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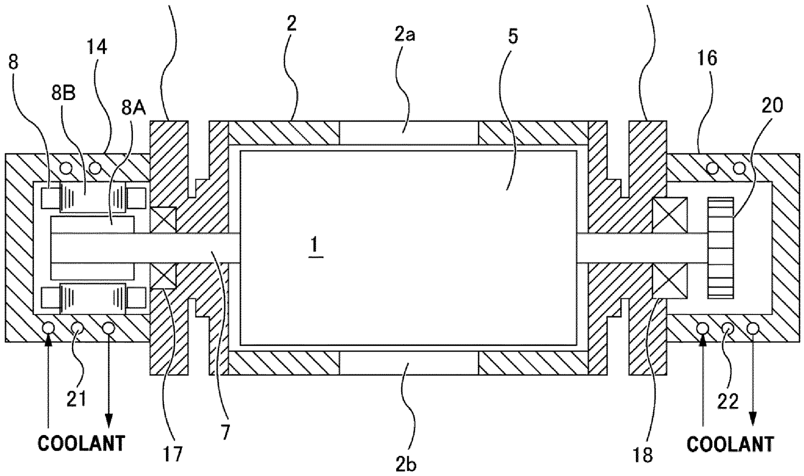
(54) VACUUM PUMP APPARATUS

(57) 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 is disclosed. A side cover is provided between a pump casing and a motor housing. The side cover includes an inner wall portion forming an end surface of the rotor chamber, an outer wall portion located outwardly of the inner wall portion, and a narrow portion located between the inner wall portion and the outer wall portion. The inner wall portion, the outer wall portion, and the narrow portion are an integrally-formed structure, and the narrow portion has a cross-sectional area smaller than cross-sectional areas of the inner wall portion and the outer wall portion.

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 evacuating 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 evacuated 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 the 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 coolant 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; pump rotors disposed in the rotor chamber; rotation shafts to which the pump rotors are fixed; an electric motor coupled to the rotation shafts; a side cover forming an end surface of the rotor chamber; and a housing structure located outwardly of the side cover in an axial direction of the rotation shafts, wherein the side cover includes an inner wall portion forming the end surface of the rotor chamber, an outer wall portion located outwardly of the inner wall portion in the axial direction of the rotation shafts, and a narrow portion located between the inner wall portion and the outer wall portion, the inner wall portion, the outer wall portion, and the narrow portion are an integrally-formed structure, and the narrow portion has a cross-sectional area smaller than cross-sectional areas of the inner wall portion and the outer wall portion.

[0009] In an embodiment, the vacuum pump apparatus further comprises a heater arranged in the side cover.

[0010] In an embodiment, the heater is removably attached to the side cover.

[0011] In an embodiment, the side cover has a heater housing having a hole, the hole is open in an outer surface of the side cover, and the heater is arranged in the hole..

[0012] In an embodiment, the hole extends linearly, and the heater is a rod-shaped heater.

[0013] In an embodiment, the vacuum pump apparatus further comprises a fixing mechanism configured to removably fix the heater to the heater housing.

[0014] In an embodiment, the heater housing is connected to the inner wall portion.

[0015] In an embodiment, at least a part of the heater housing is separated from the outer wall portion.

[0016] In an embodiment, the vacuum pump apparatus further comprises: a cooling flow passage provided in the housing structure; a flow passage valve coupled to the cooling flow passage; a temperature sensor attached to any one of the electric motor, the side cover, and the housing structure; and a valve controller configured to open the flow passage valve when a temperature measured by the temperature sensor exceeds a threshold value and close the flow passage valve when the temperature falls below the threshold value.

[0017] The side cover having the narrow portion with a small cross-sectional area can reduce heat transfer from the pump casing to the housing structure. Therefore, the inside of the rotor chamber can be maintained at a high temperature. In addition, the heat transfer to the bearing can be reduced, so that the bearing does not exceed its heat resisting temperature.

[0018] The heater can heat the side cover itself, which can in turn increase the temperature in the rotor chamber whose end surface is formed by the side cover.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

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;
FIG. 3 is a view seen from a direction indicated by arrow A in FIG 2;
FIG. 4 is a perspective view of the side cover shown in FIG. 2;
FIG. 5 is a cross-sectional view showing another embodiment of the vacuum pump apparatus;
FIG. 6 is a side view of the side cover shown in FIG. 5;
FIG. 7 is a view seen from a direction indicated by arrow B in FIG. 6;
FIG. 8 is a perspective view of the side cover shown in FIG. 6; and
FIG. 9 is a cross-sectional view showing still another embodiment of the vacuum pump apparatus.

DESCRIPTION OF EMBODIMENTS

[0020] Embodiments will now be described with reference to the drawings.

[0021] 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.

[0022] 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 an electric motor 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 and 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 rotation shafts 7. In one embodiment, a pair of electric motors 8 may be coupled to the pair of rotation shafts 7, respectively.

[0023] 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.

[0024] 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).

[0025] 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 evacuating a process gas that has been introduced into the process chamber.

[0026] 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.

[0027] Each rotary 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 structures, and the housing structures are not limited to this embodiment. For example, the housing structure may be a bearing housing that holds the bearing.

[0028] A pair of gears 20 that mesh with each other are arranged in the gear housing 16. In FIG. 1, only one gear 20 is depicted. The electric motor 8 is rotated by a motor driver (not shown), and one rotation shaft 7 that is coupled the electric motor 8 rotates the other rotation shaft 7 to which the electric motor 8 is not coupled in the opposite direction via the gears 20.

[0029] In one embodiment, a pair of electric motors 8 may be coupled to the pair of rotation shafts 7, respectively. The pair of motors 8 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 are synchronously rotated in opposite directions. The role of the gears 20 in this case is to prevent out of the synchronous rotations of the pump rotors 5 due to a sudden external cause.

[0030] 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 rotors 5.

