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

(11) EP 4 239 197 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.09.2023 Bulletin 2023/36

(21) Application number: **23154594.8**

(22) Date of filing: **02.02.2023**

(51) International Patent Classification (IPC):
F04C 18/12 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04C 18/126

(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
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **09.02.2022 JP 2022018854**

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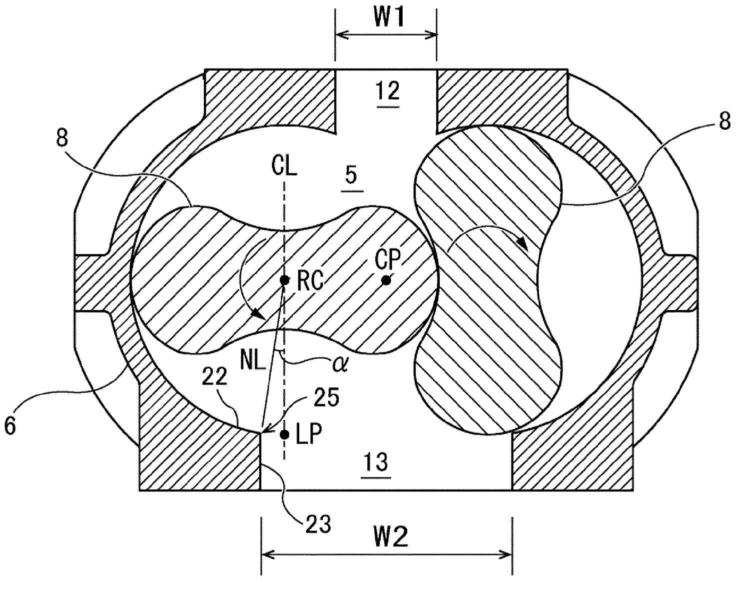
(54) VACUUM PUMP

(57) A vacuum pump that can discharge particles contained in gas from a rotor chamber well is disclosed. The vacuum pump 1 includes: a pump casing 6 having a rotor chamber 5 therein; a pair of Roots rotors 8 disposed in the rotor chamber 5; and a pair of rotation shafts 9 supporting the pair of Roots rotors 8. The pump casing 6 has a gas inlet 12 and a gas outlet 13 communicating with the rotor chamber 5. A connection 25 between an inner wall 22 forming the rotor chamber 5 and an inner wall 23 forming the gas outlet 13 is located on or located more outwardly than a rotor center line CL extending through a center of rotation RC and a bottom dead center LP of each Roots rotor 8.

FIG. 2



EP 4 239 197 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a vacuum pump, and more particularly to a vacuum pump suitable for use in evacuating a process gas used in manufacturing of semiconductor devices, liquid crystal panels, 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. Generally, the vacuum pump used in these manufacturing processes that require high cleanliness is so-called dry vacuum pump that does not use oil in its gas flow passage. One typical example of such a dry vacuum pump is a positive-displacement vacuum pump having a pair of Roots rotors in a rotor chamber which are rotated in opposite directions to deliver the gas.

Citation List

Patent Literature

[0003] Patent document 1: Japanese laid-open patent publication No. 2010-101321

[0004] A process gas may contain particles of by-products. Such particles flow into the vacuum pump along with the process gas. Most of the particles are discharged from the vacuum pump along with the process gas, but some of the particles remain in the rotor chamber and gradually accumulate in the rotor chamber. The particles may be deposited on an inner wall of the rotor chamber and on outer surfaces of the Roots rotors, thus hindering the rotation of the Roots rotors.

SUMMARY OF THE INVENTION

[0005] Therefore, the present invention provides a vacuum pump that can discharge particles contained in gas from a rotor chamber well.

[0006] In an embodiment, there is provided a vacuum pump comprising: a pump casing having at least one rotor chamber therein; at least one pair of Roots rotors disposed in the rotor chamber; and at least one pair of rotation shafts supporting the at least one pair of Roots rotors, wherein the pump casing has a gas inlet and a gas outlet communicating with the rotor chamber, and a connection between an inner wall forming the rotor chamber and an inner wall forming the gas outlet is located on or located more outwardly than a rotor center line extending through a center of rotation and a bottom dead center of each Roots rotor.

[0007] In an embodiment, a width of the gas outlet is larger than a width of the gas inlet.

[0008] In an embodiment, the at least one pair of Roots rotors comprises at least one pair of two-lobe Roots rotors, and an angle of a straight line extending from the center of rotation to the connection with respect to the rotor center line is in a range of 0 to 35 degrees.

[0009] In an embodiment, the at least one pair of Roots rotors comprises at least one pair of three-lobe Roots rotor, and an angle of a straight line extending from the center of rotation to the connection with respect to the rotor center line is in a range of 0 to 45 degrees.

[0010] In an embodiment, the at least one pair of Roots rotors includes a pair of first Roots rotors and a pair of second Roots rotors located downstream of the pair of first Roots rotors in a gas transfer direction, the at least one rotor chamber includes a first rotor chamber in which the pair of first Roots rotors are located and a second rotor chamber in which the pair of second Roots rotors are located, the pump casing has a first gas inlet and a first gas outlet communicating with the first rotor chamber and a second gas inlet and a second gas outlet communicating with the second rotor chamber, a first connection between an inner wall forming the first rotor chamber and an inner wall forming the first gas outlet is located more outwardly than a first rotor center line extending through a center of rotation and a bottom dead center of each first Roots rotor, a second connection between an inner wall forming the second rotor chamber and an inner wall forming the second gas outlet is located on or located more outwardly than a second rotor center line extending through a center of rotation and a bottom dead center of each second Roots rotor, and a width of the first gas outlet is larger than a width of the second gas outlet.

[0011] According to the present invention, the width of the gas outlet communicating with the rotor chamber is large, so that the particles contained in the gas are less likely to remain in the rotor chamber. As a result, the particles are discharged from the rotor chamber together with the gas, and an amount of particles deposited in the rotor chamber can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a cross-sectional view showing an embodiment of a vacuum pump apparatus;

FIG. 2 is a cross-sectional view taken along a line A-A of FIG. 1;

FIG. 3 is a cross-sectional view of another embodiment of a connection between an inner wall forming a rotor chamber and an inner wall forming a gas outlet;

FIG. 4 is a cross-sectional view of yet another embodiment of the connection between the inner wall forming the rotor chamber and the inner wall forming the gas outlet;

FIG. 5 is a cross-sectional view of another embodiment of the gas outlet;

FIG. 6 is a cross-sectional view showing an embodiment of three-lobe Roots rotors;

FIG. 7 is a cross-sectional view showing another embodiment of the vacuum pump apparatus;

FIG. 8 is a cross-sectional view taken along a line B-B of FIG. 7; and

FIG. 9 is a cross-sectional view taken along a line C-C of FIG. 7.

DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[0014] 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 equipment that requires high cleanliness.

