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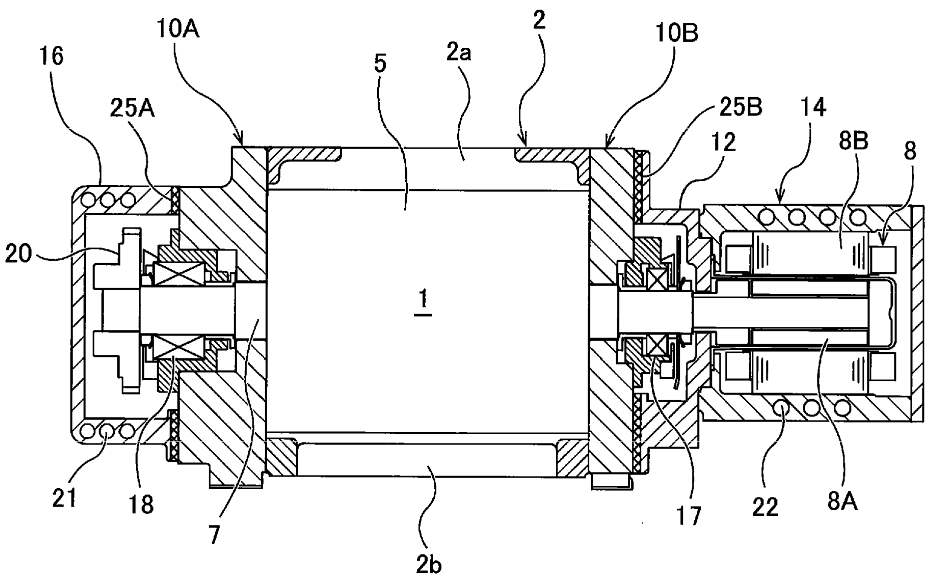
(54) **VACUUM PUMP WITH THERMAL INSULATION**

(57) A vacuum pump apparatus includes: 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 secured; an electric motor (8) coupled to the rotation shaft (7); a side cover (10A) forming an end surface of the rotor chamber (1); a housing structure (16) located outwardly of the side cover (10A) in an axial direction of the rotating shaft (1); and a heat insulator (25A) located between the pump casing (2) and the housing structure (16).

FIG. 1



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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 manufacturing process for 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 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 a so-called dry vacuum pump apparatus that does not use oil in gas 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 a 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 cooling system can prevent overheating of the electric motor and the gears and can therefore achieve stable operation of the vacuum pump apparatus.

Citation List

Patent Literature

[0005]

Patent document 1: Japanese laid-open patent publication No. 2003-35290
Patent document 2: Japanese laid-open patent publication No. 2012-251470

[0006] However, the heat of the pump casing heated by the heater is likely to be transferred to the motor housing and the gear housing having low temperatures. As a result of such heat transfer, the temperature of the rotor chamber in the pump casing may drop. In particular, since an end surface of the rotor chamber is located near the motor housing or the gear housing having a low temperature, the temperature of the end surface of the rotor chamber tends to decrease. As a result, the by-product contained in the process gas may be solidified in the rotor chamber. One solution for such a drawback may be to use a high-power heater, but such a heater requires more electric power, and an energy-saving operation of the vacuum pump apparatus cannot be achieved.

SUMMARY OF THE INVENTION

[0007] Therefore, the present invention provides a vacuum pump apparatus capable of preventing a decrease in temperature of a pump casing due to heat transfer, and capable of maintaining a high temperature in a rotor chamber.

[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 secured; 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 rotating shaft; and a heat insulator located between the pump casing and the housing structure.

[0009] In an embodiment, the heat insulator includes a heat insulating structure sandwiched between the side cover and the housing structure.

[0010] In an embodiment, the side cover has a hollow structure having a space therein, and the heat insulator comprises a gas layer existing in the space of the side cover.

[0011] In an embodiment, the heat insulator includes a heat insulating member arranged in the side cover.

[0012] In an embodiment, the side cover includes an inner side cover forming the end surface of the rotor chamber, and an outer side cover located outwardly of the inner side cover in the axial direction, and the heat insulating member is sandwiched between the inner side cover and the outer side cover.

[0013] In an embodiment, a cross-sectional area of the heat insulating member is smaller than a cross-sectional area of the side cover.

[0014] In an embodiment, the vacuum pump apparatus further comprises a side heater provided in the side cover.

[0015] The heat insulating member arranged between the pump casing and the housing structure can reduce the heat transfer from the pump casing to the housing structure. Therefore, the inside of the rotor chamber can be maintained at a high temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a cross-sectional view showing an embodiment of a vacuum pump apparatus;
FIG. 2 is an exploded perspective view showing a side cover, a heat insulator, and a gear housing;
FIG. 3 is a cross-sectional view showing another embodiment of the vacuum pump apparatus;
FIG. 4 is an enlarged cross-sectional view of the side cover shown in FIG. 3;
FIG. 5 is a cross-sectional view showing another embodiment of the vacuum pump apparatus;
FIG. 6 is an exploded perspective view showing a side cover and a plurality of heat insulating members shown in FIG. 5;
FIG. 7 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus;
FIG. 8 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus;
FIG. 9 is a cross-sectional view showing an embodiment in which a heater is attached to an outer surface of a pump casing;
FIG. 10 is a cross-sectional view showing an embodiment in which a side heater is embedded in a side cover;
FIG. 11 is a cross-sectional view taken along line A-A of FIG. 10;
FIG. 12 is a diagram showing an embodiment in which a plurality of side heaters are arranged in a side cover;
FIG. 13 is a cross-sectional view showing an embodiment of a vacuum pump apparatus including two heat insulators shown in FIG. 8 and the side heater shown in FIG. 10;
FIG. 14 is a cross-sectional view taken along line B-B shown in FIG. 13;
FIG. 15 is a diagram showing an embodiment in which a plurality of side heaters are arranged in a side cover;
FIG. 16 is a cross-sectional view showing an embodiment of a vacuum pump apparatus including both a side heater embedded in a side cover and a heater mounted to an outer surface of a pump casing; and
FIG. 17 is a cross-sectional view showing an embodiment of a vacuum pump apparatus including multistage pump rotors.

DESCRIPTION OF EMBODIMENTS

[0017] Embodiments will now 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 motors 8 coupled to the rotation shafts 7. The pump rotor 5 and the rotation shaft 7 may be an integral structure. Although only one pump rotor 5, one rotation shaft 7, and one electric motor 8 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. A pair of electric motors 8 are 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 screws (not shown). In one embodiment, the side covers 10A and 10B may be integrated with the pump casing 2.

[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 bearing housing 12, 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 gear housing 16, and the side cover 10B is located between the pump casing 2 and the bearing housing 12. The bearing housing 12 is located between the side cover 10B and the motor housing 14.

[0024] Each rotation shaft 7 is rotatably supported by a bearing 17 arranged in the bearing housing 12 and a bearing 18 arranged in the gear housing 16. The motor housing 14 accommodates motor rotors 8A and motor stators 8B of the electric motors 8 therein. The bearing housing 12, the motor housing 14, and the gear housing 16 are examples of the housing structures, and the housing structures are not limited to this embodiment.

[0025] The two electric motors 8 (only one electric motor 8 is shown in FIG. 1) are synchronously rotated in opposite directions by a motor driver (not shown), so that the pair of rotation shafts 7 and the pair of pump rotors 5 can be synchronously rotated in opposite directions. When the pump rotors 5 are rotated by the electric motors 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.

[0026] 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. As described above, since the pair of pump rotors 5 are rotated synchronously by the two electric motors 8, 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] A cooling pipe 21 is embedded in the gear housing 16. Similarly, a cooling pipe 22 is embedded in the motor housing 14. The cooling pipe 21 extends through an entire circumferential wall of the gear housing 16, and the cooling pipe 22 extends through an entire circumferential wall of the motor housing 14. The cooling pipe 21 and the cooling pipe 22 are coupled to a cooling-liquid supply source (not shown). The cooling liquid is supplied from the cooling-liquid supply source to the cooling pipe 21 and the cooling pipe 22. The cooling liquid flowing through the cooling pipe 21 cools the gear housing 16, so that the gears 20 and the bearings 18 arranged in the gear housing 16 can be cooled. The cooling liquid flowing through the cooling pipe 22 cools the motor housing 14 and the bearing housing 12, so that the electric motors 8 arranged in the motor housing 14 and the bearings 17 arranged in the bearing housing 12 can be cooled.

[0028] A heat insulating structure 25A, which is a heat insulator, is sandwiched between the side cover 10A and the gear housing (housing structure) 16. The side cover 10A and the gear housing 16 are separated from each other (i.e., not in contact with each other), while the heat insulating structure 25A is in contact with both the side cover 10A and the gear housing 16. The heat insulating structure 25A is located between the pump casing 2 and the gear housing 16, and has a function of reducing heat transfer from the pump casing 2 to the gear housing 16 via the side cover 10A.

[0029] Some of the process gases to be handled by the vacuum pump apparatus of the present embodiment 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, the inside of the rotor chamber 1 becomes hot due to the heat of compression of the process gas. The heat insulating structure 25A can reduce heat transfer from the pump casing 2 to the gear housing 16 via the side cover 10A, and can maintain the inside of the rotor chamber 1 at a high temperature. In particular, the heat insulating structure 25A can maintain the inside of the rotor chamber 1 at a high temperature, while the cooling liquid, flowing through the cooling pipe 21, can cool the gear housing 16.

[0030] The heat insulating structure 25A has a lower thermal conductivity than that of the side cover 10A. More specifically, the heat insulating structure 25A is made of a material having a lower thermal conductivity than that of a material constituting the side cover 10A. 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. The bearing housing 12, the motor housing 14, and the gear housing 16 are made of aluminum. The heat insulating structure 25A is made of a resin having a lower thermal conductivity than that of the material of the side cover 10A. In one example, the heat insulating structure 25A is made of polytetrafluoroethylene (PTFE), which is a kind of fluororesin. Polytetrafluoroethylene (PTFE) has a lower thermal conductivity than that of cast iron and has a property of withstanding high temperatures. However, as long as the heat insulating structure 25A has a lower thermal conductivity than that of the material of the side cover 10A, the material of the heat insulating structure 25A may be metal, such as stainless steel, titanium, or spheroidal graphite-based austenite cast iron (or Ni-Resist).

