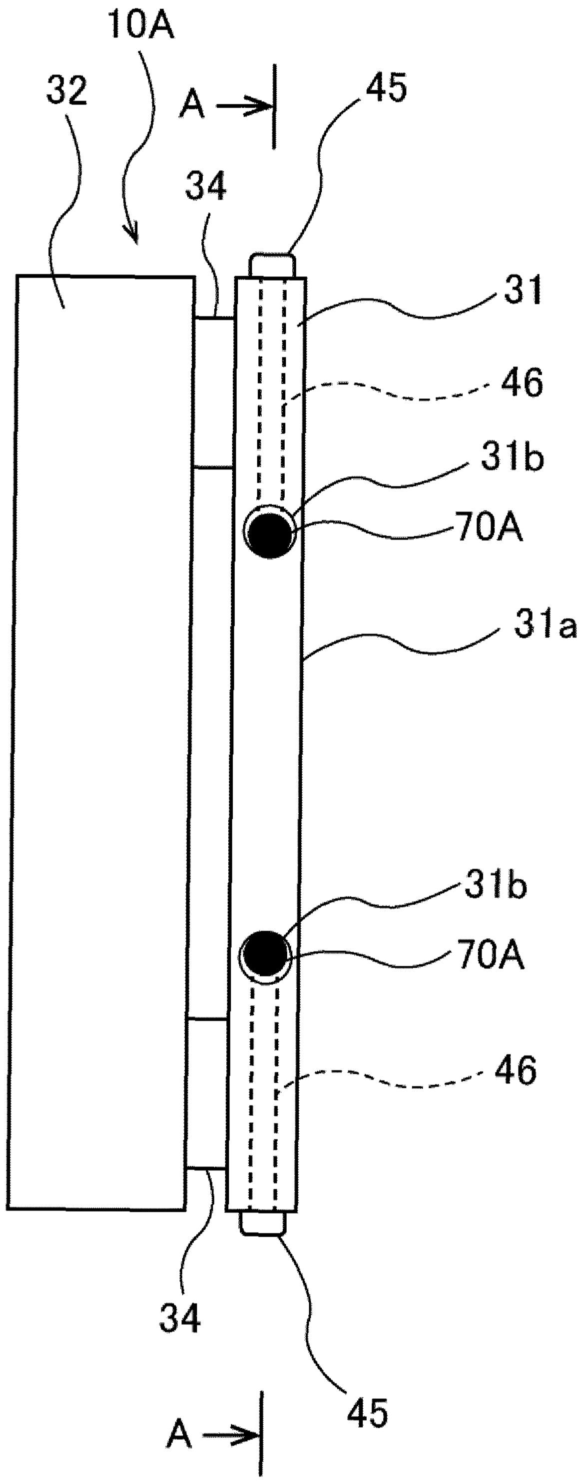


FIG. 3

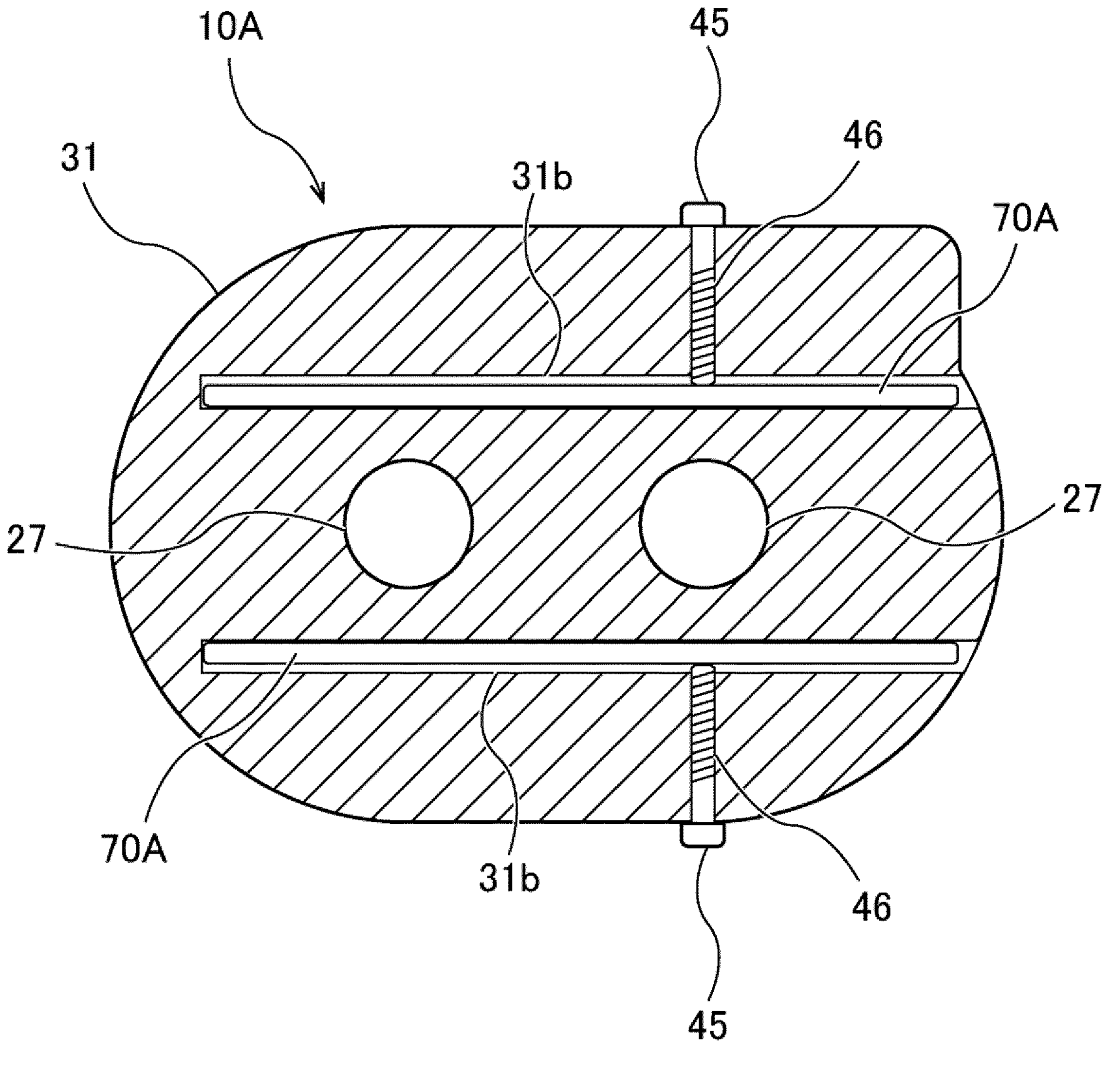


FIG. 4