[0015] As shown in FIG. 1, the vacuum pump apparatus has a vacuum pump 1 and an electric motor 2 that drives the vacuum pump 1. The vacuum pump 1 has a pump casing 6 having a rotor chamber 5 therein, a pair of Roots rotors 8 located in the rotor chamber 5, and a pair of rotation shafts 9 supporting the pair of Roots rotors 8. Each Roots rotor 8 and each rotary shaft 9 may be an integral structure. Although only one Roots rotor 8 and only one rotation shaft 9 are depicted in FIG. 1, the pair of Roots rotors 8 are arranged in the rotor chamber 5 and are secured to the pair of rotation shafts 9, respectively. The electric motor 2 is coupled to one of the pair of rotation shafts 9. In one embodiment, a pair of electric motors 2 may be coupled to the pair of rotation shafts 9, respectively.

[0016] Although the Roots rotors 8 of the present embodiment are single-stage pump rotors, in one embodiment the Roots rotors 8 may be multistage pump rotors.

[0017] The pump casing 6 has a gas inlet 12 and a gas outlet 13 communicating with the rotor chamber 5. The gas inlet 12 is coupled to a chamber (not shown) filled with gas to be delivered. In one example, the gas inlet 12 may be coupled to a process chamber of a semiconductor-device manufacturing equipment, and the vacuum pump 1 may be used for evacuating a process gas that has been introduced into the process chamber.

[0018] The vacuum pump 1 further includes a gear housing 16 located outside a side wall 6A of the pump casing 6. 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. These gears 20 are fixed to the rotation shafts 9, respectively. The electric motor 2 is driven by a not-shown motor driver, and one rotation shaft 9 to which the electric motor 2 is coupled rotates the other rotation shaft 9 to which the electric motor 2 is not coupled in an opposite direction via the gears 20.

[0019] The rotation shafts 9 are rotatably supported by bearings 17 held on the side wall 6A of the pump casing 6 and bearings 18 held on other side wall 6B of the pump casing 6. The electric motor 2 has a motor housing 14 located outside the side wall 6B of the pump casing 6, and a motor rotor 2A and a motor stator 2B disposed in the motor housing 14.

[0020] In one embodiment, a pair of electric motors 2, which are coupled to the pair of rotation shafts 9, respectively, may be provided. The pair of electric motors 2 are synchronously rotated in opposite directions by a not-shown motor driver, so that the pair of rotation shafts 9 and the pair of Roots rotors 8 are synchronously rotated in opposite directions. In this configuration, the role of the gears 20 is to prevent loss of the synchronous rotation of the Roots rotors 8 due to a sudden external cause.

[0021] When the Roots rotors 8 are rotated by the electric motor 2, gas is sucked into the pump casing 6 through the gas inlet 12. The gas is transferred from the gas inlet 12 to the gas outlet 13 by the rotating Roots rotors 8.

[0022] FIG. 2 is a cross-sectional view taken along a line A-A of FIG. 1. As shown in FIG. 2, each Roots rotor 8 in this embodiment is a two-lobe Roots rotor. The gas inlet 12 is located in one side of the pump casing 6, and the gas outlet 13 is located in the opposite side of the pump casing 6. The pair of Roots rotors 8 are located between the gas inlet 12 and the gas outlet 13. The Roots rotors 8 are in non-contact with an inner wall 22 of the pump casing 6 forming the rotor chamber 5, and the two Roots rotors 8 are also in non-contact with each other. These Roots rotors 8 rotate in the opposite directions in the rotor chamber 5 as indicated by arrows.

[0023] As the Roots rotor 8 rotates, an enclosed space is formed between outer surface of the Roots rotor 8 and the inner wall 22 forming the rotor chamber 5. The gas flowing in through the gas inlet 12 fills this enclosed space, and as the pair of Roots rotors 8 rotate in the opposite directions, the gas is transferred from the gas inlet 12 to the gas outlet 13. Such transferring of the gas in the enclosed space is performed continuously, so that the gas is evacuated by the vacuum pump 1.

[0024] The gas inlet 12 and the gas outlet 13 communicate with the rotor chamber 5. An inner wall 23 forming the gas outlet 13 is coupled to the inner wall 22 forming the rotor chamber 5. As shown in FIG. 2, a connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 is located more outwardly than a rotor center line CL. The rotor center line CL is a straight line extending through a center of rotation RC and a bottom dead center LP of each Roots rotor 8. The bottom dead center LP of the Roots rotor 8 corresponds to the lowest end of the rotating Roots rotor 8. In this specification, "located more outwardly than a rotor center line CL" means being located across the rotor center line CL from a center point CP of the rotor chamber 5.

[0025] A width W2 of the gas outlet 13 is larger than a width W1 of the gas inlet 12. For example, the width W2 of the gas outlet 13 is 1.1 to 2.0 times, preferably 1.7 times, the width W1 of the gas inlet 12.

[0026] An example of the gas handled by the vacuum pump 1 in this embodiment is process gas used in semiconductor-device manufacturing equipment, such as CVD equipment or etching equipment. This type of process gas contains particles of by-products. As can be seen from FIG. 2, the width W2 of the gas outlet 13 is larger than the width W1 of the gas inlet 12, so the particles are less likely to stay in the rotor chamber 5. As a result, the particles are less likely to be deposited in the rotor chamber 5. Therefore, this embodiment can prevent a failure of the rotations of the Roots rotors 8 (e.g., rotation stoppage) due to deposition of the particles in the rotor chamber 5.

[0027] In this embodiment, each of the Roots rotors 8 is a two-lobe Roots rotor. In order to deliver the gas from the gas inlet 12 to the gas outlet 13, the enclosed space must be formed between the outer surface of each Roots rotor 8 and the inner wall 22 forming the rotor chamber 5. From this viewpoint, the connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 is closer to the gas outlet 13 than the gas inlet 12. An angle α of a straight line NL extending from the center of rotation RC to the connection 25 with respect to the rotor center line CL is in a range of 0 to 35 degrees. In one embodiment, the connection 25 may be located on the rotor center line CL.

[0028] Although the width W2 of the gas outlet 13 is larger than the width W1 of the gas inlet 12, the pumping performance of the vacuum pump 1 is not substantially reduced because, as mentioned above, the enclosed space is formed between the outer surface of the Roots rotor 8 and the inner wall 22 forming the rotor chamber 5.

[0029] The embodiment shown in FIG. 2 describes the arrangements of the connection 25 and the rotor center line CL associated with one of the two Roots rotors 8. Arrangements of a connection and a rotor center line associated with the other Roots rotor 8 are also the same, and therefore their redundant descriptions and the illustration of their reference numerals are omitted.

[0030] As shown in FIG. 3, the connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 may have an arc-shaped cross-section. Alternatively, as shown in FIG. 4, the connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 may have a beveled cross-section. According to the configurations shown in FIGS. 3 and 4, gas turbulence is less likely to occur, and the particles can be smoothly delivered to the gas outlet 13.

[0031] In the embodiments shown in FIGS. 2 through 4, the inner wall 23 forming the gas outlet 13 is parallel to the rotor center line CL, and the width of the gas outlet 13 is constant. In one embodiment, as shown in FIG. 5, the inner wall 23 forming the gas outlet 13 may be inclined outwardly with a distance from the center point CP of the rotor chamber 5. In other words, the width of the gas outlet 13 may gradually increase with a distance from the center point CP of the rotor chamber 5. This configuration allows the gas containing particles to pass smoothly through the gas outlet 13.