[0031] Another housing structure, such as a bearing housing, may be arranged between the side cover 10A and the gear housing 16. In such an arrangement, the heat insulating structure 25A is sandwiched between the side cover 10A and the housing structure.

[0032] FIG. 2 is an exploded perspective view showing the side cover 10A, the heat insulating structure 25A, and the gear housing 16. As shown in FIG. 2, the heat insulating structure 25A has an annular shape and is arranged so as to surround the outer circumferential surfaces of the rotation shafts 7 (see FIG. 1). 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. The heat insulating structure 25A is arranged around these through-holes 27. An inner surface of the heat insulating structure 25A is in contact with an outer surface of the side cover 10A, and an outer surface of the heat insulating structure 25A is in contact with an inner end surface of the gear housing 16. The heat insulating structure 25A has a continuous annular shape, so that the heat insulating structure 25A functions as a seal for sealing a gap between the side cover 10A and the gear housing 16.

[0033] Similarly, the heat insulating structure 25B is sandwiched between the side cover 10B and the bearing housing (housing structure) 12. Specifically, the side cover 10B and the bearing housing 12 are separated from each other (not in contact with each other), and the heat insulating structure 25B is in contact with both the side cover 10B and the bearing housing 12. The heat insulating structure 25B is located between the pump casing 2 and the bearing housing 12, and has a function of reducing heat transfer from the pump casing 2 to the bearing housing 12 via the side cover 10B. In particular, the heat insulating structure 25B can maintain the inside of the rotor chamber 1 at a high temperature, while the cooling liquid, flowing through the cooling pipe 22, can cool the motor housing 14 and the bearing housing 12.

[0034] The heat insulating structure 25B has a continuous annular shape, so that the heat insulating structure 25B functions as a seal for sealing a gap between the side cover 10B and the bearing housing 12. Specifically, an inner surface of the heat insulating structure 25B is in contact with an outer surface of the side cover 10B, and an outer surface of the heat insulating structure 25B is in contact with an inner end surface of the bearing housing 12. The heat insulating structure 25B has a lower thermal conductivity than that of the side cover 10B. More specifically, the heat insulating structure 25B is made of a material having a lower thermal conductivity than that of a material constituting the side cover 10B. Since the configurations of the heat insulating structure 25B are the same as those of the heat insulating structure 25A, repetitive descriptions thereof will be omitted.

[0035] Another housing structure may be arranged between the side cover 10B and the bearing housing 12. In such an arrangement, the heat insulating structure 25B is sandwiched between the side cover 10B and the housing structure. Further, the bearing housing 12 may not be provided between the side cover 10B and the motor housing 14. In such an arrangement, the heat insulating structure 25B is sandwiched between the side cover 10B and the motor housing 14.

[0036] FIG. 3 is a cross-sectional view showing another embodiment of the vacuum pump apparatus. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiment described with reference to FIG. 1, and therefore repetitive descriptions will be omitted. In this embodiment, a gas layer 29A as a heat insulator is provided in the side cover 10A. The heat insulating structures 25A and 25B are not provided.

[0037] The gas layer 29A is located between the pump casing 2 and the gear housing 16 and has a lower thermal conductivity than that of the side cover 10A. Therefore, the gas layer 29A has a function of reducing heat transfer from the pump casing 2 to the gear housing 16 via the side cover 10A. The side cover 10A has a hollow structure having a space therein. The heat insulator of the present embodiment is the gas layer 29A existing in the space inside the side cover 10A.

[0038] FIG. 4 is an enlarged cross-sectional view of the side cover 10A shown in FIG. 3. The side cover 10A includes an inner side cover 31A forming an end surface of the rotor chamber 1 and an outer side cover 32A located outwardly of the inner side cover 31A in the axial direction of the rotation shafts 7. A recess 33 is formed in an outer surface of the inner side cover 31A. The recess 33 may be formed in an inner surface of the outer side cover 32A, or may be formed in both the outer surface of the inner side cover 31A and the inner surface of the outer side cover 32A.

[0039] When the outer surface of the inner side cover 31A and the inner surface of the outer side cover 32A face each other, a space 34 is formed in the side cover 10A by the recess 33 and the inner surface of the outer side cover 32A. This space 34 extends radially outwardly from the through-holes 27 through which the rotation shafts 7 extend. The space 34 communicates with the through-holes 27, and the through-holes 27 communicate with the rotor chamber 1. An annular seal 35, such as an O-ring, is arranged radially outwardly of the recess 33. The recess 33 is surrounded by the seal 35. The seal 35 seals a gap between the outer surface of the inner side cover 31A and the inner surface of the outer side cover 32A.

[0040] The gas layer 29A is formed in the space 34. A gas generally has a lower thermal conductivity than that of a solid. In particular, since the space 34 communicates with the rotor chamber 1, the gas layer 29A is composed of a gas having a pressure lower than the atmospheric pressure during the operation of the vacuum pump apparatus. The gas constituting the gas layer 29A may be air, N_2, or a gas existing in the rotor chamber 1, or a mixture thereof. A low-pressure gas has a lower thermal conductivity than that of an atmospheric pressure gas.

[0041] The gas layer 29A has a lower thermal conductivity than that of the side cover 10A. Therefore, the gas layer 29A located in the side cover 10A can reduce heat transfer from the pump casing 2 to the gear housing (housing structure) 16. In particular, the gas layer 29A can maintain the inside of the rotor chamber 1 at a high temperature while the cooling liquid, flowing through the cooling pipe 21, can cool the gear housing 16. Further, since the gas layer 29A substantially reduces a cross section of the side cover 10A, it contributes to the reduction of heat transfer from the pump casing 2 to the gear housing (housing structure) 16.

[0042] As shown in FIG. 3, a gas layer 29B as a heat insulator is provided in the other side cover 10B as well. The side cover 10B has a hollow structure having a space therein. The side cover 10B includes an inner side cover

31B forming an end surface of the rotor chamber 1 and an outer side cover 32B located outwardly of the inner side cover 31B in the axial direction of the rotation shafts 7. The configuration of the side cover 10B is substantially the same as that of the side cover 10A. The descriptions of the side cover 10A with reference to FIGS. 3 and 4 can be applied to the side cover 10B, and therefore other detailed descriptions of the side cover 10B will be omitted.

[0043] The gas layer 29B formed in the side cover 10B is located between the pump casing 2 and the bearing housing 12. The gas layer 29B has a lower thermal conductivity than that of the side cover 10B. Therefore, the gas layer 29B has a function of reducing heat transfer from the pump casing 2 to the bearing housing 12 via the side cover 10B. In particular, the gas layer 29B can maintain the inside of the rotor chamber 1 at a high temperature while the cooling liquid, flowing through the cooling pipe 22, can cool the motor housing 14 and the bearing housing 12. Further, since the gas layer 29B substantially reduces a cross section of the side cover 10B, it contributes to the reduction of heat transfer from the pump casing 2 to the bearing housing 12.

[0044] FIG. 5 is a cross-sectional view showing another embodiment of the vacuum pump apparatus. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiment described with reference to FIG. 3, and therefore repetitive descriptions will be omitted. In this embodiment, a plurality of heat insulating members 41A and 42A as heat insulators are provided in the side cover 10A. The side cover 10A includes an inner side cover 31A forming an end surface of the rotor chamber 1 and an outer side cover 32A located outwardly of the inner side cover 31A in the axial direction of the rotation shafts 7.

[0045] The plurality of heat insulating members 41A and 42A are sandwiched between the inner side cover 31A and the outer side cover 32A. Specifically, the inner side cover 31A and the outer side cover 32A are separated from each other (i.e., not in contact with each other), and the plurality of heat insulating members 41A and 42A are in contact with both the inner side cover 31A and the outer side cover 32A. The plurality of heat insulating members 41A and 42A as the heat insulator are located between the pump casing 2 and the gear housing 16 and have a lower thermal conductivity than that of the side cover 10A. Therefore, the plurality of heat insulating members 41A and 42A have a function of reducing heat transfer from the pump casing 2 to the gear housing 16 via the side cover 10A.

[0046] FIG. 6 is an exploded perspective view showing the side cover 10A and the plurality of heat insulating members 41A and 42A shown in FIG. 5. The plurality of heat insulating members 41A and 42A include a heat insulating plate 41A having two through-holes 45 through which the rotation shafts 7 extend, and a plurality of heat insulating spacers 42A arranged around the heat insulating plate 41A. A recess 47 is formed in the outer surface of the inner side cover 31A, and the heat insulating plate 41A is arranged in the recess 47. In one embodiment, the recess 47 may be formed in the inner surface of the outer side cover 32A, and the heat insulating plate 41A may be arranged in the recess 47 of the outer side cover 32A. The heat insulating plate 41A of the present embodiment is a single structure, but may be separated into a plurality of structures. A seal (not shown), such as an O-ring, is arranged between the heat insulating plate 41A and the inner side cover 31A. A seal (not shown), such as an O-ring, is arranged between the heat insulating plate 41A and the outer side cover 32A.

[0047] The heat insulating plate 41A and the heat insulating spacers 42A have lower thermal conductivities than that of the side cover 10A. Therefore, the heat insulating plate 41A and the heat insulating spacers 42A can reduce heat transfer from the pump casing 2 to the gear housing 16 via the side cover 10A, and can maintain the inside of the rotor chamber 1 at a high temperature. In particular, the heat insulating plate 41A and the heat insulating spacers 42A can maintain the inside of the rotor chamber 1 at a high temperature while the cooling liquid, flowing through the cooling pipe 21 (see FIG. 5), can cool the gear housing 16.