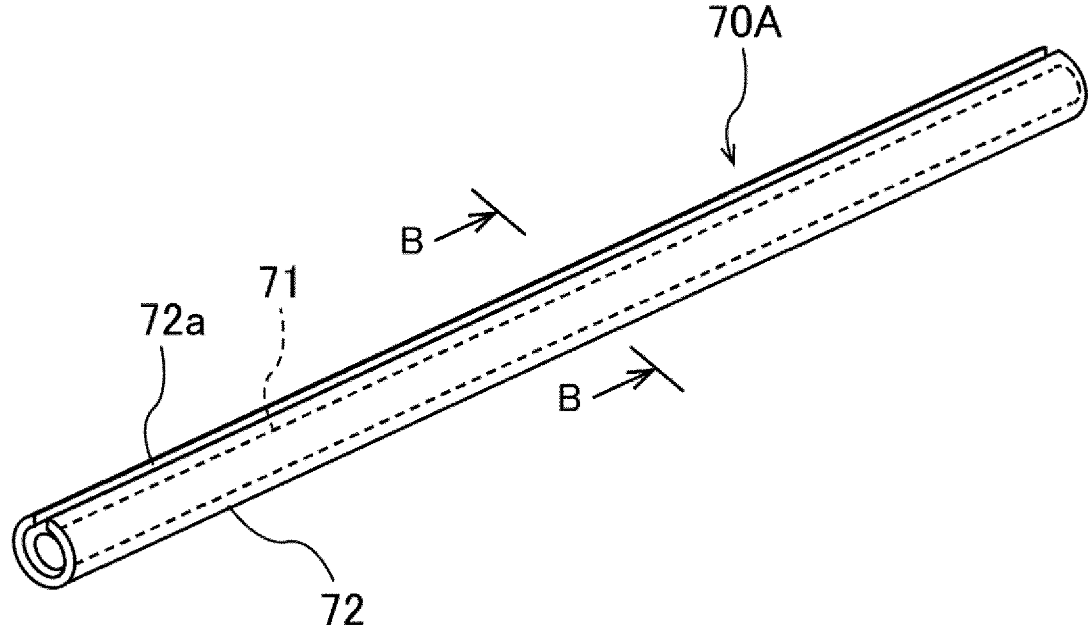


FIG. 5

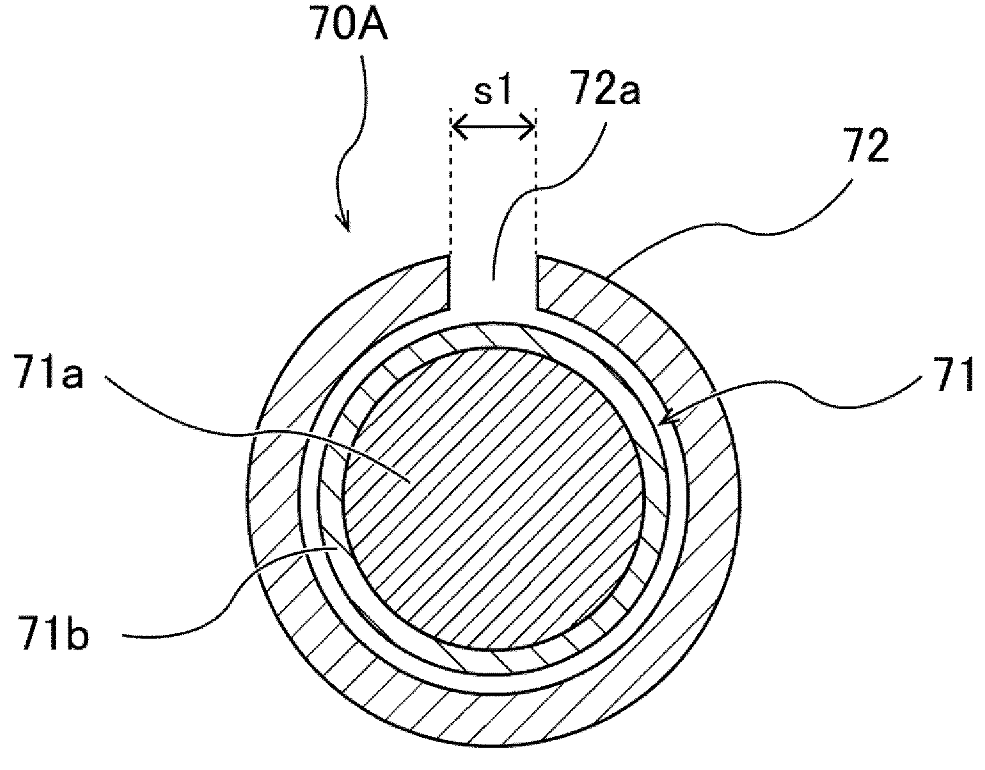


FIG. 6

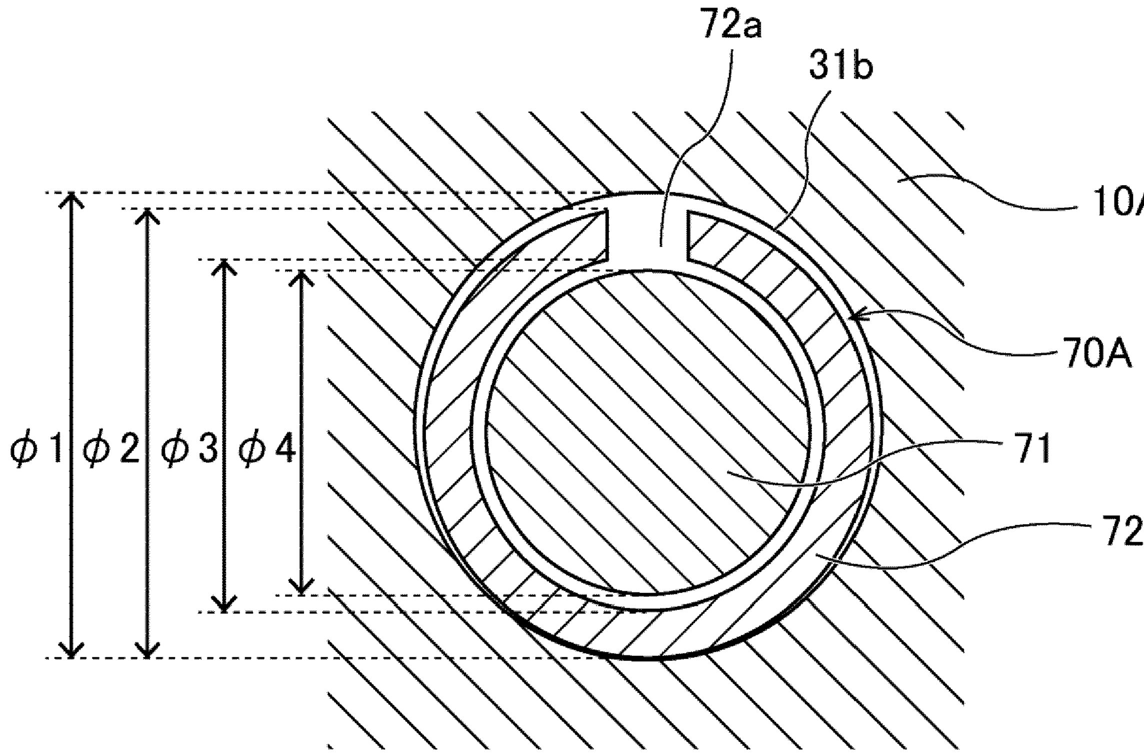