[0032] The Roots rotors 8 may be three-lobe Roots rotors, as shown in FIG. 6. In the embodiment shown in FIG. 6, the connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 is also located on or located more outwardly than the rotor center line CL extending through the center of rotation RC and the bottom dead center LP of each Roots rotor 8. Configurations of the embodiment shown in FIG. 6, which will not be particularly described, are the same as those of the embodiments described with reference to FIG. 2, and their redundant descriptions are omitted.

[0033] As well as the embodiments described with reference to FIG. 2, an enclosed space must be formed between the outer surface of each Roots rotor 8 and the inner wall 22 forming the rotor chamber 5. From this viewpoint, in the embodiment shown in FIG. 6, an angle α of the straight line NL extending from the center of rotation RC to the connection 25 with respect to the rotor center line CL is in a range of 0 to 45 degrees.

[0034] Although not shown in the figures, the Roots rotors 8 may be four or more lobe Roots rotors. In that case also, the connection 25 between the inner wall 22 forming the rotor chamber 5 and the inner wall 23 forming the gas outlet 13 is located on or located more outwardly than the rotor center line CL which extends through the center of rotation RC and the bottom dead center LP of each Roots rotor 8. Since the width of the gas outlet 13 is larger than the width of the gas inlet 12, particles are less likely to stay in the rotor chamber 5 and as a result, the particles are less likely to be deposited in the rotor chamber 5.

[0035] FIG. 7 shows a cross-sectional view of another embodiment of the vacuum pump 1. This embodiment of the vacuum pump 1 is a multi-stage vacuum pump. The descriptions of the embodiments with reference to FIGS. 1 through 6 can be applied to configurations and operations of this embodiment, and their redundant descriptions will be omitted.

[0036] As shown in FIG. 7, the vacuum pump 1 has a pump casing 6 having a plurality of rotor chambers 5A to 5E therein, pairs of Roots rotors 8A to 8E disposed in the rotor chambers 5A to 5E, respectively, and a pair of rotation shafts 9 supporting the pairs of Roots rotors 8A to 8E. The Roots rotors 8A to 8E and the rotation shaft 9 may be an integral structure. Although only one set of Roots rotors 8A to 8E and the rotation shaft 9 are depicted in FIG. 1, the pairs of Roots rotors 8A to 8E are located in the rotor chambers 5A to 5E, respectively, and are supported by the pair of rotation shafts 9. The electric motor 2 is coupled to one of the pair of rotation shafts 9. In one embodiment, a pair of electric motors 2 may be coupled to the pair of rotation shafts 9, respectively.

[0037] The Roots rotors 8A to 8E and the rotor chambers 5A to 5E are arranged along a gas transfer direction. Specifically, the Roots rotor 8A and rotor chamber 5A are located most upstream in the gas transfer direction in the pump casing 6. The Roots rotor 8B and the rotor chamber 5B are located downstream of the Roots rotor 8A and the rotor chamber 5A, the Roots rotor 8C and the rotor chamber 5C are located downstream of the Roots rotor 8B and the rotor chamber 5B, the Roots rotor 8D and the rotor chamber 5D are located downstream of the Roots rotor 8C and the rotor chamber 5C, and the Roots rotor 8E and the rotor chamber 5E are located downstream of the Roots rotor 8D and the rotor chamber 5D. The Roots rotor 8E and the rotor chamber 5E are located most downstream in the gas transfer direction in the pump casing 6.

[0038] The pump casing 6 has a gas inlet 12A and a gas outlet 13A communicating with the rotor chamber 5A, a gas inlet 12B and a gas outlet 13B communicating with the rotor chamber 5B, a gas inlet 12C and a gas outlet 13C communicating with the rotor chamber 5C, a gas inlet 12D and a gas outlet 13D communicating with the rotor chamber 5D, and a gas inlet 12E and a gas outlet 13E communicating with the rotor chamber 5E. The gas outlet 13A comminates with the gas inlet 12B via a channel not shown, the gas outlet 13B comminates with the gas inlet 12C via a channel not shown, the gas outlet 13C comminates with the gas inlet 12D via a channel not shown, and the gas outlet 13D comminates with the gas inlet 12E via a channel not shown.

[0039] When the electric motor 2 rotates the Roots rotors 8A to 8E, gas is sucked into the rotor chamber 5A through the gas inlet 12A. The gas is sequentially compressed by the Roots rotors 8A to 8E in the rotor chambers 5A to 5E and discharged from the pump casing 6 through the gas outlet 13E.

[0040] FIG. 8 is a cross-sectional view taken along a line B-B of FIG. 7. As shown in FIG. 8, the Roots rotors 8A to 8E are three-lobe Roots rotors. A connection 25A between an inner wall 22A forming the rotor chamber 5A and an inner wall 23A forming the gas outlet 13A is located more outwardly than a rotor center line CL1 extending through a center of rotation RC1 and a bottom dead center LP1 of the Roots rotor 8A. An angle $\alpha 1$ of a straight line NL1 extending from the center of rotation RC1 of the Roots rotor 8A to the connection 25A with respect to the rotor center line CL1 is in a range of 0 to 45 degrees. A width W4 of the gas outlet 13A is larger than a width W3 of the gas inlet 12A.

[0041] FIG. 9 is a cross-sectional view taken along a line C-C of FIG. 7. As shown in FIG. 9, a connection 25E between an inner wall 22E forming the rotor chamber 5E and an inner wall 23E forming the gas outlet 13E is located more outwardly than a rotor center line CL2 extending through a center of rotation RC2 and a bottom dead center LP2 of the Roots rotor 8E. In one embodiment, the connection 25E may be located on the rotor center line CL2. An angle $\alpha 2$ of a straight line NL2 extending from the center of rotation RC2 of the Roots rotor 8E to the connection 25E with respect to the rotor center line CL2 is in a range of 0 to 45 degrees and smaller than the angle $\alpha 1$ shown in FIG. 8. A width W6 of the gas outlet 13E is larger than a width W5 of the gas inlet 12E.

[0042] Although not shown, a connection between an inner wall forming the rotor chamber 5B and an inner wall forming the gas outlet 13B, a connection between an inner wall forming the rotor chamber 5C and an inner wall forming the gas outlet 13C, and a connection between an inner wall forming the rotor chamber 5D and an inner wall forming the gas outlet 13D are also located more outwardly than corresponding rotor center lines or are located on the corresponding rotor center lines.

[0043] According to the embodiments described with reference to FIGS. 7 through 9, the widths of the gas outlets 13A to 13E are larger than the widths of the gas inlets 12A to 12E, respectively, so that the particles are less likely to stay in the rotor chambers 5A to 5E and as a result, the particles are less likely to be deposited in the rotor chambers 5A to 5E.