[0048] The heat insulating plate 41A and the heat insulating spacers 42A are made of material(s) having lower thermal conductivity than that of the material constituting the side cover 10A. In the present embodiment, the pump casing 2 and the side covers 10A and 10B constituting the rotor chamber 1 are made of cast iron. The heat insulating plate 41A and the heat insulating spacers 42A are made of metal, such as stainless steel, titanium, or spheroidal graphite-based austenite cast iron (or Ni-Resist), which has a lower thermal conductivity than that of the material of the side cover 10A. In this embodiment, the heat insulating plate 41A and the heat insulating spacers 42A are made of stainless steel. Stainless steel has a lower thermal conductivity than that of cast iron. Further, stainless steel has high mechanical rigidity, so that high dimensional accuracy can be ensured when the vacuum pump apparatus is assembled. However, the heat insulating plate 41A and/or the heat insulating spacers 42A may be made of another material, such as resin, as long as the heat insulating plate 41A and/or the heat insulating spacers 42A have a lower thermal conductivity than that of the material of the side cover 10A and have high mechanical rigidity.

[0049] A total cross-sectional area of the heat insulating plate 41A and the heat insulating spacers 42A is smaller than a cross-sectional area of the side cover 10A. Therefore, the heat insulating plate 41A and the heat insulating spacers 42A, having small thermal conductivity and small cross-sectional area, contribute to the reduction of heat transfer from the pump casing 2 to the gear housing 16.

[0050] As shown in FIG. 5, a plurality of heat insulating members 41B and 42B (i.e., a heat insulating plate 41B and a plurality of heat insulating spacers 42B) as heat insulator are provided in the other side cover 10B as well.

The side cover 10B includes an inner side cover 31B forming an end surface of the rotor chamber 1 and an outer side cover 32B located outwardly of the inner side cover 31B in the axial direction of the rotation shafts 7.

[0051] The configurations and arrangements of the side cover 10B, the heat insulating plate 41B, and the plurality of heat insulating spacers 42B are substantially the same as those of the side cover 10A, the heat insulating plate 41A, and the plurality of heat insulating spacers 42A. The descriptions of the side cover 10A, the heat insulating plate 41A, and the plurality of heat insulating spacers 42A with reference to FIGS. 5 and 6 are also applicable to the side cover 10B, the heat insulating plate 41B, and the plurality of heat insulating spacers 42B, and therefore detailed descriptions thereof will be omitted.

[0052] The heat insulating plate 41B and the heat insulating spacers 42B provided in the side cover 10B are located between the pump casing 2 and the bearing housing 12. The heat insulating plate 41B and the heat insulating spacers 42B have lower thermal conductivity than that of the side cover 10B. Therefore, the heat insulating plate 41B and the heat insulating spacers 42B have a function of reducing heat transfer from the pump casing 2 to the bearing housing 12 via the side cover 10B. In particular, the heat insulating plate 41B and the heat insulating spacers 42B can maintain the inside of the rotor chamber 1 at a high temperature while the cooling liquid, flowing through the cooling pipe 22, can cool the motor housing 14 and the bearing housing 12.

[0053] A total cross-sectional area of the heat insulating plate 41B and the heat insulating spacers 42B is smaller than a cross-sectional area of the side cover 10B. Therefore, the heat insulating plate 41B and the heat insulating spacers 42B, having small thermal conductivity and small cross-sectional area, contribute to the reduction of heat transfer from the pump casing 2 to the bearing housing 12.

[0054] FIG. 7 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiments described with reference to FIGS. 1 to 4, and therefore repetitive descriptions will be omitted. In this embodiment, as shown in FIG. 7, the vacuum pump apparatus includes both the heat insulating structures 25A and 25B and the gas layers 29A and 29B. According to this embodiment, the inside of the rotor chamber 1 can be maintained at a high temperature by the heat insulating structures 25A and 25B and the gas layers 29A and 29B.

[0055] FIG. 8 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiments described with reference to FIGS. 1, 2, 5, and 6, and therefore repetitive descriptions will be omitted. In this embodiment, as shown in FIG. 8, the vacuum pump apparatus includes both the heat insulating structures 25A and 25B and the heat insulating members 41A, 42A, 41B and 42B. According to the present embodiment, the heat insulating structure 25A, 25B and the heat insulating members 41A, 42A, 41B, 42B form double heat insulators, so that the inside of the rotor chamber 1 can be maintained at a high temperature.

[0056] In order to keep the rotor chamber 1 at a higher temperature, a heater 50 may be provided on the outer surface of the pump casing 2 as shown in FIG. 9. The type of the heater 50 is not particularly limited, but for example, an electric heater may be attached to the outer surface of the pump casing 2. Since the pump casing 2 is heated by the heater 50 and the rotor chamber 1 is maintained at a high temperature, solidification of by-product contained in the process gas can be reliably prevented. Further, since the heat insulating structures 25A and 25B have a function of retaining the heat in the rotor chamber 1, the electric power required for operating the heater 50 can be reduced.

[0057] The embodiment shown in FIG. 9 has a structure in which the heater 50 is attached to the outer surface of the pump casing 2 of the vacuum pump apparatus of the embodiment shown in FIG. 1. The heater 50 shown in FIG. 9 can also be applied to each of the embodiments shown in FIGS. 3, 5, 7 and 8.

[0058] FIG. 10 is a cross-sectional view showing an embodiment in which side heaters 55A and 55B are embedded in the side covers 10A and 10B, and FIG. 11 is a cross-sectional view taken along line A-A of FIG. 10. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiments described with reference to FIGS. 1 and 2, and therefore repetitive descriptions will be omitted.

[0059] The side cover 10A includes inner side cover 31A forming the end surface of the rotor chamber 1 and outer side cover 32A located outwardly of the inner side cover 31A in the axial direction of the rotation shafts 7. The side heater 55A is arranged between the inner side cover 31A and the outer side cover 32A.

[0060] As shown in FIG. 11, the outer surface of the inner side cover 31A has a groove 56 surrounding through-holes 27 into which the rotation shafts 7 are inserted, and the side heater 55A is installed in the groove 56. The side heater 55A is arranged so as to surround the through-holes 27. The side heater 55A is an annular heater arranged so as to surround the rotation shafts 7 extending through the through-holes 27. The type of the side heater 55A is not particularly limited, but a sheathed heater, which is a kind of electric heater, can be used for the side heater 55A.

[0061] Since the side cover 10A is located closer to the gear housing 16 in which the cooling pipe 21 is installed than the pump casing 2, the temperature of the side cover 10A tends to be lower than that of the pump casing 2. According to the embodiment shown in FIGS. 10 and 11, the side heater 55A is installed between the pump casing 2 and the gear housing (housing structure) 16. Since the side heater 55A can heat the side cover

10A itself, the inside of the rotor chamber 1 whose end surface is formed by the side cover 10A can be heated to a high temperature.

[0062] The specific configuration for arranging the side heater 55A in the side cover 10A is not limited to the embodiment shown in FIGS. 10 and 11. For example, the side cover 10A having a hole in which the side heater 55A is arranged may be formed by casting, and the side heater 55A may be inserted into the hole. In this case, the side cover 10A may not be separated into the inner side cover 31A and the outer side cover 32A.

[0063] In one embodiment, as shown in FIG. 12, a plurality of side heaters 55A may be arranged in the side cover 10A. In the embodiment shown in FIG. 12, two side heaters 55A extending in parallel with each other are arranged in the side cover 10A. Three or more side heaters 55A may be provided.

[0064] As shown in FIG. 10, the side heater 55B is also arranged in the side cover 10B. The side cover 10B includes inner side cover 31B forming the end surface of the rotor chamber 1 and outer side cover 32B located outwardly of the inner side cover 31B in the axial direction of the rotation shafts 7. The outer surface of the inner side cover 31B has a groove (not shown), and the side heater 55B is installed in the groove. The side heater 55B is an annular heater arranged so as to surround the rotation shafts 7. Since the descriptions of the side heater 55A and the side cover 10A with reference to FIGS. 10 to 12 can be applied to the side heater 55B and the side cover 10B, other descriptions of the side heater 55B and the side cover 10B will be omitted.

[0065] The side heaters 55A and 55B shown in FIGS. 10 to 12 can also be applied to the respective embodiments shown in FIGS. 3, 5, 7, and 8.

[0066] FIG. 13 is a cross-sectional view showing an embodiment of the vacuum pump apparatus including the heat insulating structures 25A and 25B and the heat insulating members 41A, 42A, 41B and 42B shown in FIG. 8 and the side heaters 55A and 55B shown in FIG. 10. FIG. 14 is a cross-sectional view taken along line B-B shown in FIG. 13. As shown in FIG. 14, the side heater 55A is arranged so as to surround the heat insulating plate 41A. Although not shown, the side heater 55B is also arranged so as to surround the heat insulating plate 41B. As shown in FIG. 15, a plurality of side heaters 55A may be provided. Similarly, a plurality of side heaters 55B may be provided.

[0067] According to the embodiments shown in FIGS. 13 to 15, the inside of the rotor chamber 1 can be maintained at a high temperature by the combination of the double heat insulators 25A, 25B, 41A, 42A, 41B, 42B and the side heaters 55A, 55B. Further, the electric power required for operating the side heaters 55A and 55B can be reduced.

[0068] As shown in FIG. 16, the side heaters 55A and 55B may be combined with the heater 50 attached to the outer surface of the pump casing 2. The combination of the side heaters 55A and 55B and the heater 50 can be applied to each of the above-described embodiments.

[0069] In each of the embodiments described so far, the heat insulators are arranged at both sides of the rotor chamber 1, while the present invention is not limited to such arrangements. In one embodiment, a heat insulator may be located at only one side of the rotor chamber 1. For example, when the gear housing 16 is not provided with the cooling pipe 21, the heat insulating structure 25A and/or the heat insulating members 41A and 42A may be omitted. Similarly, the side heaters 55A and 55B described above are arranged at both sides of the rotor chamber 1, while in one embodiment, the side heater 55A or the side heater 55B may be arranged only at one side of the rotor chamber 1.