[0031] A cooling flow passage 21 is provided in the motor housing 14. Similarly, a cooling flow passage 22 is provided in the gear housing 16. The cooling flow passage 21 extends an entire peripheral wall of the motor housing 14, and the cooling flow passage 22 extends an entire peripheral wall of the gear housing 16. The cooling flow passage 21 and the cooling flow passage 22 are coupled to a coolant supply source (not shown). A coolant is supplied from the coolant supply source to the cooling flow passage 21 and the cooling flow passage 22. The coolant flowing through the cooling flow passage 21 can cool the motor housing 14, whereby the electric motor 8 and the bearings 17 arranged in the motor housing 14 can be cooled. The coolant flowing through the cooling flow passage 22 can cool the gear housing 16, whereby the gears 20 and the bearings 18 arranged in the gear housing 16 can be cooled.

[0032] 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 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 are cooled by the coolant flowing through the cooling passages 21 and 22.

[0033] 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 cast iron.

[0034] Since the side covers 10A and 10B basically have the same configuration, the side cover 10A will be described below. FIG. 2 is a side view of the side cover 10A, FIG. 3 is a view seen from a direction indicated by arrow A in FIG. 2, and FIG. 4 is a perspective view of the side cover 10A shown in 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.

[0035] The side cover 10A includes 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 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 (see FIG. 1), 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 housed. A heat insulating material may be arranged between the outer wall portion 32 and the motor housing 14.

[0036] The inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are an integrally-formed structure. In the present embodiment, the inner wall portion 31, the outer wall portion 32, and the narrow portion 33 are an integrally-formed casting. As described above, since the side cover 10A includes the integrally-formed structure, it is not necessary to separately prepare a plurality of parts and assemble them. As a result, a manufacturing cost can be reduced.

[0037] The narrow portion 33 has an outer peripheral length shorter than those 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, but 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. As a result, the heat is unlikely to be transferred from the inner wall portion 31 to the outer wall portion 32 through the narrow portion 33. Although descriptions are omitted, the side cover 10B basically has the same configuration. Since the side covers 10A and 10B include the narrow portions 33 have a high heat insulation, the inside of the rotor chamber 1 can be maintained at a high temperature. In addition, the side covers 10A and 10B can prevent the pump casing 2 from being cooled by the coolant flowing through the cooling flow passage 21 and the cooling flow passage 22.

[0038] FIG. 5 is a cross-sectional view showing another embodiment of the vacuum pump apparatus. Configurations of the present embodiment, which will not be particularly described, are the same as those of the embodiments described with reference to FIGS. 1 to 4, and duplicate descriptions thereof will be omitted. The vacuum pump apparatus shown in FIG. 5 further includes heaters 40A and 40B arranged in the side covers 10A and 10B, respectively. The heaters 40A and 40B are removably mounted to the side covers 10A and 10B.

[0039] The side covers 10A and 10B have basically the same configuration, and the heaters 40A and 40B have basically the same configuration. Therefore, the side cover 10A and the heater 40A will be described below. FIG. 6 is a side view of the side cover 10A shown in FIG. 5, FIG. 7 is a view seen from a direction indicated by arrow B in FIG. 6, and FIG. 8 is a perspective view of the side cover 10A shown in FIG. 6. 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 integrally-formed structure. Each hole 35a is open in an outer surface of the side cover 10A (more specifically, in an outer surface of the heater housing 35), and each heater 40A is arranged in each hole 35a. In the present embodiment, the two heaters 40A are arranged such that the rotation shafts 7 (see FIG. 5) are located between these two heaters 40A. In one embodiment, only one heater 40A may be provided, or three or more heaters 40A may be provided.

[0040] The hole 35a extends linearly, and the heater 40A is a rod-shaped heater that also extends linearly. The heater 40A is inserted into the hole 35a and fixed to the side cover 10A by a screw 45 which is a fixing mechanism. More specifically, the heater housing 35 has a screw hole 46 communicating with the hole 35a, and the screw 45 is screwed into the screw hole 46 until an end of the screw 45 presses the heater 40A in the hole 35a against the heater housing 35. As a result, the position of the heater 40A is fixed. When the screw 45 is loosened, the heater 40A can be removed from the hole 35a. Since the hole 35a is open in the outer surface of the side cover 10A, the heater 40A can be removed from the side cover 10A without disassembling the vacuum pump apparatus. Therefore, the heater 40A can be easily replaced with a new heater in case the heater 40A gets out of order.

[0041] The heat generated by the heater 40A is transferred to the rotor chamber 1 (see FIG. 5) through the heater housing 35 and the inner wall portion 31 to thereby heat the rotor chamber 1. In particular, since the heater housing 35 and the inner wall portion 31 are integrally formed, an efficiency of the heat transfer from the heater 40A to the inner wall portion 31 is improved.

[0042] As shown in FIG. 8, at least a part of the heater housing 35 is separated from the outer wall portion 32. Although not shown, the entire heater housing 35 may be separated from the outer wall portion 32. With such a configuration, the heat generated by the heater 40A is unlikely to be transferred to the outer wall portion 32. Therefore, the heater 40A hardly heats the motor housing 14 (see FIG. 5), which is a housing structure coupled to the outer wall portion 32, while the heater 40A can heat the rotor chamber 1.

[0043] As shown in FIG. 5, the heater 40B is also arranged in the side cover 10B. The descriptions with reference to FIGS. 6 to 8 can be applied to the side cover 10B and the heater 40B disposed in the side cover 10B, and repetitive descriptions thereof will be omitted.