[0044] As can be seen from the comparison between FIG. 8 and FIG. 9, the width W4 of the gas outlet 13A shown in FIG. 8 is larger than the width W6 of the gas outlet 13E shown in FIG. 9. This is based on simulation results of particles flow that have shown that particle discharge is facilitated when the width of the gas outlet is large at a lower pressure side and the width of the gas outlet is relatively small at the atmospheric pressure side. According to this embodiment, the particles can be discharged from the pump casing 6 through the rotor chambers 5A to 5E sequentially.

[0045] A relationship between the widths of the gas outlets 13A to 13E is not limited as long as the width of the gas outlet 13A is larger than the width of the gas outlet 13E. For example, the widths of the gas outlets 13A, 13B, and 13C may be the same and larger than the widths of the gas outlets 13D and 13E. In other example, the widths of the gas outlets 13A, 13B, 13C, 13D, 13E may gradually decrease according to the gas transfer direction in the pump casing 6.

[0046] The vacuum pump 1 shown in FIG. 7 is a five-stage vacuum pump, while the number of stages of the Roots rotors 8 is not limited particularly. For example, the vacuum pump 1 may be a two-stage vacuum pump with two pairs of Roots rotors, or a multi-stage vacuum pump with six or more pairs of Roots rotors.

[0047] 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 comprising:

a pump casing having at least one rotor chamber therein;
at least one pair of Roots rotors disposed in the rotor chamber; and
at least one pair of rotation shafts supporting the at least one pair of Roots rotors,
wherein the pump casing has a gas inlet and a gas outlet communicating with the rotor chamber, and
a connection between an inner wall forming the rotor chamber and an inner wall forming the gas outlet is located on or located more outwardly than a rotor center line extending through a center of rotation and a bottom dead center of each Roots rotor.

2. The vacuum pump according to claim 1, wherein a width of the gas outlet is larger than a width of the gas inlet.

3. The vacuum pump according to claim 1 or 2, wherein the at least one pair of Roots rotors comprises at least one pair of two-lobe Roots rotors, and an angle of a straight line extending from the center of rotation to the connection with respect to the rotor center line is in a range of 0 to 35 degrees.

4. The vacuum pump according to claim 1 or 2, wherein the at least one pair of Roots rotors comprises at least one pair of three-lobe Roots rotor, and an angle of a straight line extending from the center of rotation to the connection with respect to the rotor center line is in a range of 0 to 45 degrees.

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

the at least one pair of Roots rotors includes a pair of first Roots rotors and a pair of second Roots rotors located downstream of the pair of first Roots rotors in a gas transfer direction,
the at least one rotor chamber includes a first rotor chamber in which the pair of first Roots rotors are located and a second rotor chamber in which the pair of second Roots rotors are located,
the pump casing has a first gas inlet and a first gas outlet communicating with the first rotor chamber and a second gas inlet and a second gas outlet communicating with the second rotor chamber,
a first connection between an inner wall forming the first rotor chamber and an inner wall forming the first gas outlet is located more outwardly than a first rotor center line extending through a center of rotation and a bottom dead center of each first Roots rotor,
a second connection between an inner wall forming the second rotor chamber and an inner wall forming the second gas outlet is located on or located more outwardly than a second rotor center line extending through a center of rotation and a bottom dead center of each second Roots rotor, and
a width of the first gas outlet is larger than a width of the second gas outlet.