[0070] FIG. 17 is a cross-sectional view showing an embodiment of a vacuum pump apparatus including multistage pump rotors. Configurations of this embodiment, which will not be particularly described, are the same as those of the embodiment described with reference to FIG. 13, and therefore repetitive descriptions will be omitted. The vacuum pump apparatus shown in FIG. 17 includes multistage pump rotors 5 each including a plurality of rotors 5a to 5e. The intake port 2a is located at the end of the pump casing 2 on the gear side, and the exhaust port 2b is located at the end of the pump casing 2 on the motor side. As the multistage pump rotors 5 rotate, a gas is transferred from the intake port 2a to the exhaust port 2b while being compressed. The heat of compression generated when the gas is compressed is highest at the exhaust port 2b. Therefore, the temperature on the exhaust side of the rotor chamber 1 is higher than the temperature on the intake side of the rotor chamber 1.

[0071] Some types of process gases contain by-product with relatively low sublimation temperatures. Such by-product is likely to be solidified on the intake side of the rotor chamber 1, while the by-product is less likely to be solidified on the exhaust side of the rotor chamber 1. Therefore, as shown in FIG. 17, the vacuum pump apparatus may have the heat insulating structure 25A and/or the heat insulating member 41A, 42A and/or the side heater 55A only at a location between the gear housing 16 and the pump casing 2.

[0072] 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 having a rotor chamber therein;
a pump rotor arranged in the rotor chamber;
a rotation shaft to which the pump rotor is secured;
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 rotating shaft; and
a heat insulator located between the pump casing and the housing structure.

2. The vacuum pump apparatus according to claim 1, wherein the heat insulator includes a heat insulating structure sandwiched between the side cover and the housing structure.

3. The vacuum pump apparatus according to claim 1 or 2, wherein the side cover has a hollow structure having a space therein, and the heat insulator comprises a gas layer existing in the space of the side cover.

4. The vacuum pump apparatus according to claim 1 or 2, wherein the heat insulator includes a heat insulating member arranged in the side cover.

5. The vacuum pump apparatus according to claim 4, wherein:

the side cover includes an inner side cover forming the end surface of the rotor chamber, and an outer side cover located outwardly of the inner side cover in the axial direction; and
the heat insulating member is sandwiched between the inner side cover and the outer side cover.

6. The vacuum pump apparatus according to claim 5, wherein a cross-sectional area of the heat insulating member is smaller than a cross-sectional area of the side cover.

7. The vacuum pump apparatus according to any one of claims 1 to 6, further comprising a side heater provided in the side cover.

FIG. 1

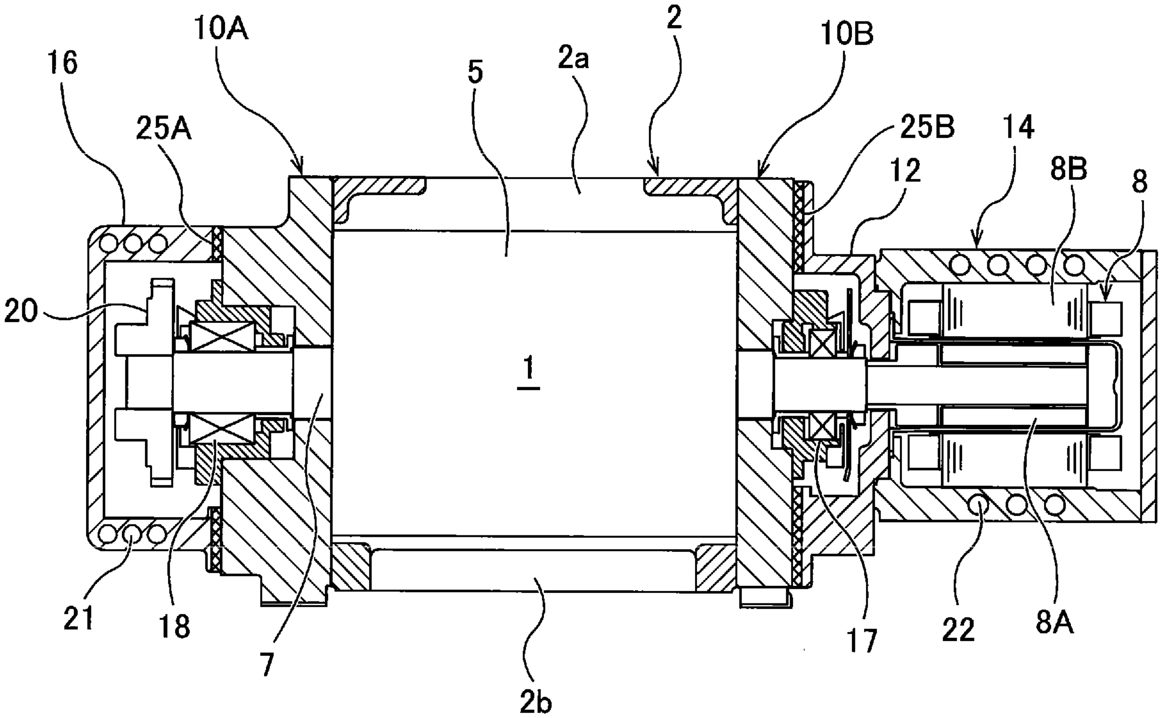


FIG. 2

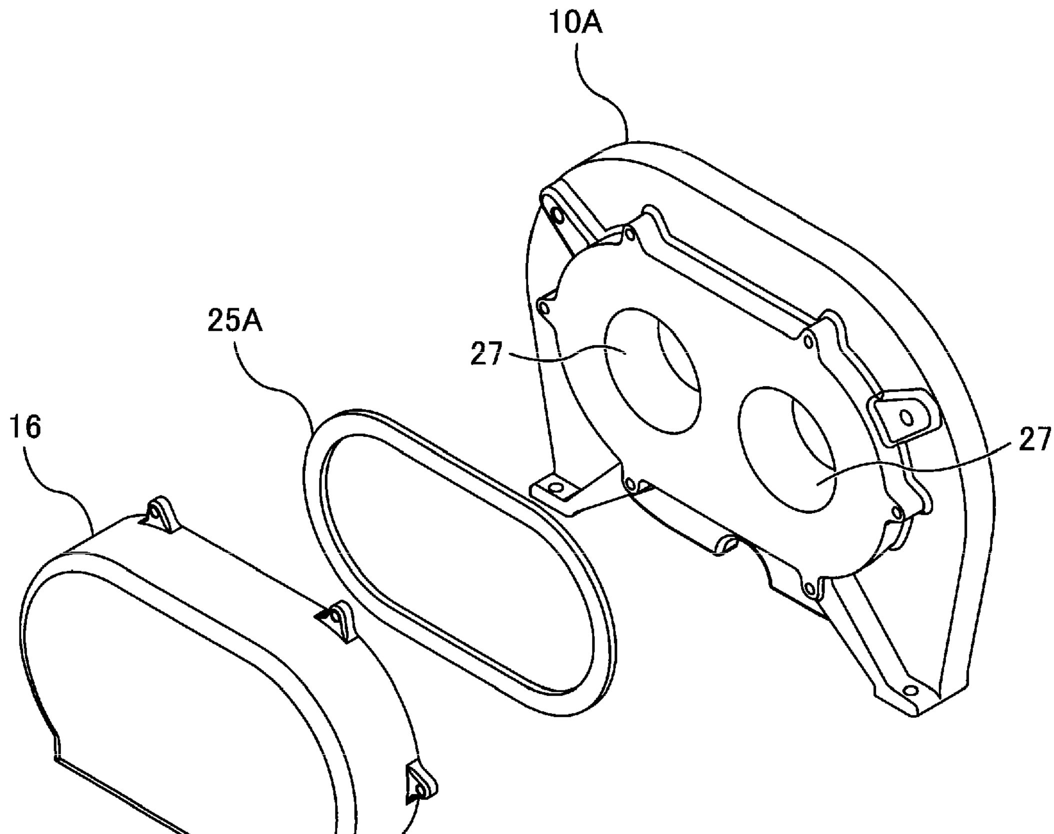
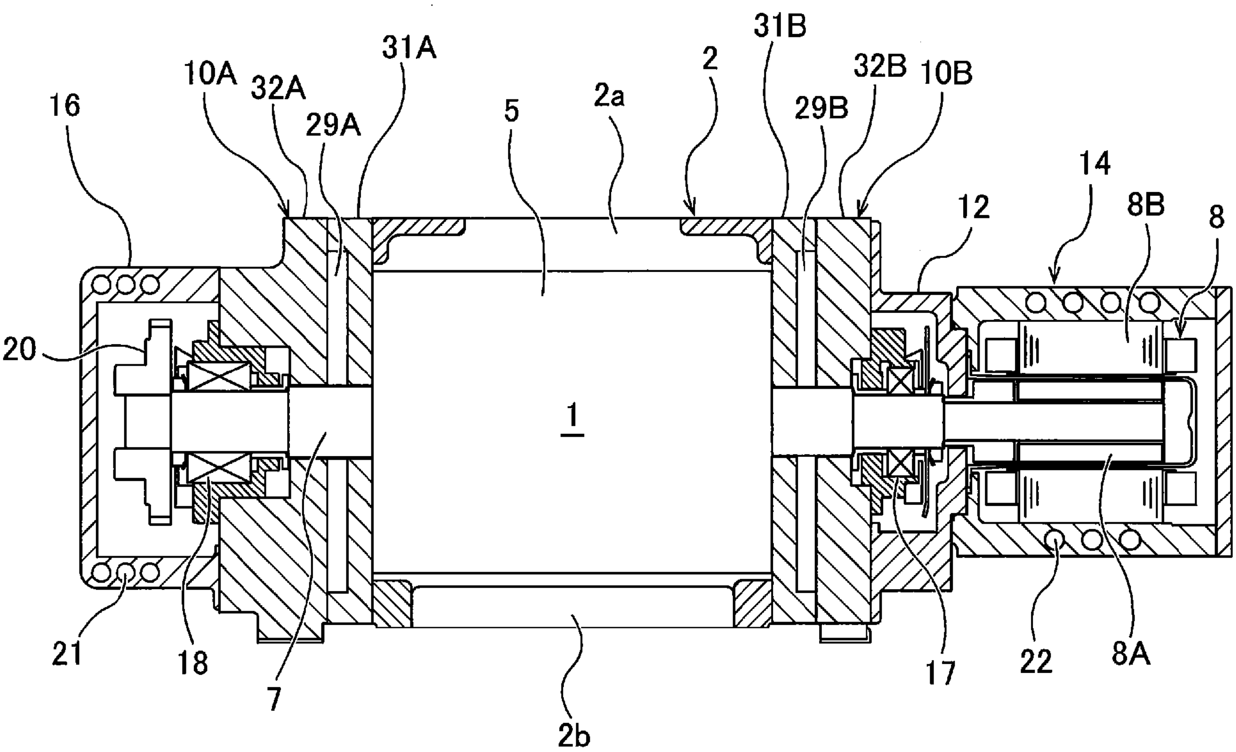