[0044] FIG. 9 is a cross-sectional view showing another embodiment of the vacuum pump apparatus. Configurations of the present embodiment, which will not be particularly described, are the same as those of the embodiments described with reference to FIGS. 1 to 4, and duplicate descriptions thereof will be omitted. The vacuum pump apparatus shown in FIG. 9 includes cooling flow passages 21 and 22 provided in the motor housing 14 and the gear housing 16 which are housing structures, flow passage valves 51 and 52 coupled to the cooling flow passages, respectively, a temperature sensor 55 attached to the electric motor 8, a temperature sensor 56 attached to the side cover 10B, and a valve controller 60 configured to control operations of the flow passage valves 51 and 52 based on temperatures measured by the temperature sensors 55 and 56. In the present embodiment, the temperature sensor 55 is attached to the motor stator 8B of the electric motor 8, and the temperature sensor 56 is attached to the outer wall portion 32 (see FIGS. 2 to 4) coupled to the gear housing 16. The valve controller 60 is constituted by at least one computer.

[0045] The temperature sensors 55, 56 and the flow passage valves 51, 52 are electrically coupled to the valve controller 60. The temperature sensor 55 attached to the electric motor 8 measures the temperature of the electric motor 8 and transmits a measured value of the temperature to the valve controller 60. The valve controller 60 is configured to open the flow passage valve 51 when the temperature of the electric motor 8 exceeds a predetermined threshold value and close the flow passage valve 51 when the temperature of the electric motor 8 falls below the threshold value. Similarly, the temperature sensor 56 attached to the side cover 10B measures the temperature of the side cover 10B and transmits a measured value of the temperature to the valve controller 60. The valve controller 60 is configured to open the flow passage valve 52 when the temperature of the side cover 10B exceeds a predetermined threshold value and close the flow passage valve 52 when the temperature of the side cover 10B falls below the threshold value.

[0046] According to the present embodiment, the coolant flows through the cooling flow passage 21 in the motor housing 14 only when the temperature of the electric motor 8 exceeds the threshold value, so that excessive cooling of the side cover 10A by the coolant can be prevented. Similarly, the coolant flows through the cooling flow passage 22 in the gear housing 16 only when the temperature of the side cover 10B exceeds the threshold value, so that excessive cooling of the side cover 10B by the coolant can be prevented.

[0047] In one embodiment, the temperature sensor 55 may be attached to the motor housing 14 or the outer wall portion 32 (see FIGS. 2 to 4) of the side cover 10A, instead of the electric motor 8. In this case also, the valve controller 60 is configured to open the flow passage valve 51 when the temperature measured by the temperature sensor 55 exceeds a predetermined threshold value and close the flow passage valve 51 when the temperature measured by the temperature sensor 55 falls below the threshold value. In one embodiment, the temperature sensor 56 may be attached to the gear housing 16, instead of the side cover 10B. The valve controller 60 is configured to open the flow passage valve 52 when the temperature measured by the temperature sensor 56 exceeds a predetermined threshold value and close the flow passage valve 52 when the temperature measured by the temperature sensor 56 falls below the threshold value. These embodiments can also prevent excessive cooling of the side covers 10A and 10B by the coolant.

[0048] The embodiment shown in FIG. 9 may be combined with the embodiments described with reference to FIGS. 5 to 8.

[0049] 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;
    pump rotors disposed in the rotor chamber;
    rotation shafts to which the pump rotors are fixed;
    an electric motor coupled to the rotation shafts;
    a side cover forming an end surface of the rotor chamber; and
    a housing structure located outwardly of the side cover in an axial direction of the rotation shafts,
    wherein the side cover includes an inner wall portion forming the end surface of the rotor chamber, an outer wall portion located outwardly of the inner wall portion in the axial direction of the rotation shafts, and a narrow portion located between the inner wall portion and the outer wall portion,
    the inner wall portion, the outer wall portion, and the narrow portion are an integrally-formed structure, and
    the narrow portion has a cross-sectional area smaller than cross-sectional areas of the inner wall portion and the outer wall portion.

2. The vacuum pump apparatus according to claim 1, further comprising a heater arranged in the side cover.

3. The vacuum pump apparatus according to claim 2, wherein the heater is removably attached to the side cover.

4. The vacuum pump apparatus according to claim 3, wherein:

    the side cover has a heater housing having a hole;
    the hole is open in an outer surface of the side cover; and
    the heater is arranged in the hole.

5. The vacuum pump apparatus according to claim 4, wherein the hole extends linearly and the heater is a rod-shaped heater.

6. The vacuum pump apparatus according to claim 4 or 5, further comprising a fixing mechanism configured to removably fix the heater to the heater housing.

7. The vacuum pump apparatus according to any one of claims 4 to 6, wherein the heater housing is connected to the inner wall portion.

8. The vacuum pump apparatus according to claim 7, wherein at least a part of the heater housing is separated from the outer wall portion.

9. The vacuum pump apparatus according to any one of claims 1 to 8, further comprising:

    a cooling flow passage provided in the housing structure;
    a flow passage valve coupled to the cooling flow passage;
    a temperature sensor attached to any one of the electric motor, the side cover, and the housing structure; and
    a valve controller configured to open the flow passage valve when a temperature measured by the temperature sensor exceeds a threshold value and close the flow passage valve when the temperature falls below the threshold value.