FIG. 1

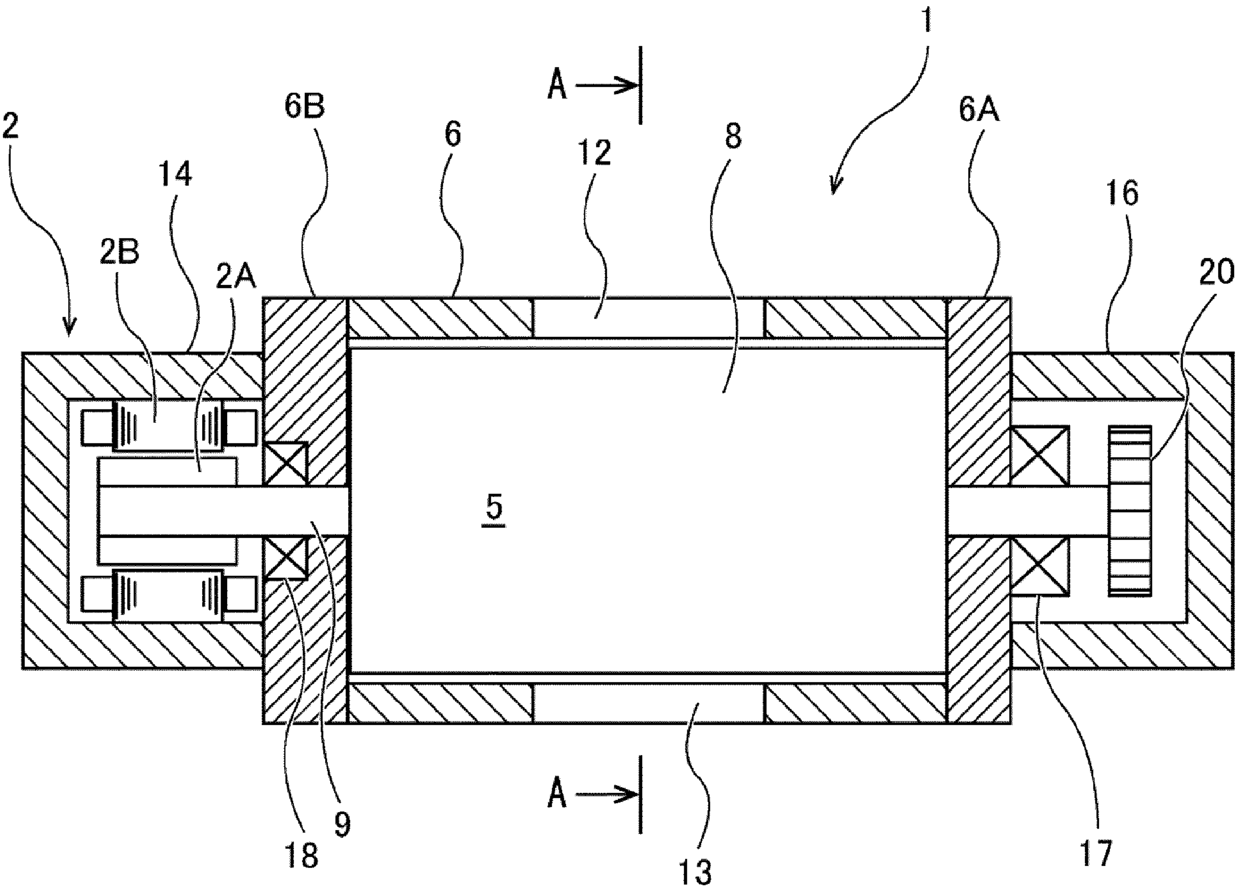


FIG. 2

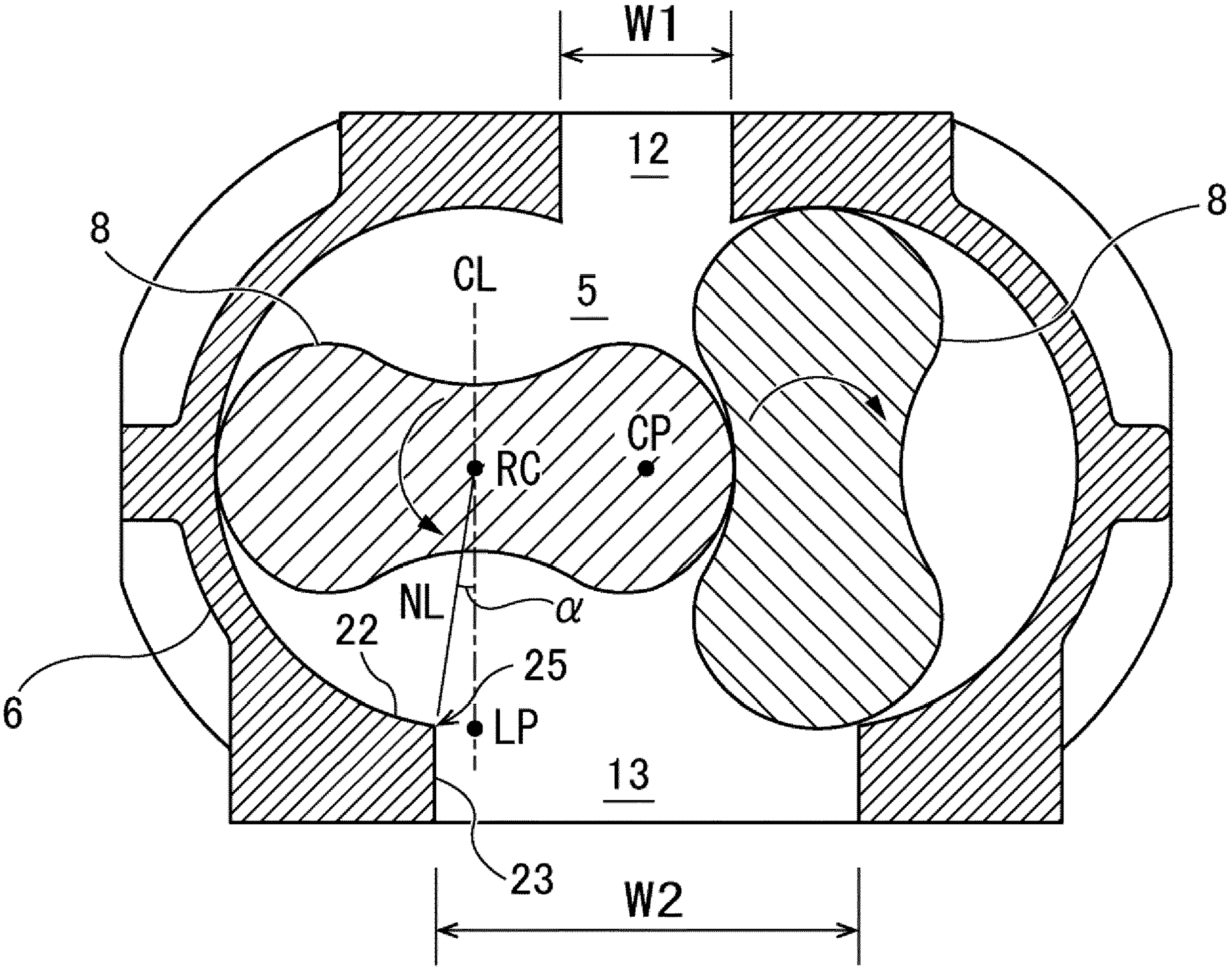


FIG. 3

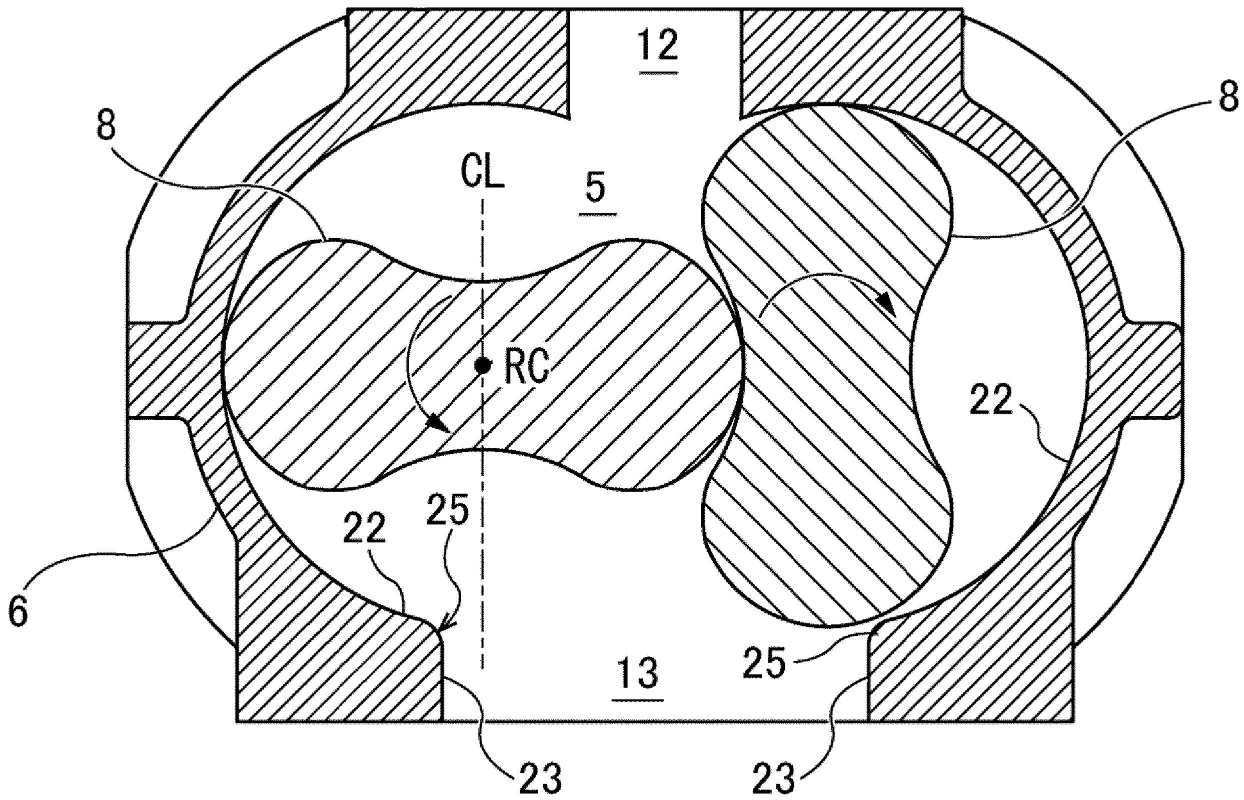


FIG. 4

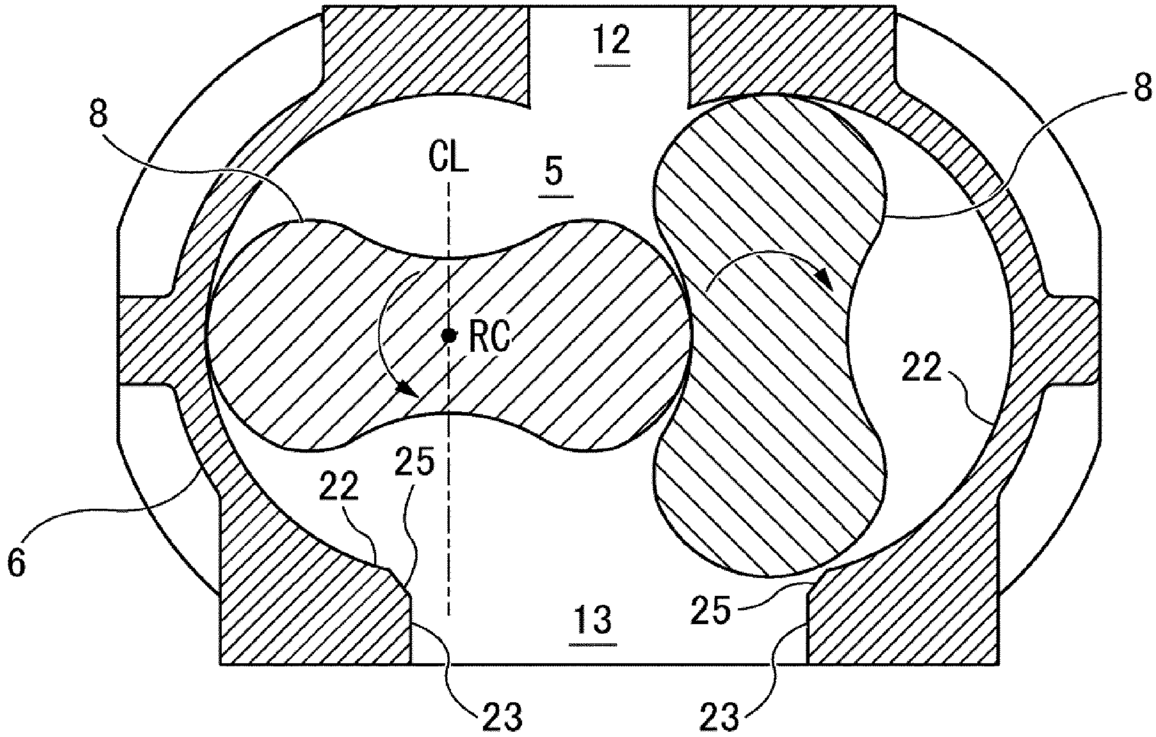


FIG. 5

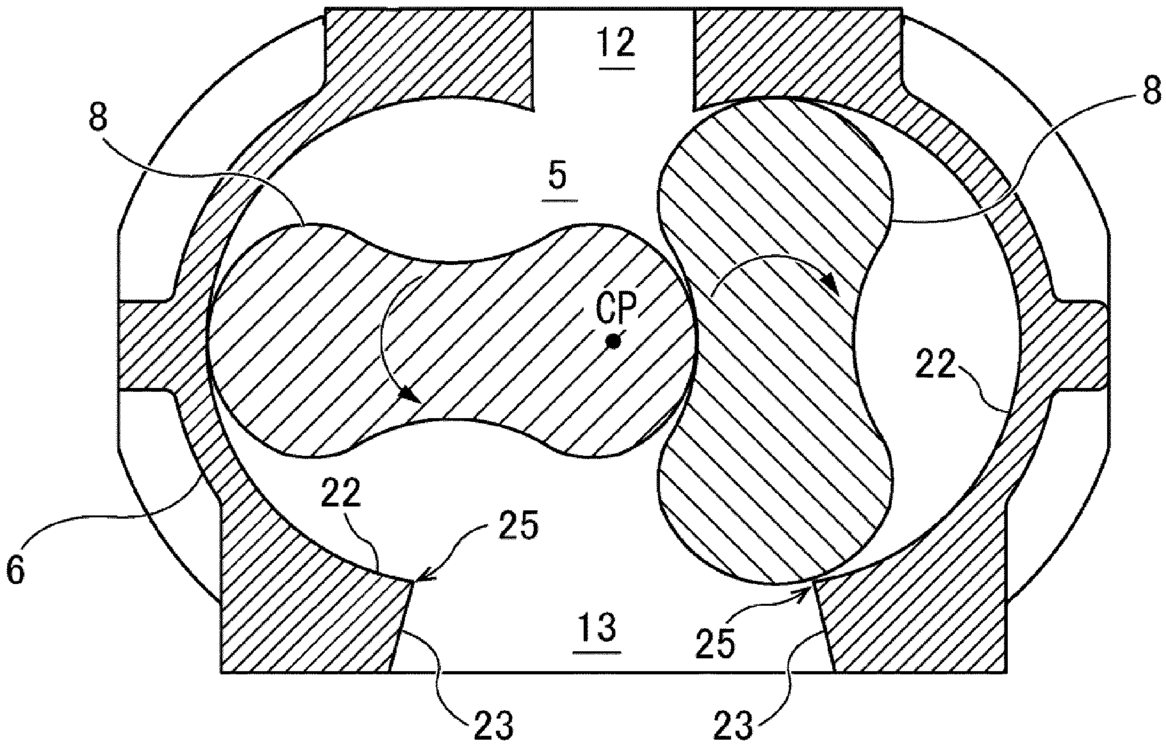


FIG. 6

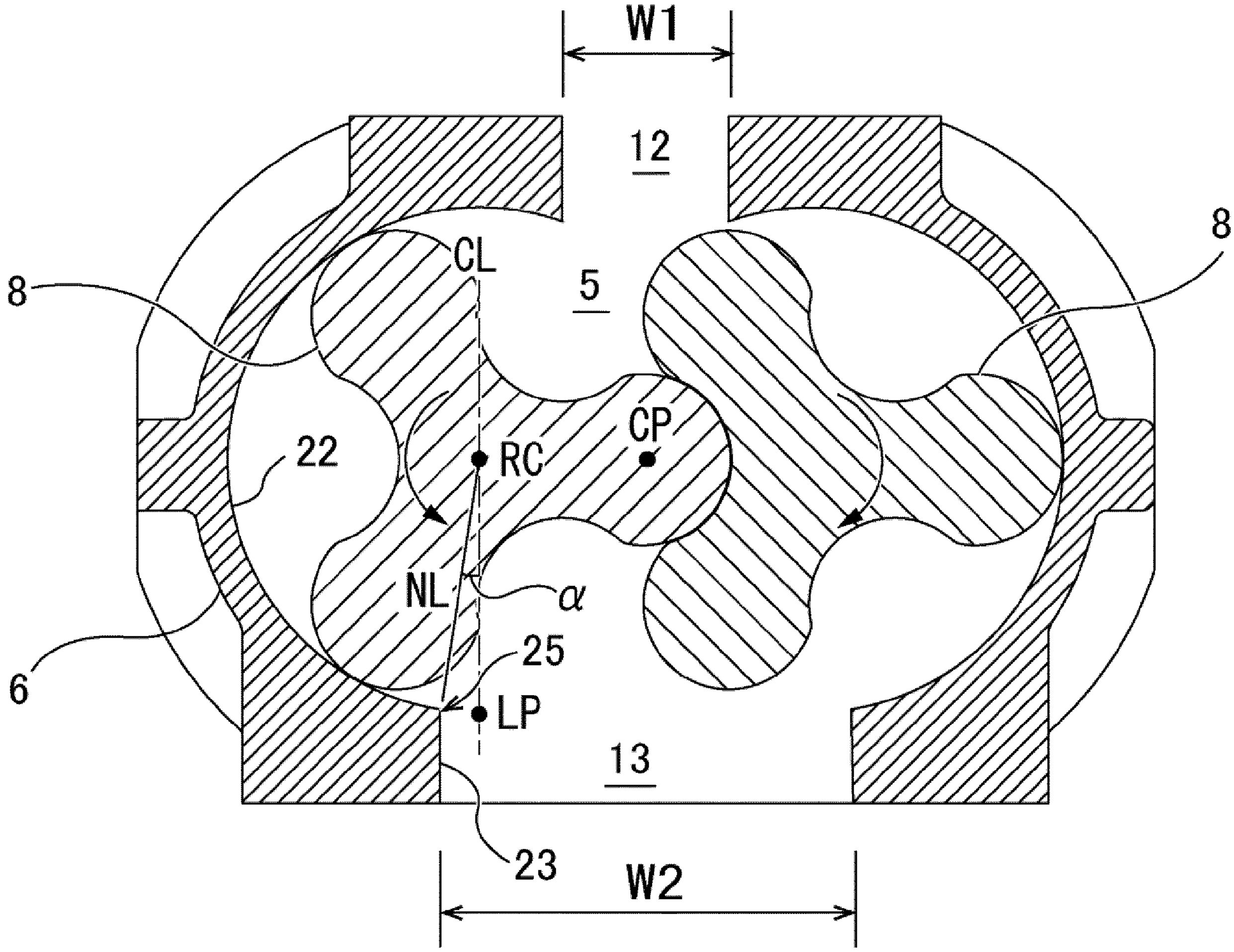


FIG. 7