FIG. 3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29A
31A
5
2a
2
31B
29B
32B
10B
12
14
8B
8
20
1
21
18
7
2b
17
22
8A

FIG. 4

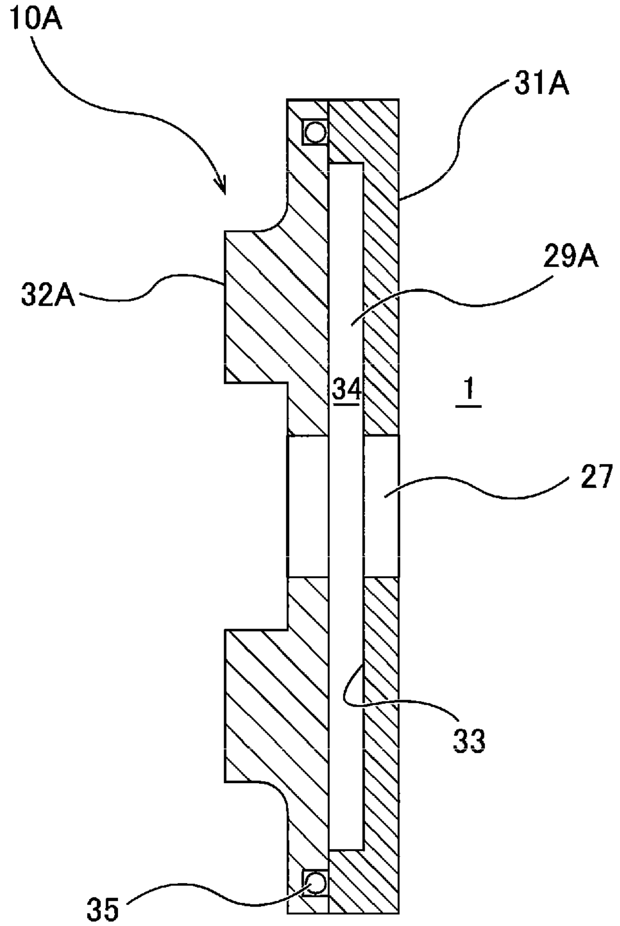
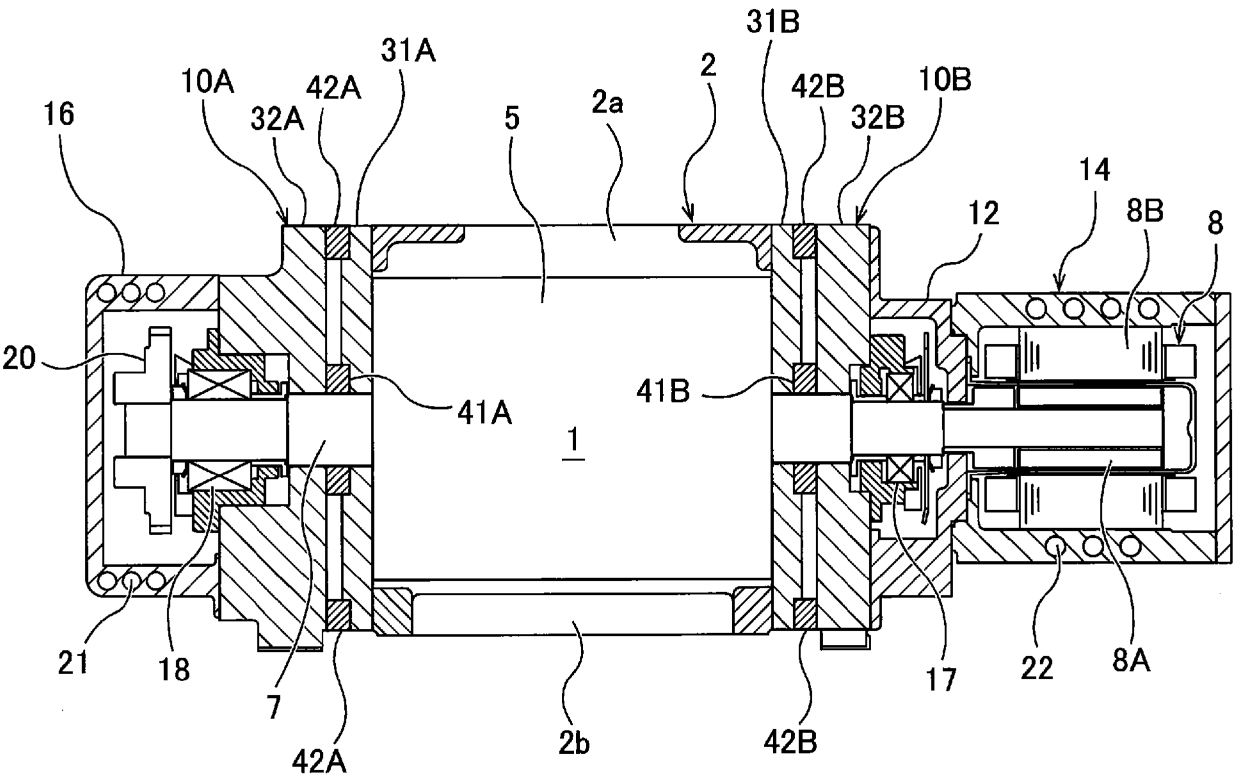


FIG. 5



16
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32A
42A
31A
5
2a
2
31B
42B
32B
10B
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42B
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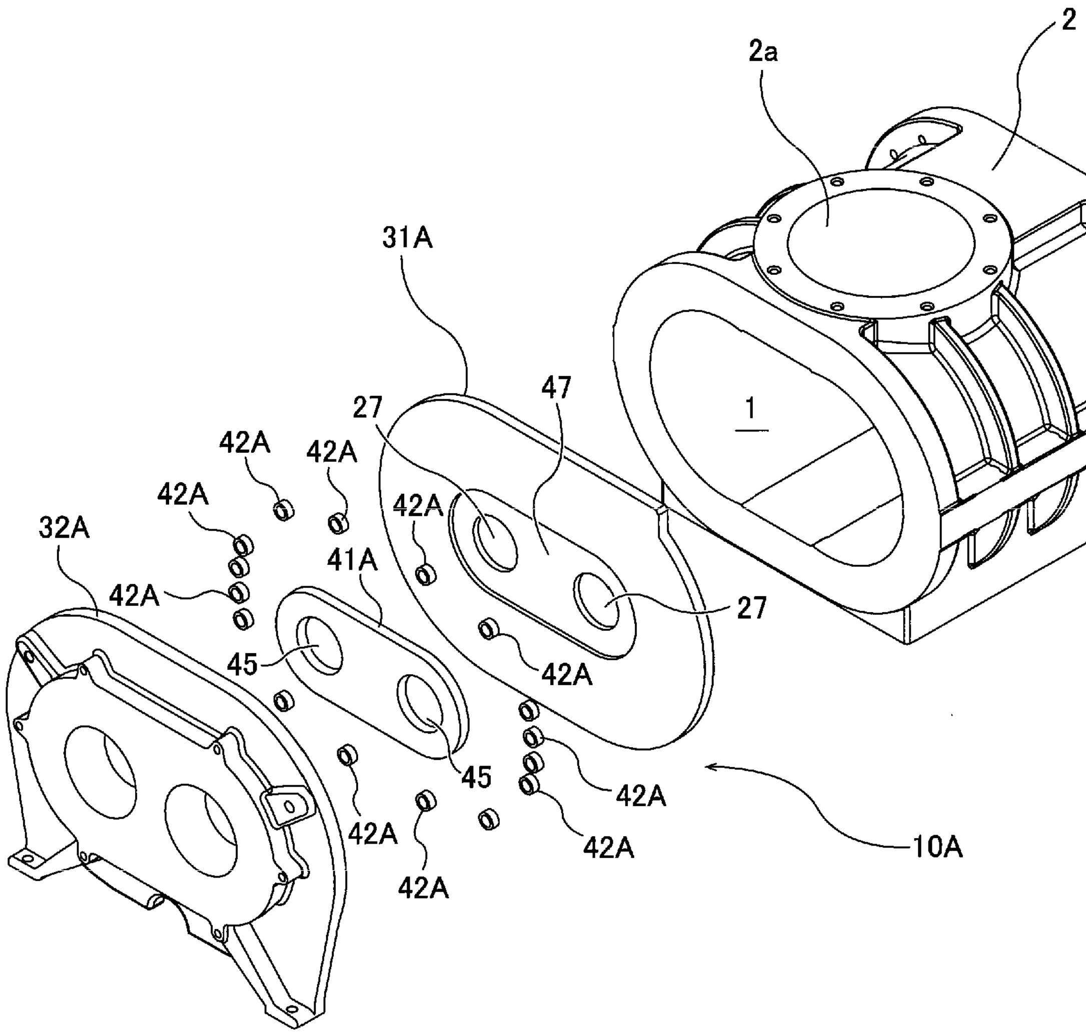
22
8A