FIG. 7

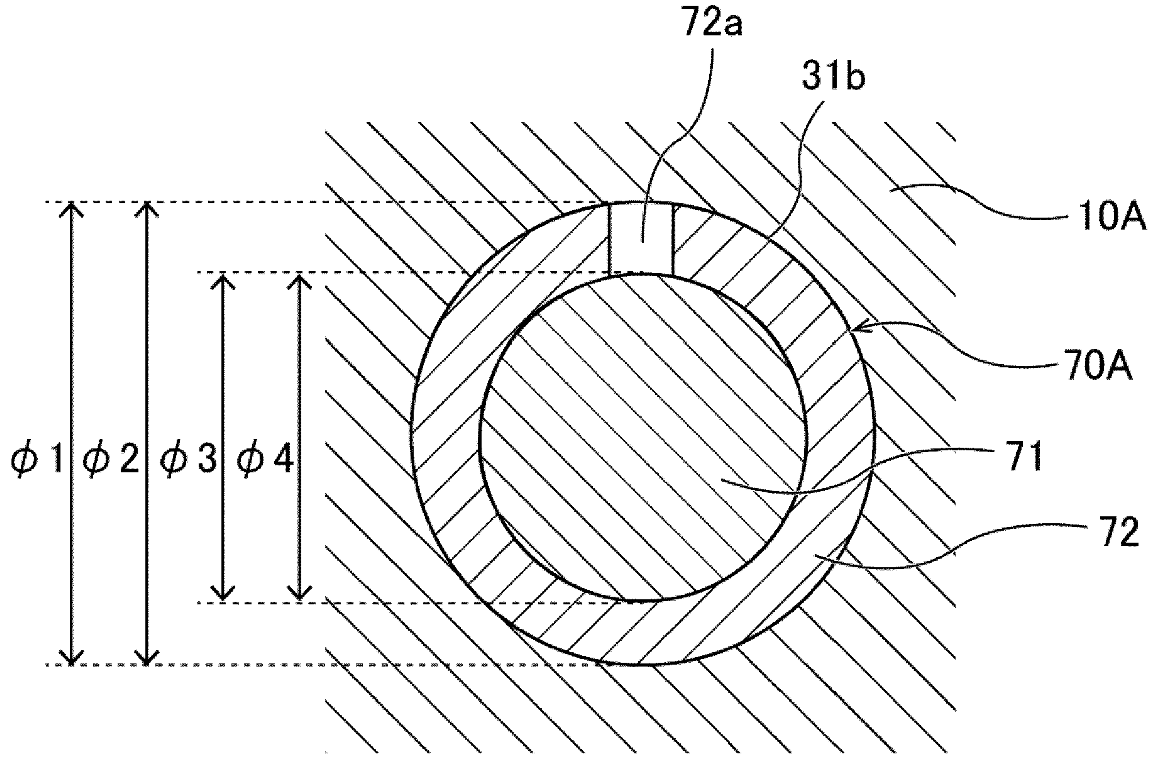


FIG. 8

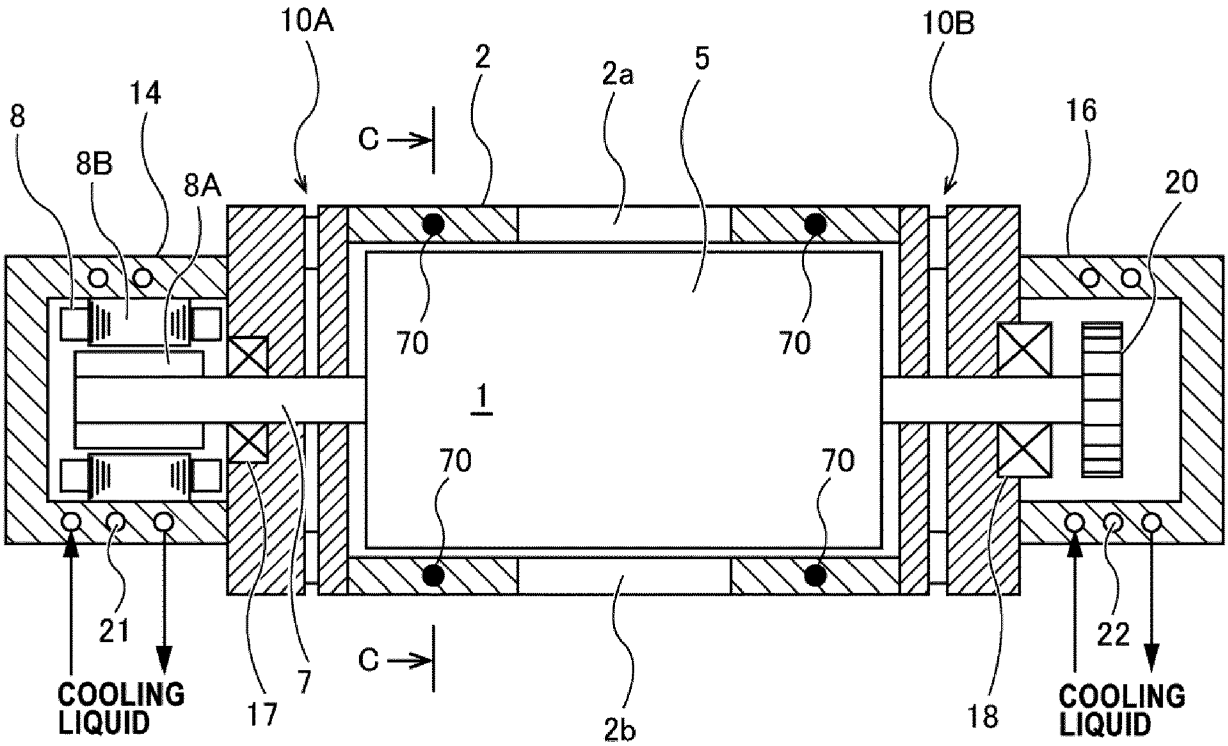

10A
2
2a