FIG. 1

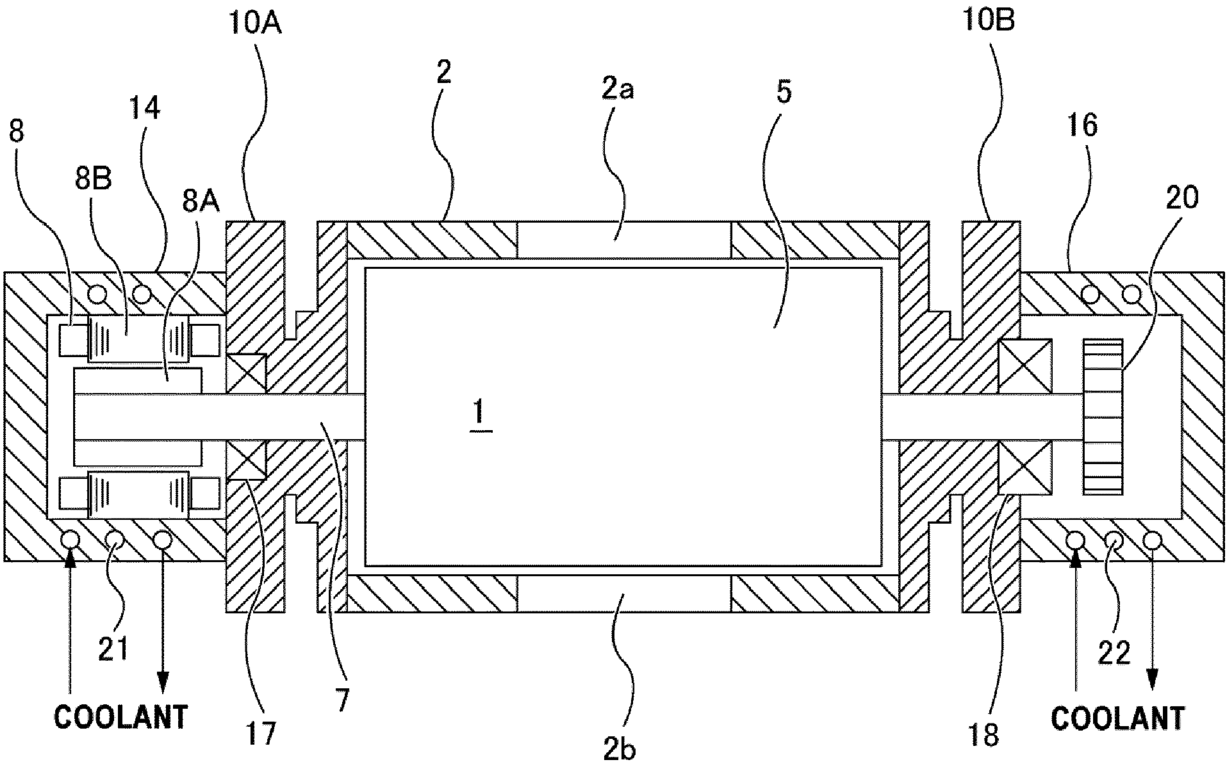

FIG. 2

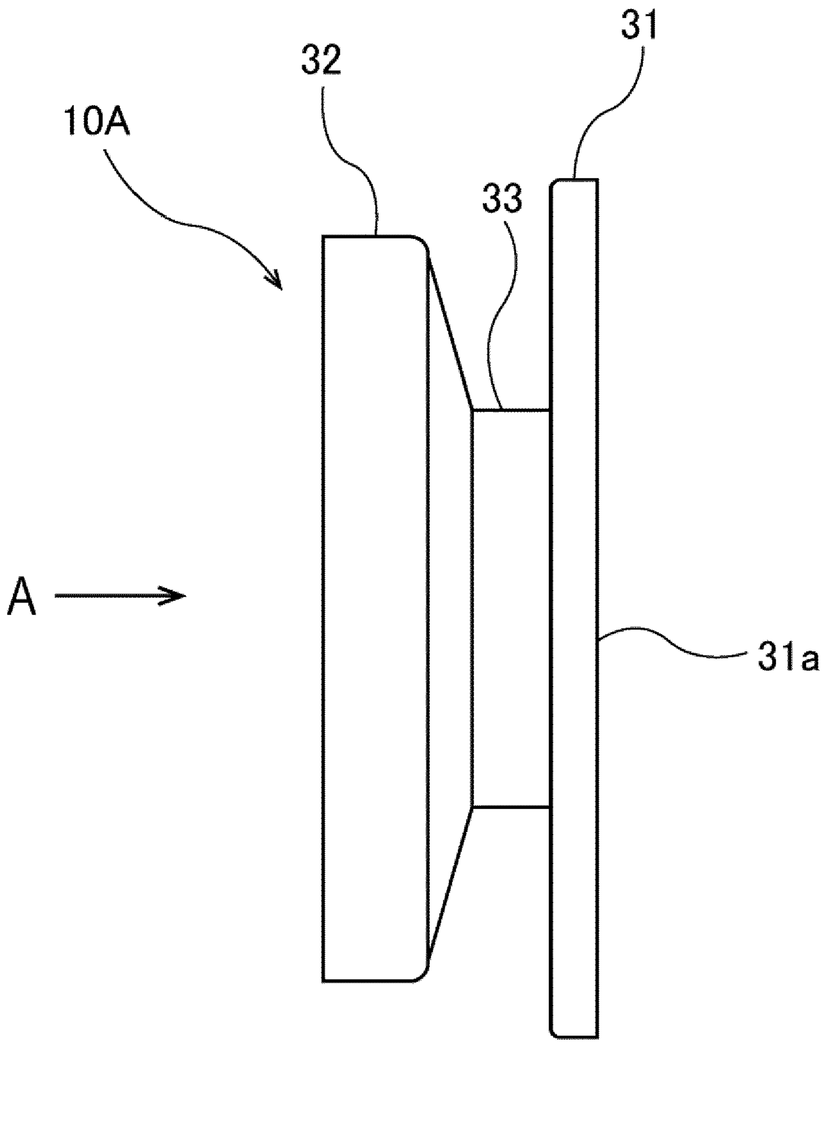