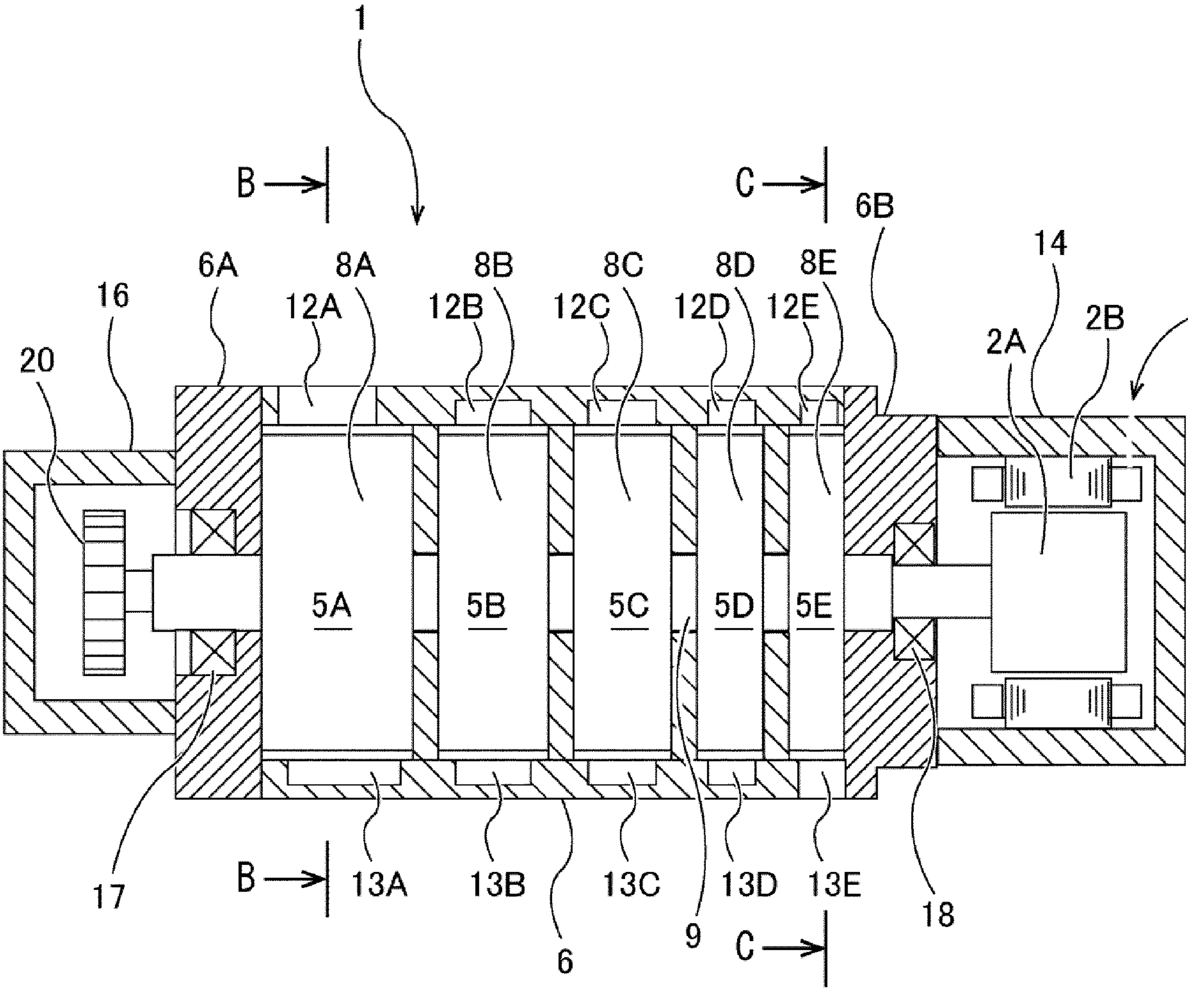

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FIG. 8

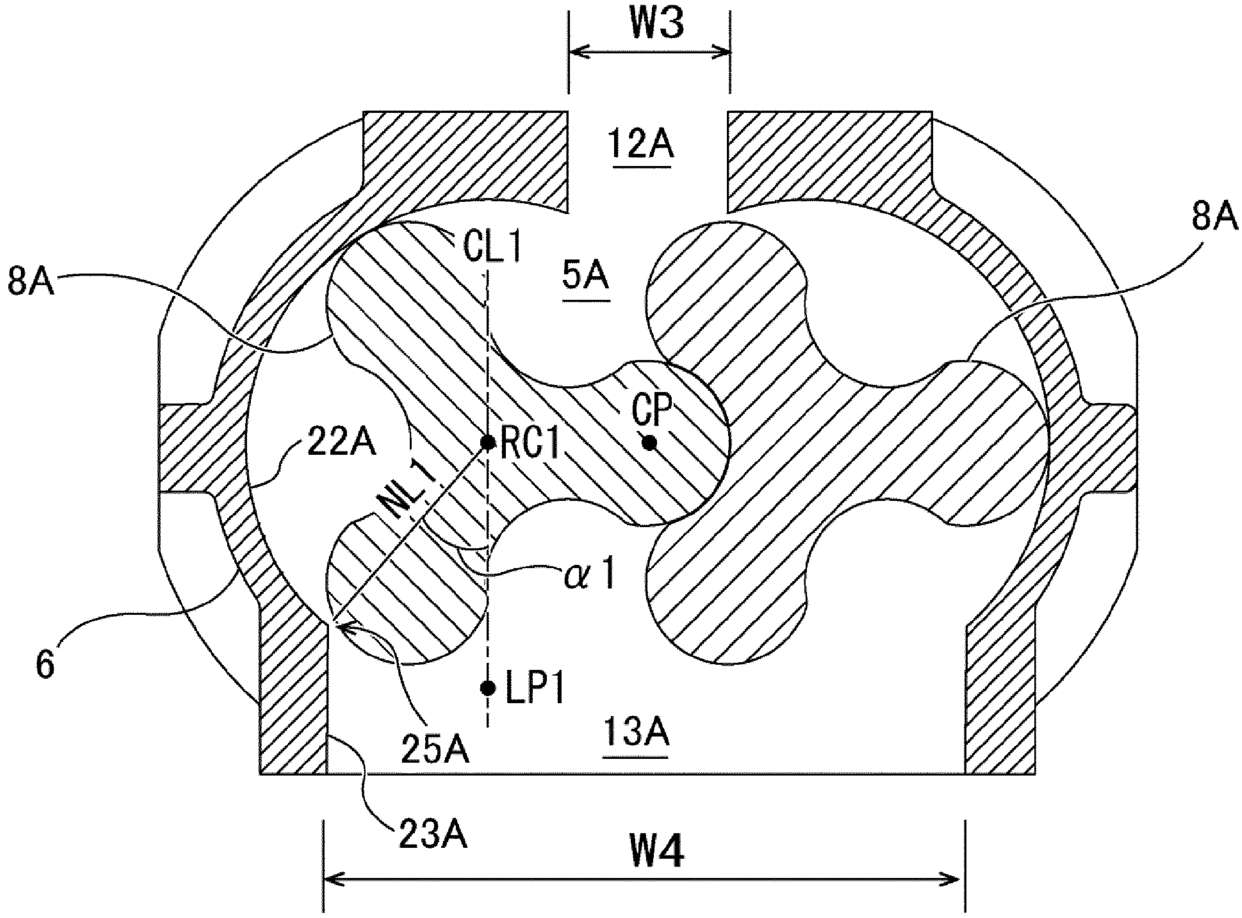
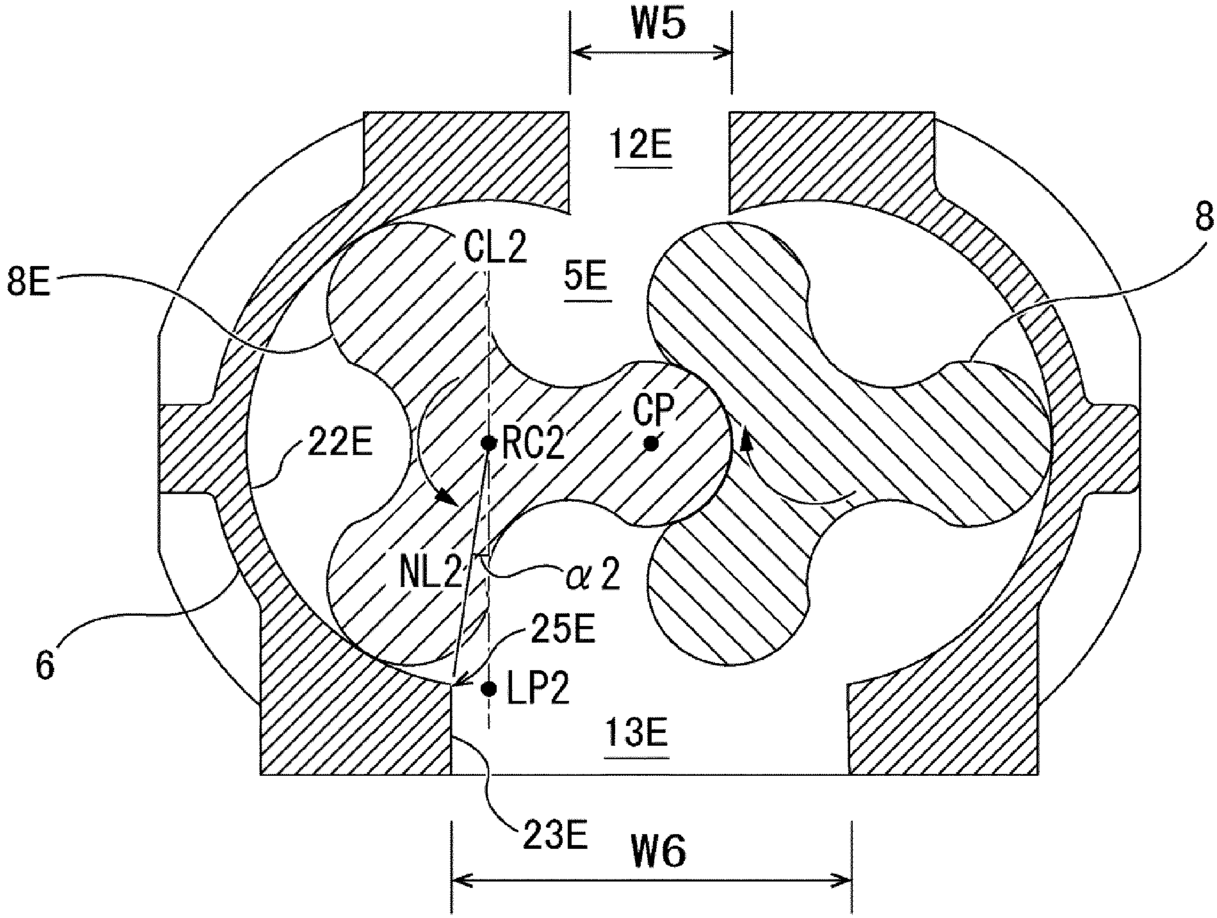


FIG. 9



Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 23 15 4594

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	US 2021/140430 A1 (DREIFERT THOMAS [DE] ET AL) 13 May 2021 (2021-05-13) * the whole document * -----	1 5 2-4	INV. F04C18/12
Y A	DE 36 03 818 A1 (MESSER GRIESHEIM GMBH [DE]) 13 August 1987 (1987-08-13) * figure 1 * -----	5 1-4	
A	DE 10 2013 110091 B3 (PFEIFFER VACUUM GMBH [DE]) 12 February 2015 (2015-02-12) * paragraph [0062] * * figure 2 * -----	1-5	
A	JP S58 91390 A (KARIYA TOKUJI) 31 May 1983 (1983-05-31) * figure 1 * -----	1-5	

TECHNICAL FIELDS SEARCHED (IPC)

F04C

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	26 June 2023	Lange, Christian

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