5
10B
16
20
14
8
8B
8A
C
70
70
1
70
70
C
21
COOLING LIQUID
17
7
2b
18
22
COOLING LIQUID

FIG. 9

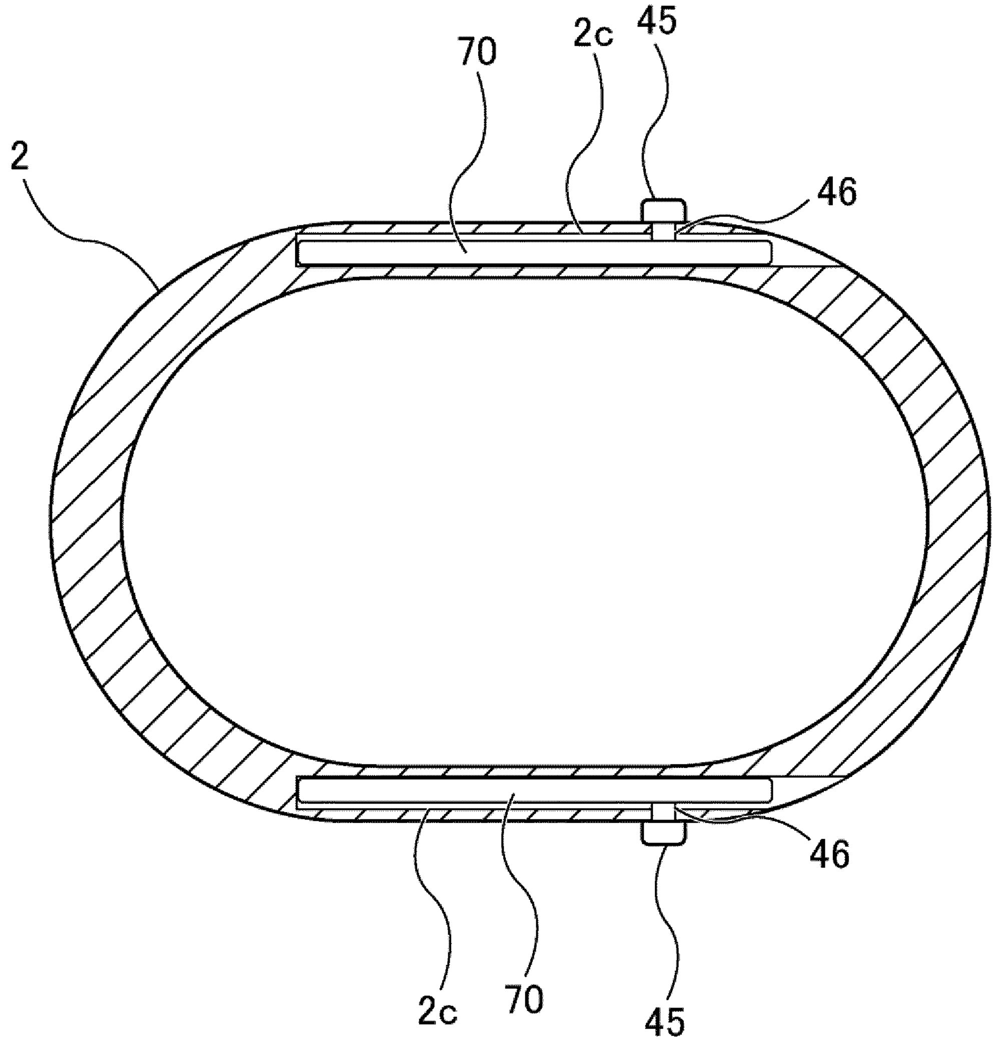