FIG. 3

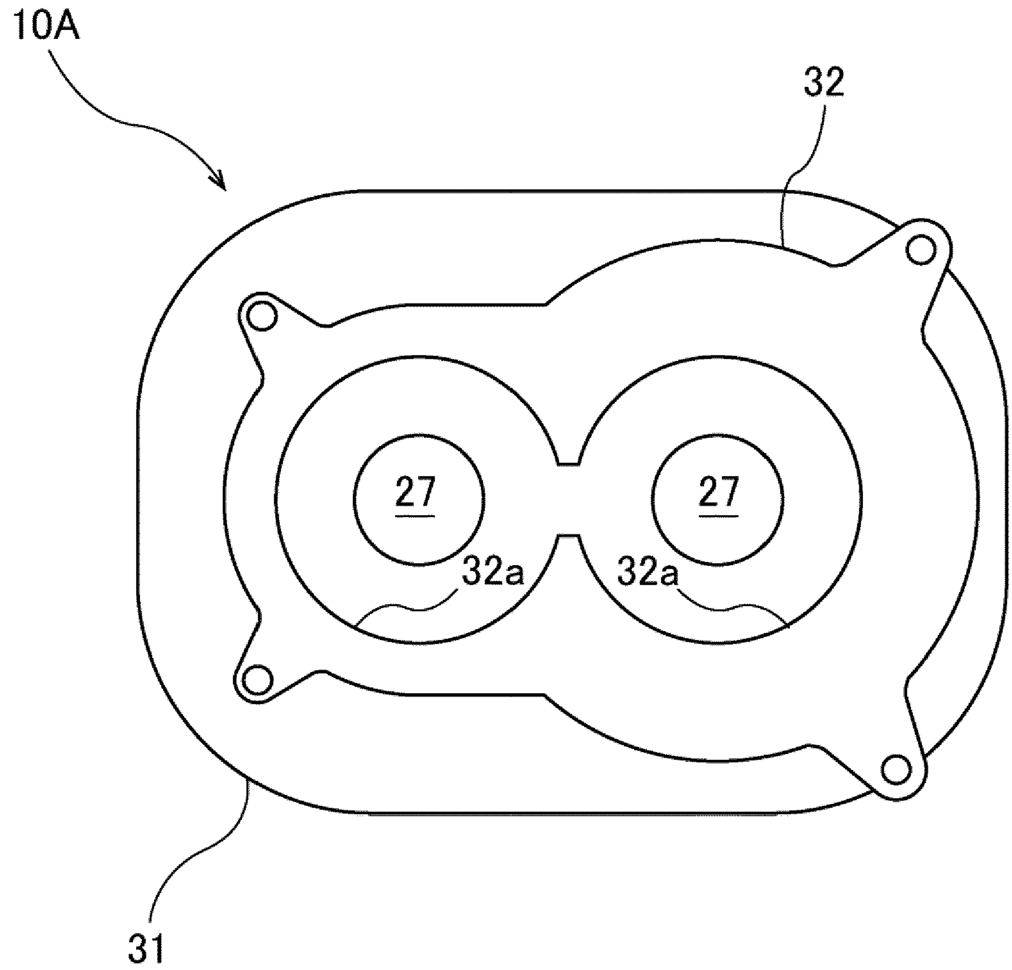

FIG. 4

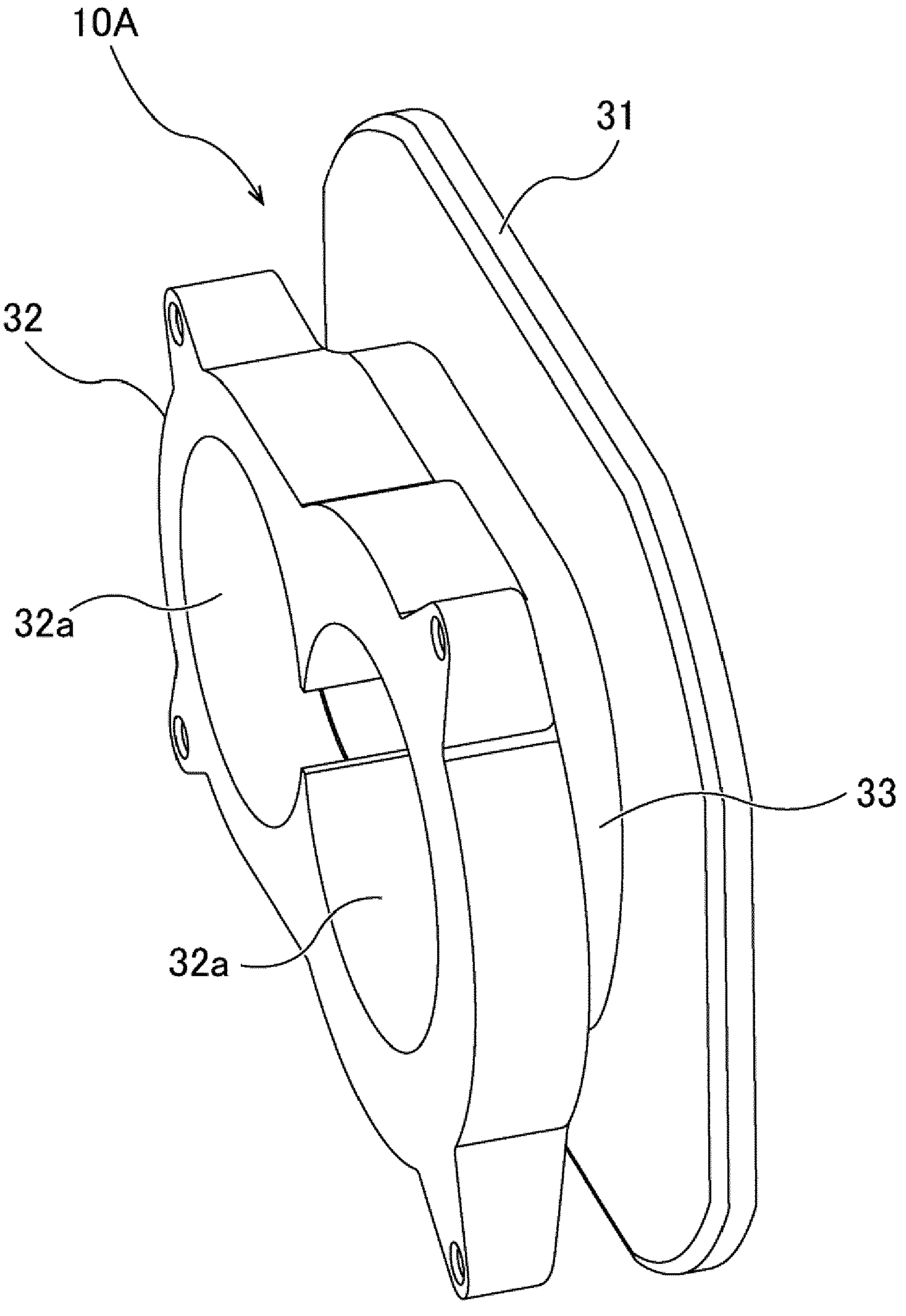

FIG. 5