FIG. 6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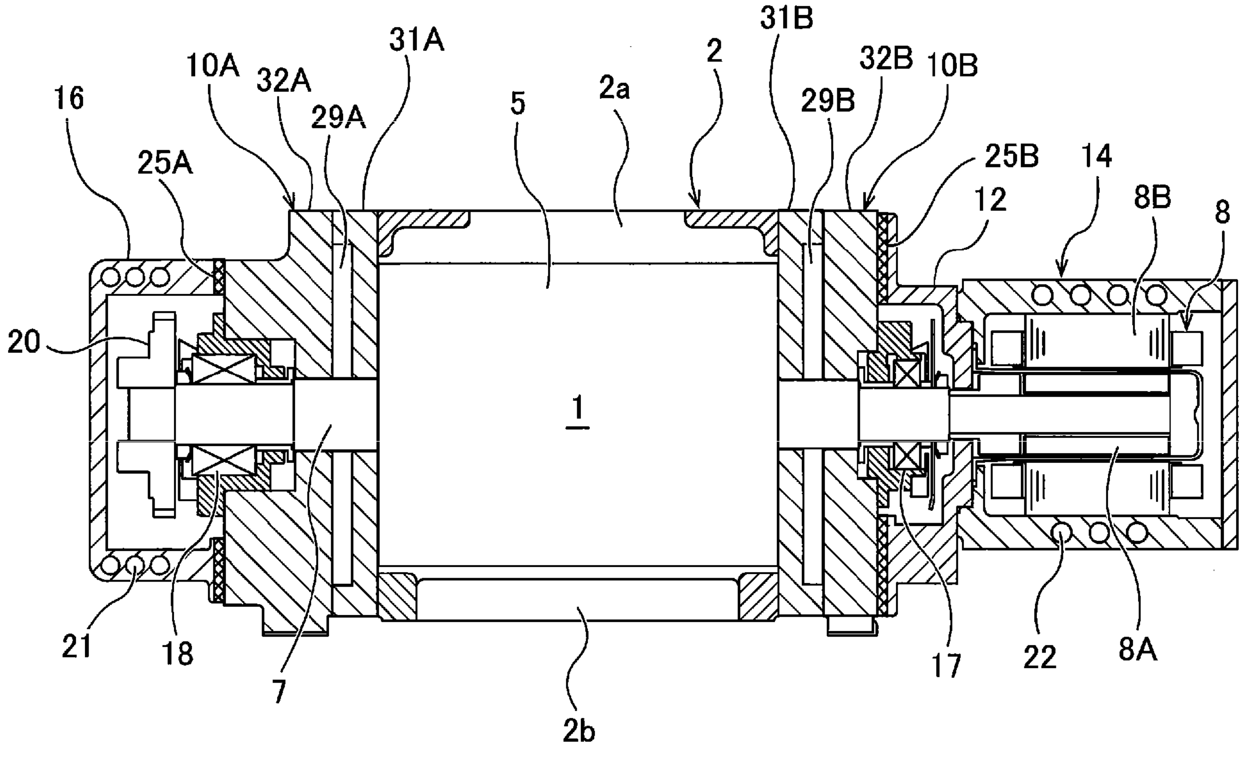
42A
42A
42A
10A

FIG. 7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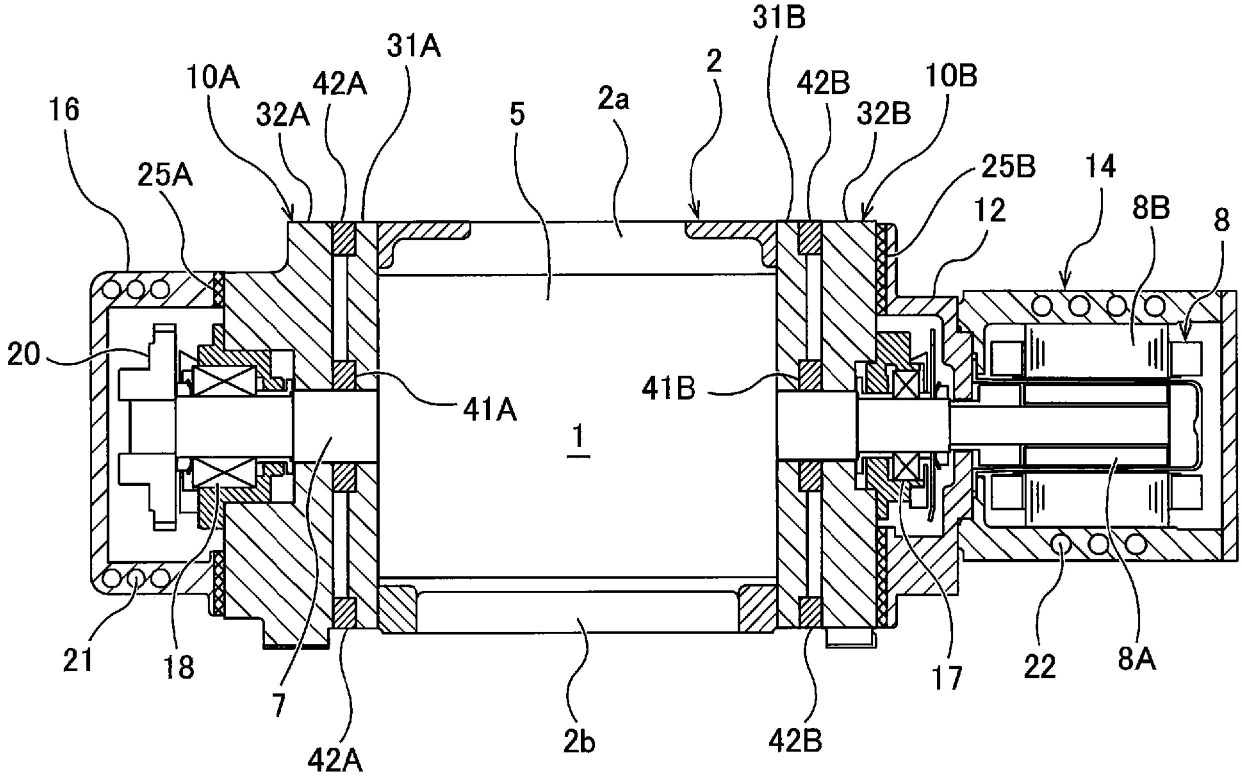
8A

FIG. 8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7
42A
2b
42B
17
22
8A

FIG. 9

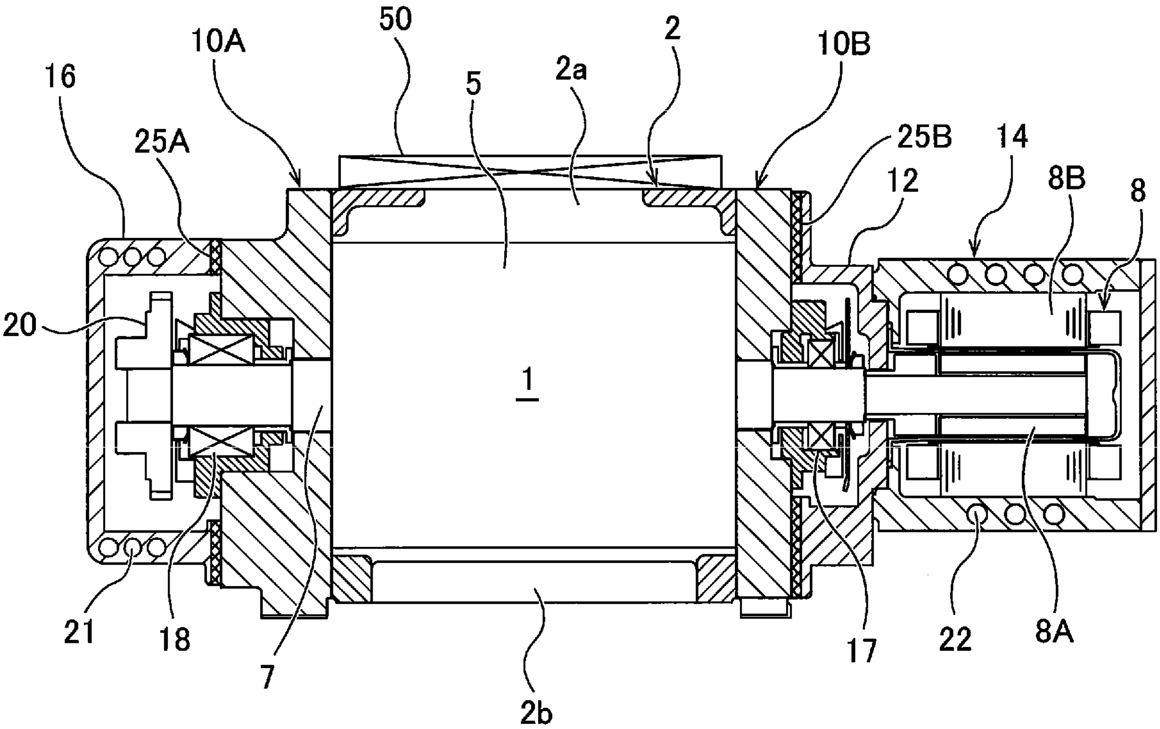
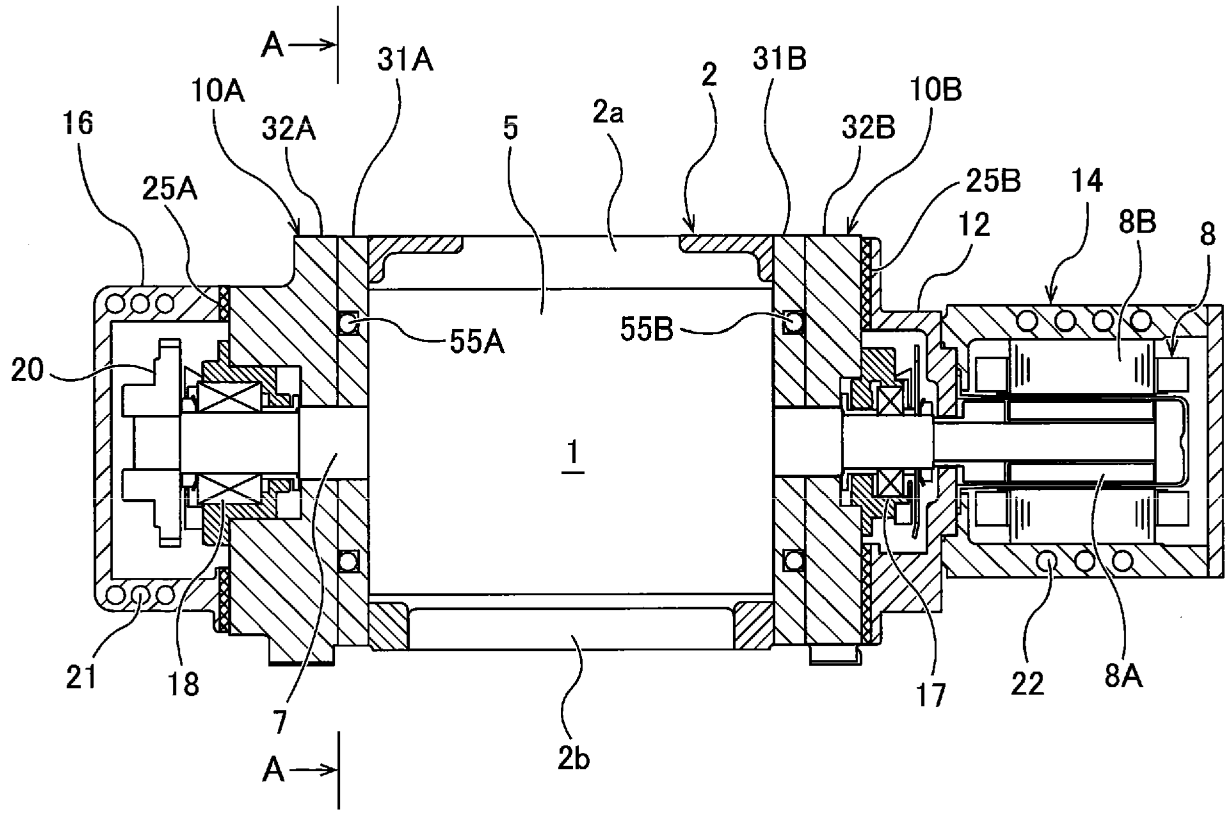