FIG. 10

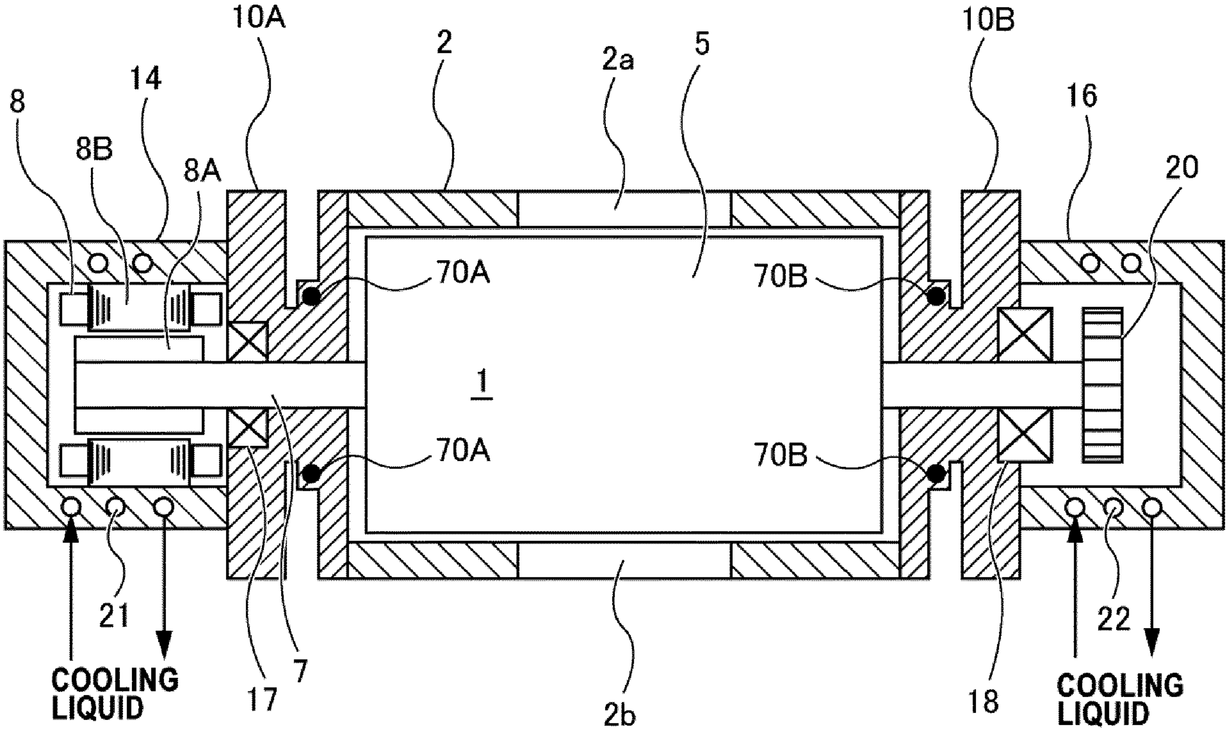

10A
2
2a
5
10B
8
14
16
8B
8A
20
70A
70B
1
70A