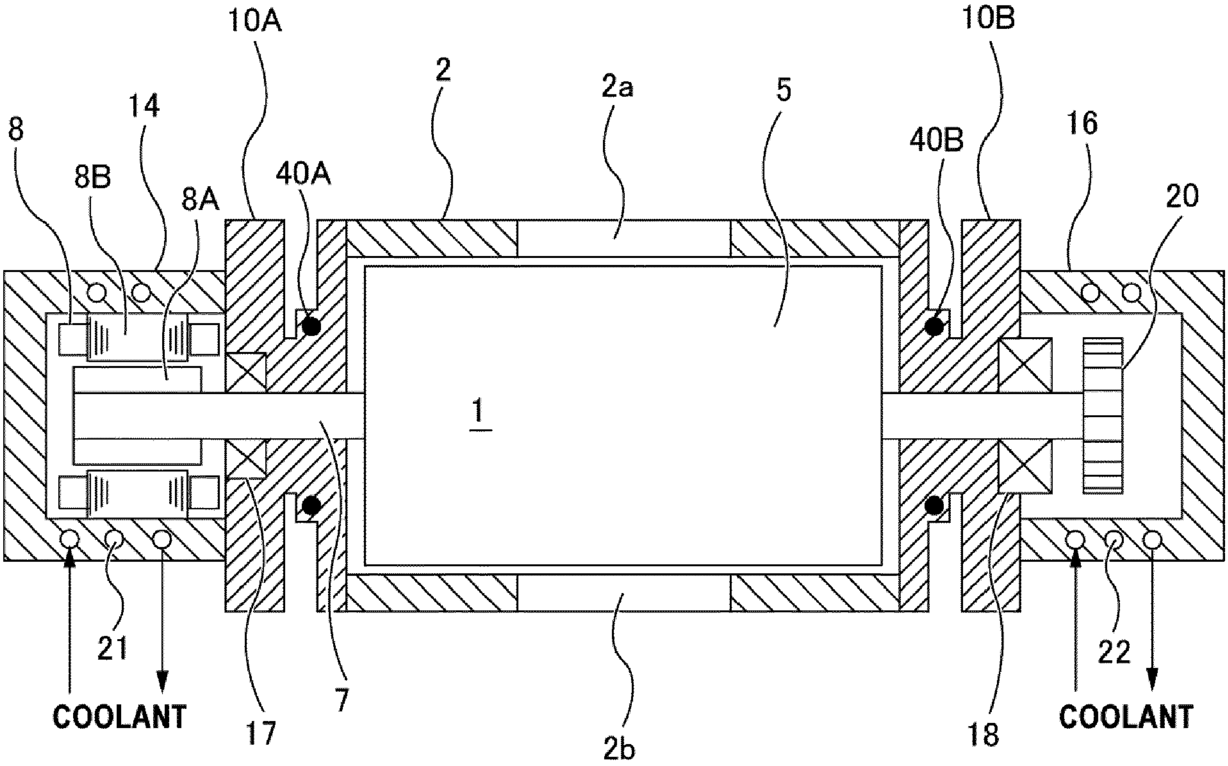
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FIG. 6