FIG. 10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2b

FIG. 11

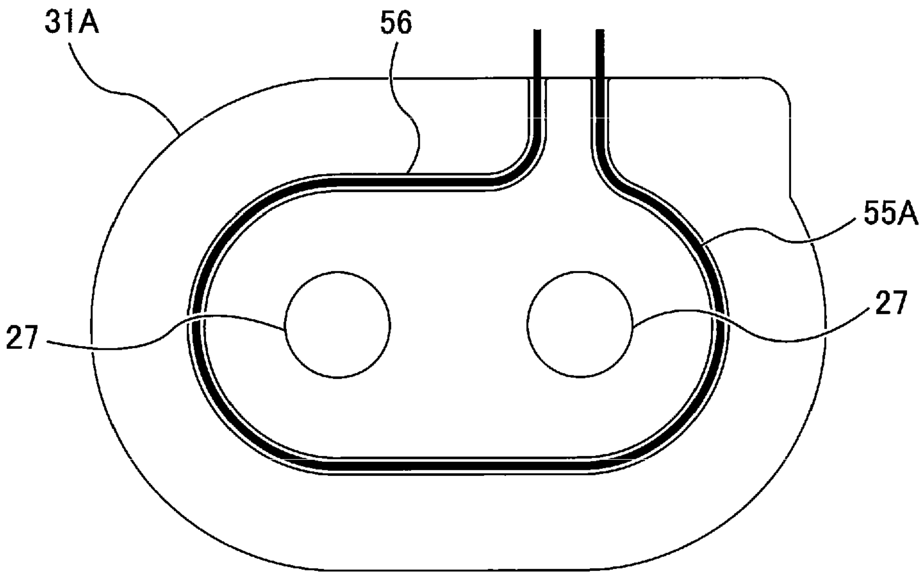


FIG. 12

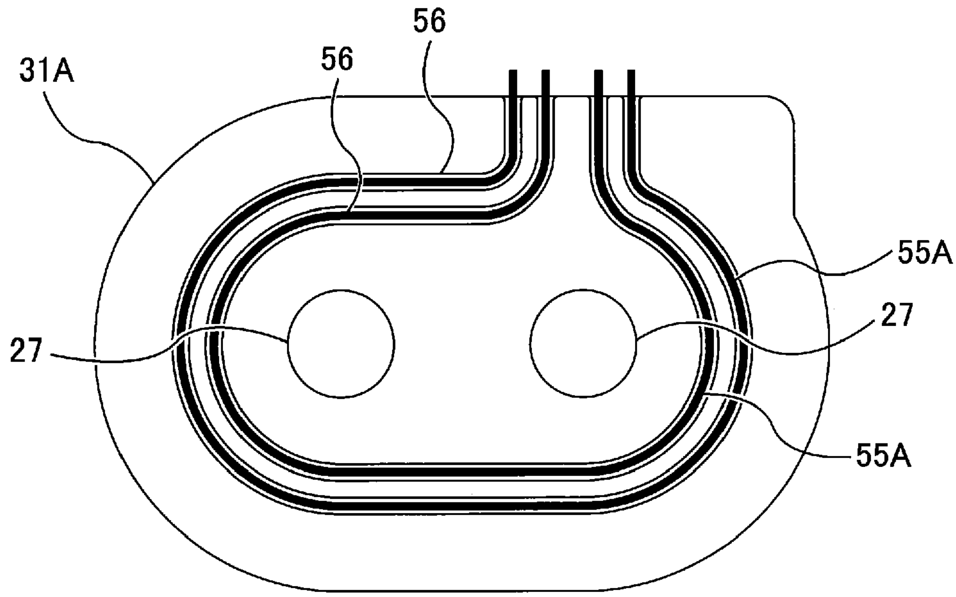
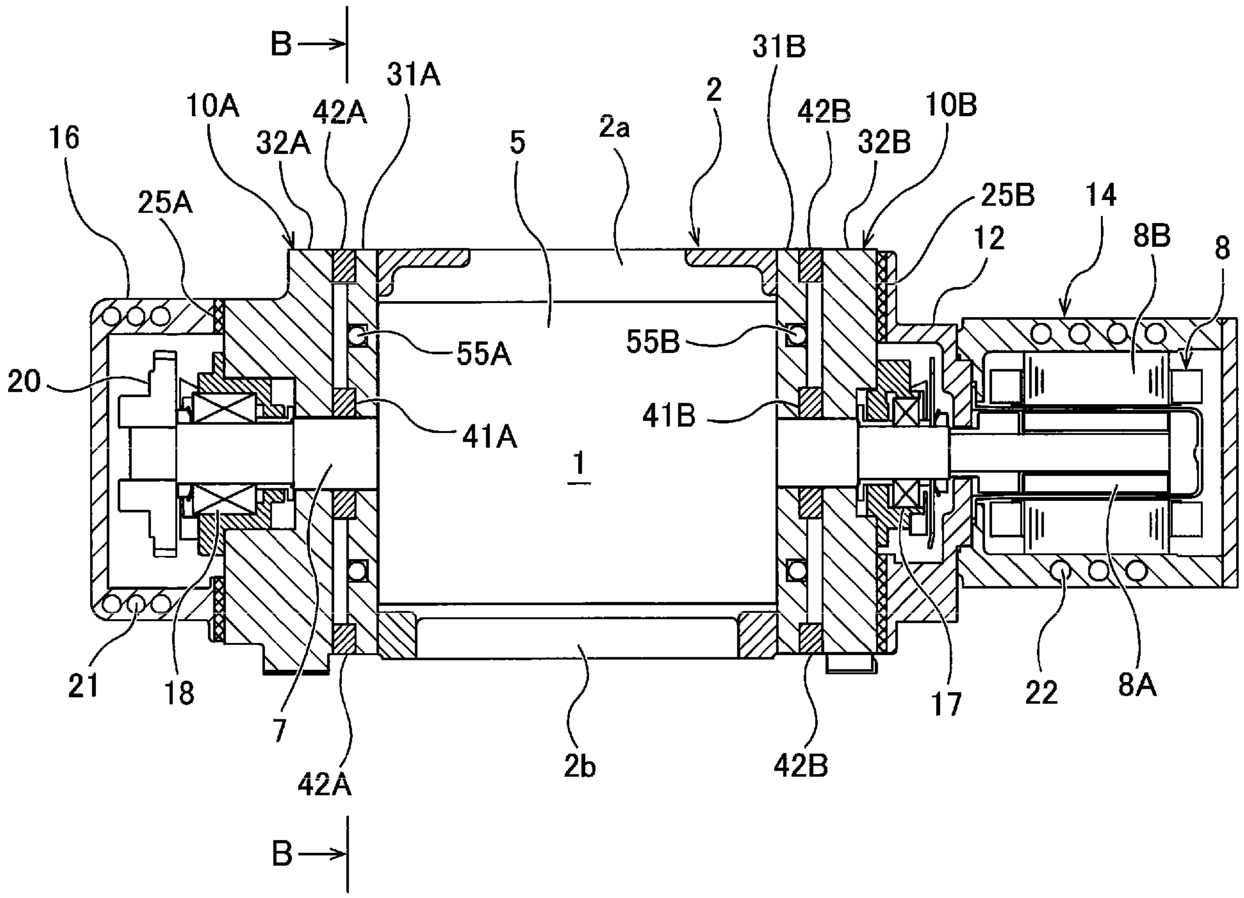


FIG. 13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8B
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21
18
7
42A
2b
42B
17
22
8A
B