70B
21
22
COOLING LIQUID
7
17
2b
18
COOLING LIQUID

FIG. 11

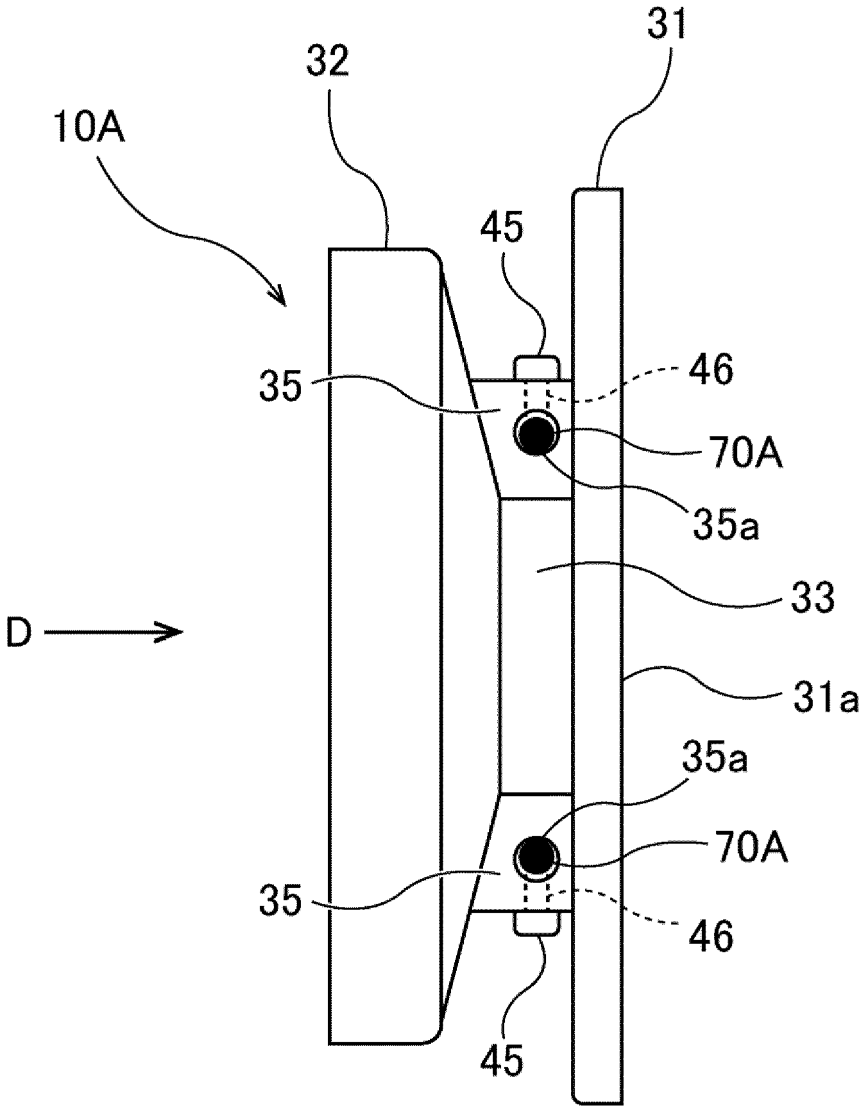


FIG. 12