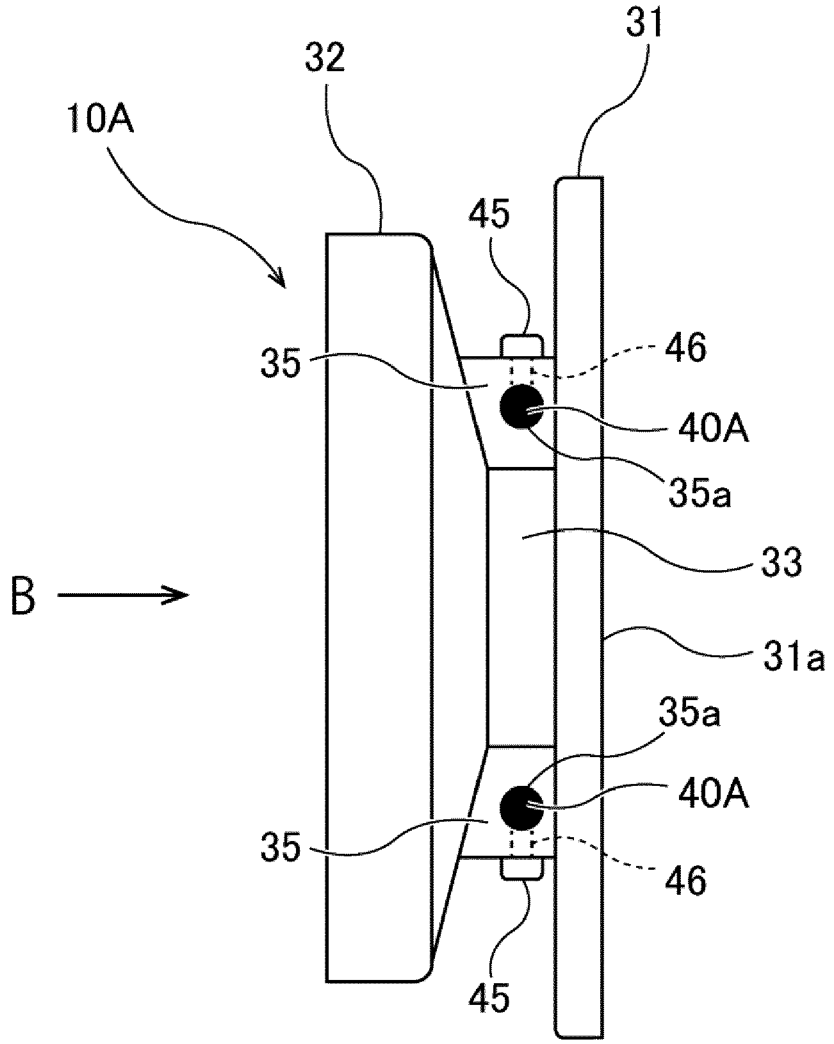


FIG. 7

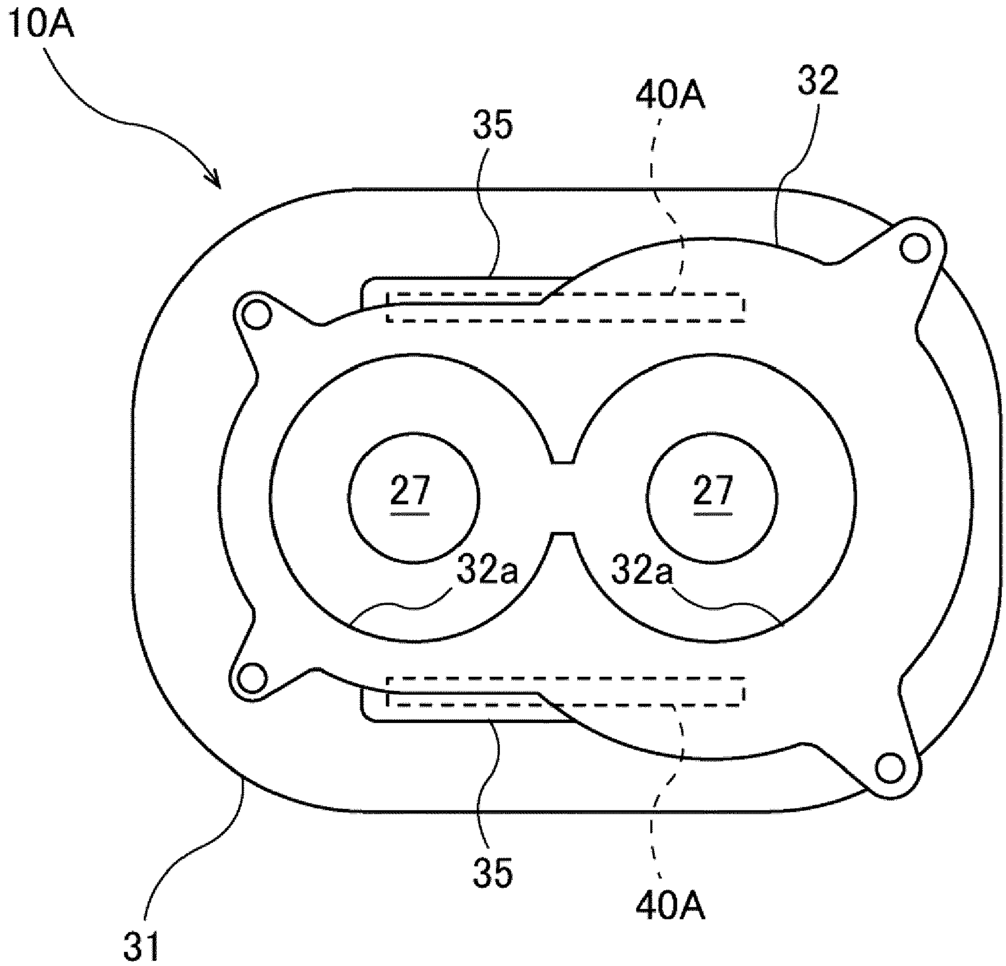


FIG. 8

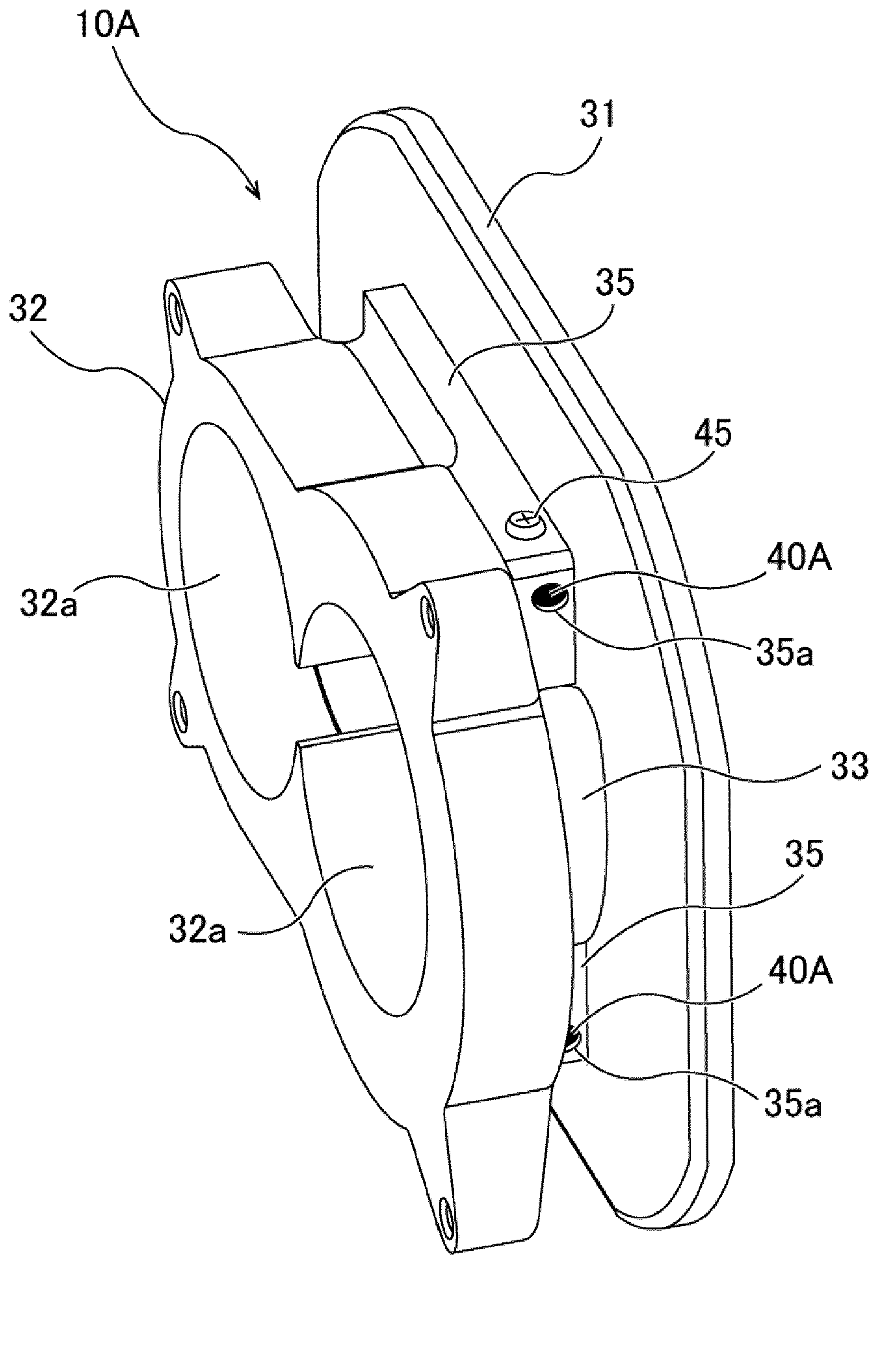
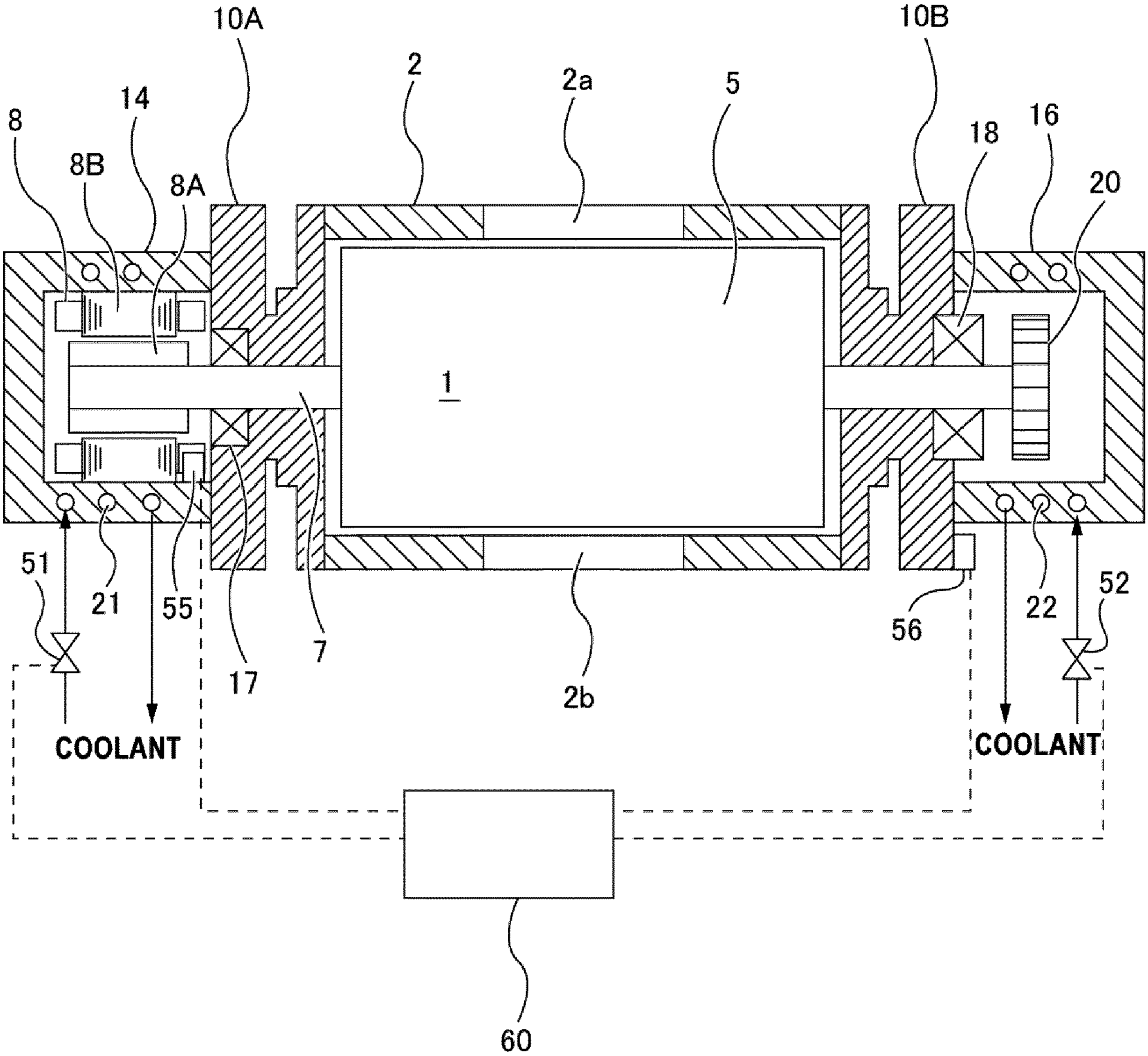


FIG. 9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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003035290 A **[0005]**
- JP 2012251470 A **[0005]**