FIG. 14

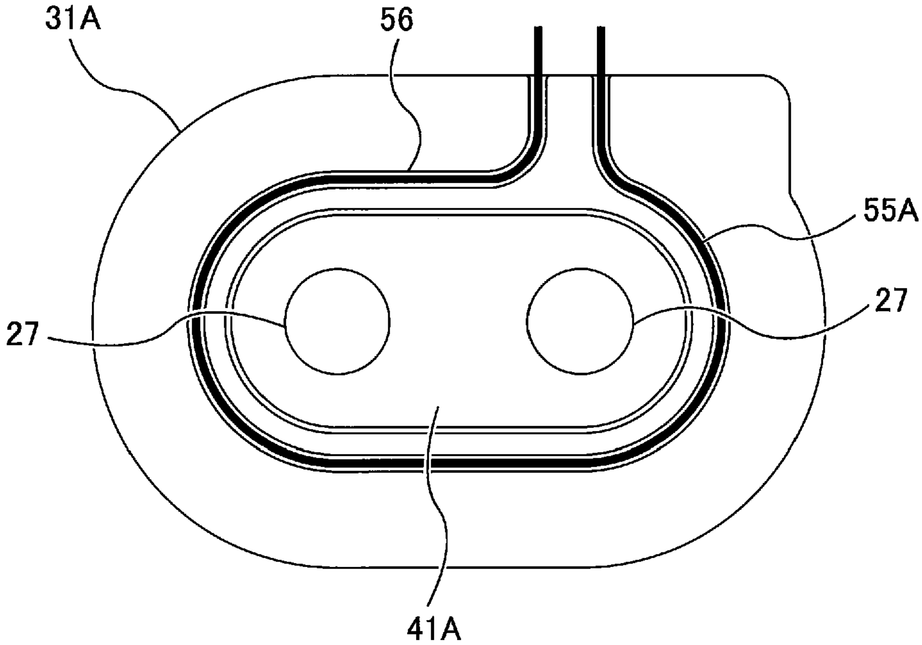

FIG. 15

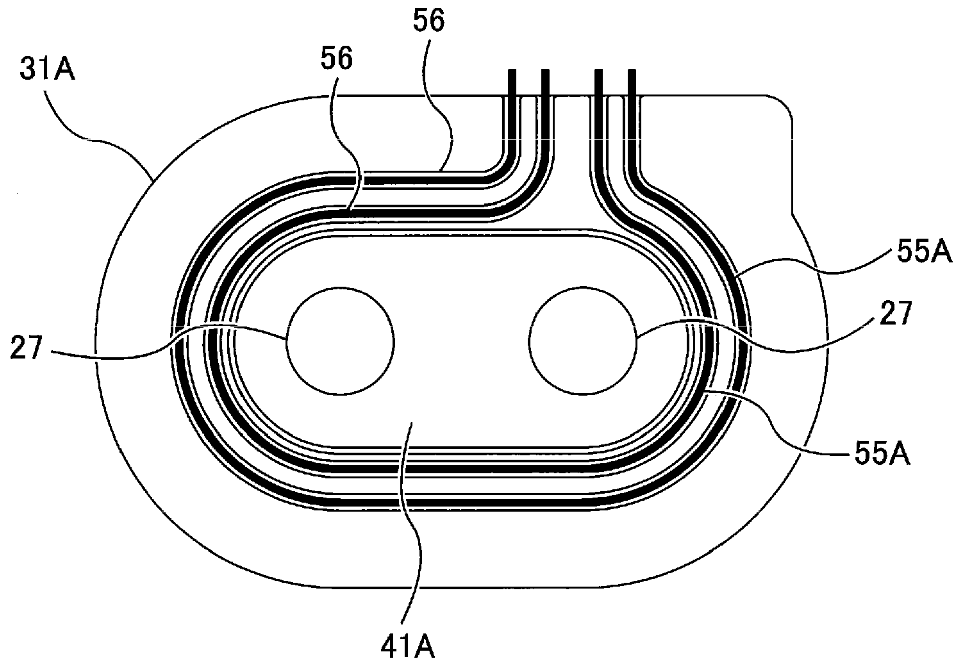

FIG. 16

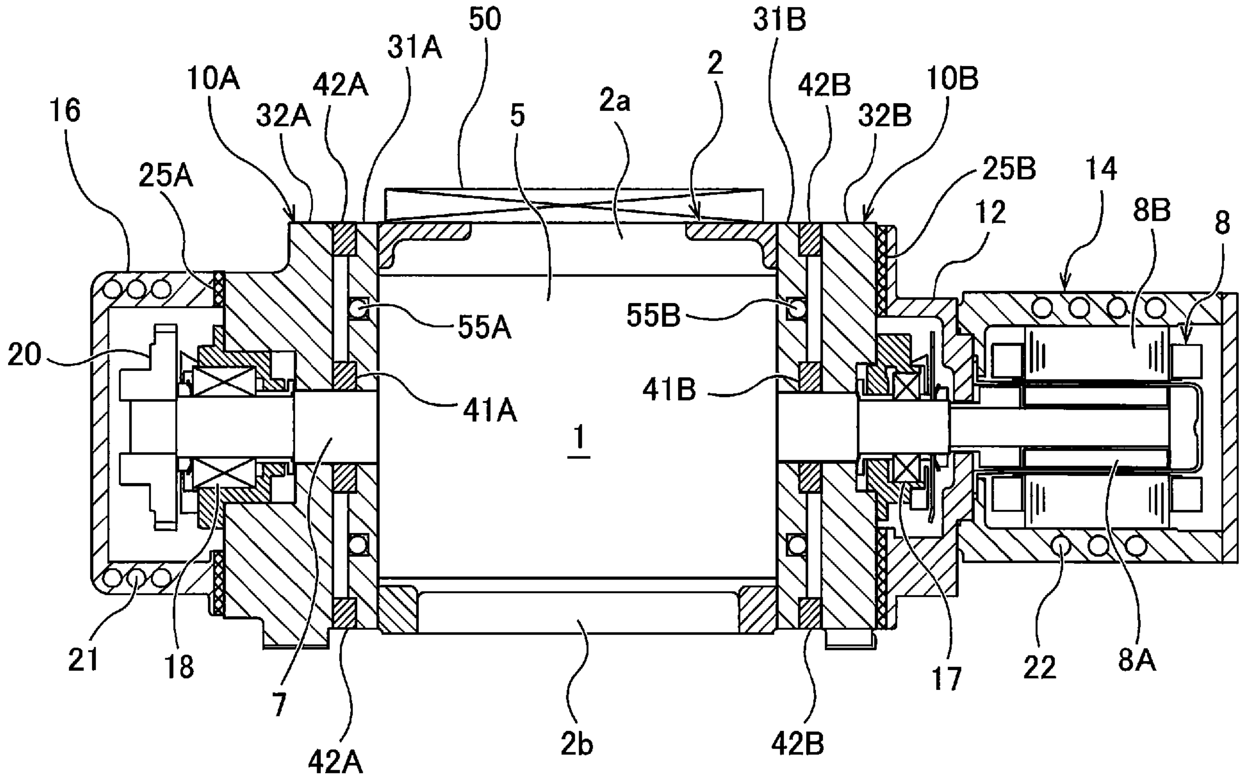
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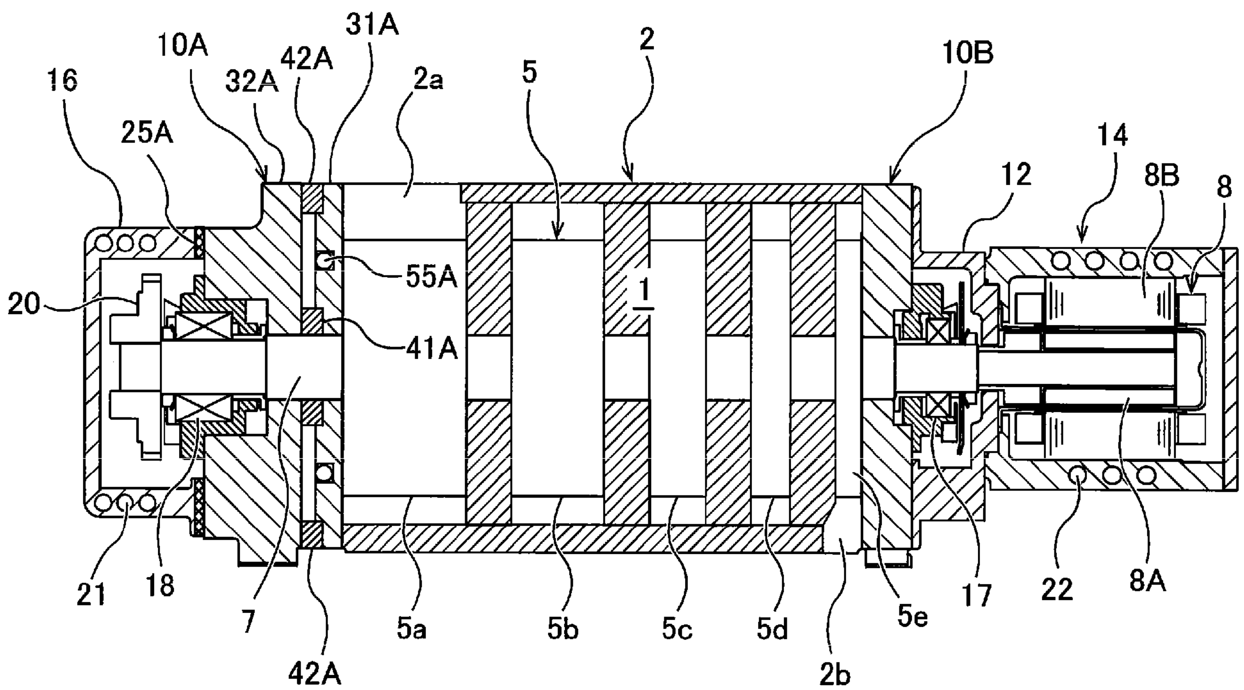
FIG. 17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5a
5b
5c
5d
2b
5e
17
22
8A
42A

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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 1640

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			F04C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	2 March 2021	Descoubes, Pierre

2

EPO FORM 1503 03.82 (P04C01)

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02-03-2021

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