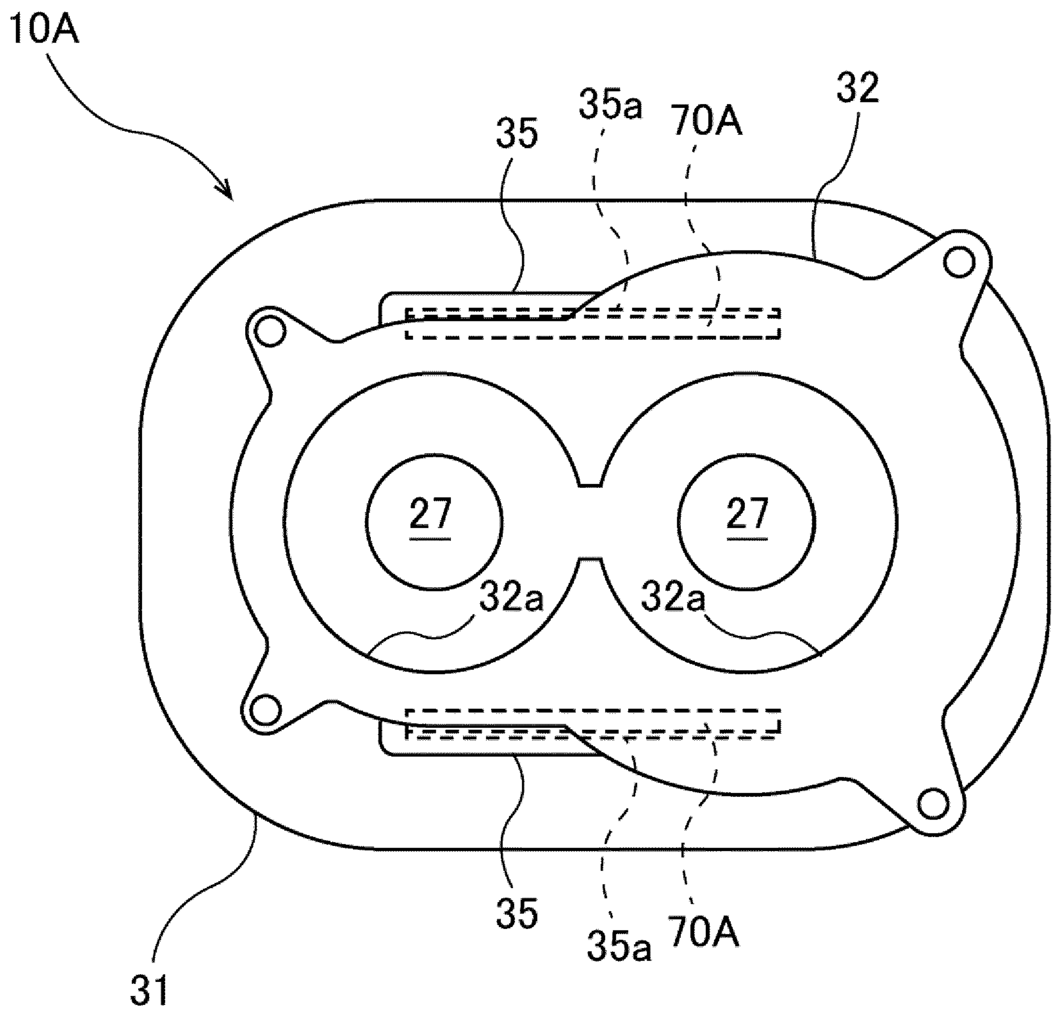
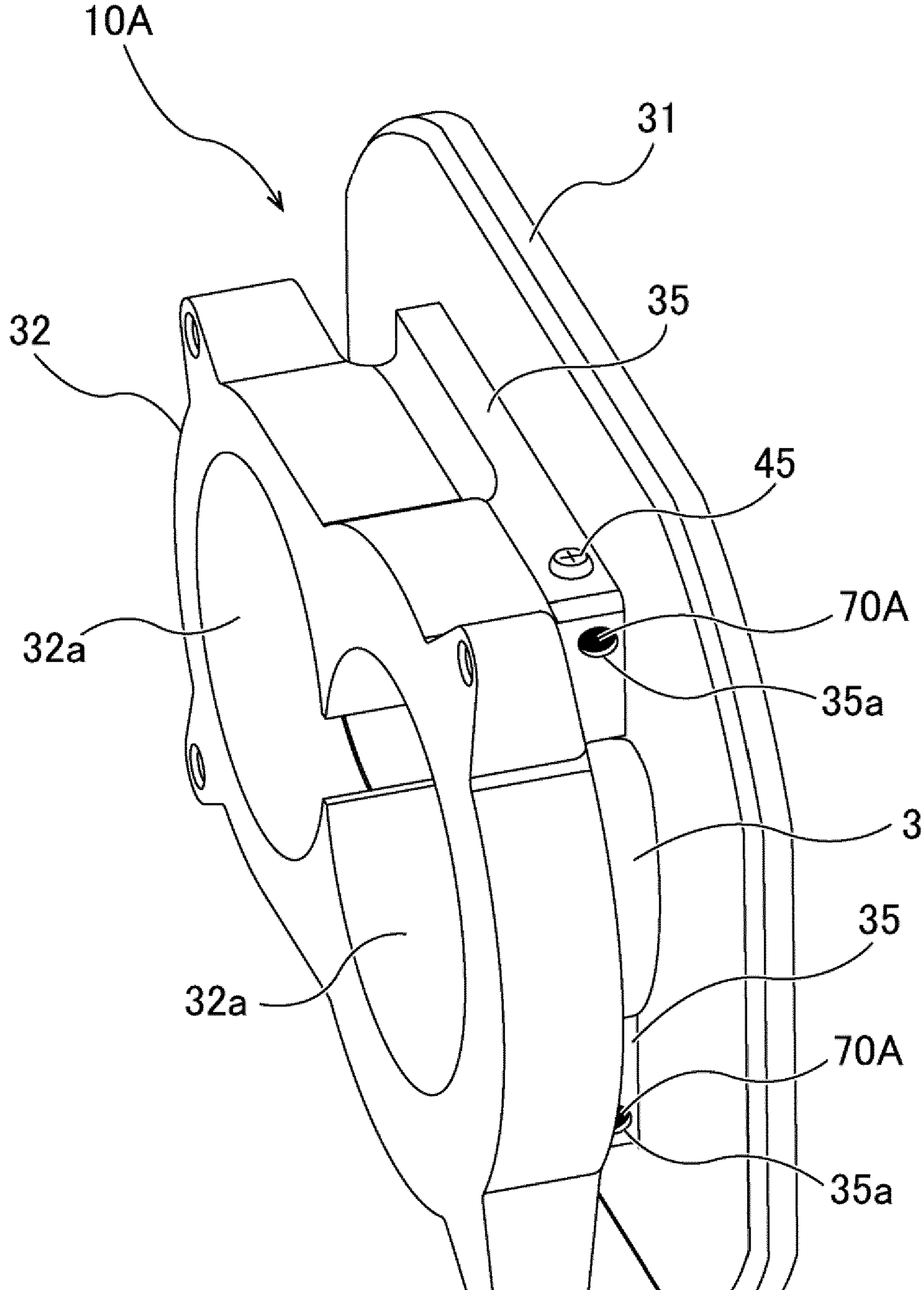


FIG. 13



REFERENCES CITED IN THE DESCRIPTION

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- JP 2021063503 A **[0005]**
- WO 2020255300 A1 **[0005]**