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

(11) **EP 2 196 675 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.06.2010 Bulletin 2010/24

(51) Int Cl.:
F04C 18/12 *(2006.01)* ***F04C 23/00*** *(2006.01)*
F04C 25/02 *(2006.01)* ***F04C 29/00*** *(2006.01)*

(21) Application number: **09178669.9**

(22) Date of filing: **10.12.2009**

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

(30) Priority: **11.12.2008 JP 2008315204**
07.12.2009 JP 2009277492

(71) Applicant: **Kabushiki Kaisha Toyota Jidoshokki**
Kariya-shi,
Aichi 448-8671 (JP)

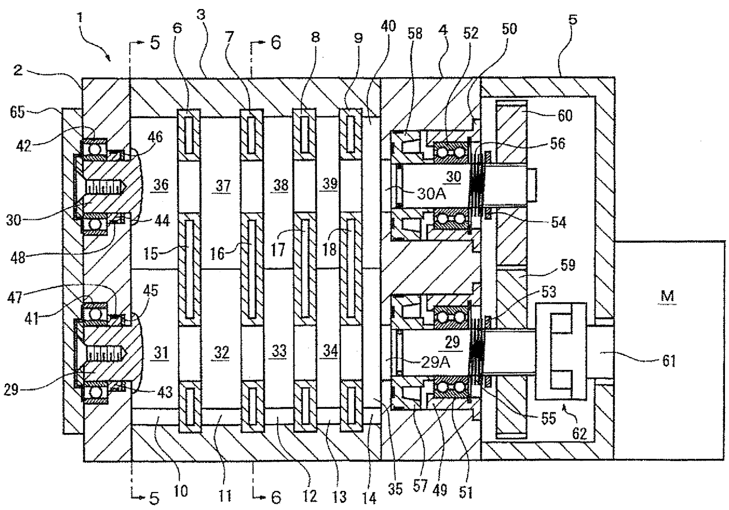
(72) Inventors:
- **Yamamoto, Shinya**
  Aichi-ken (JP)
- **Koshizaka, Ryosuke**
  Aichi-ken (JP)
- **Mishina, Takao**
  Aichi-ken (JP)
- **Suzuki, Yoshinari**
  Aichi-ken (JP)
- **Uchiyama, Osamu**
  Aichi-ken (JP)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) **Rotary vacuum pump**

(57) The rotary vacuum pump includes a pump housing, a rotary shaft, a thrust movement restriction mechanism and a first elastic member. The pump housing has therein a pump chamber. The rotary shaft has thereon a rotor rotatably disposed in the pump chamber. When the rotor is rotated with the rotary shaft, gas in the pump chamber is pumped thereby to draw gas into the pump chamber. The thrust movement restriction mechanism is provided for allowing the rotor to displace in the pump chamber in one thrust direction due to thermal expansion thereof during the operation of the rotary vacuum pump. The first elastic member is provided for urging the rotary shaft in the other thrust direction opposite to the one thrust direction.

FIG. 2



EP 2 196 675 A2

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a rotary vacuum pump having a rotor disposed in a pump chamber and a rotary shaft rotating the rotor for pumping gas in the pump chamber thereby drawing gas into the pump chamber.

[0002] Japanese Unexamined Patent Application Publication No. 2008-51116 discloses a multistage roots pump that is a type of rotary vacuum pump, The multistage roots pump of this publication has two parallel rotary shafts disposed in the housing of the roots pump with their opposite ends rotatably supported by radial bearings. Each rotary shaft has thereon a plurality of rotors each disposed in each of a plurality of pump chambers of the housing. The pump chambers are juxtaposed along the axis of the rotary shaft.

[0003] Specifically, the rotors of one of the rotary shafts and those of the other rotary shaft are paired to make a plurality of pairs of rotors, and each pair of rotors is disposed in engagement with each other in each pump chamber. Each pump chamber has a suction region and a discharge region connected to the suction region of its adjacent pump chamber through a communicating passage. The suction region of the pump chamber at the first stage of the roots pump is connected to an inlet port that communicates with the outside of the roots pump and the discharge region of the pump chamber at the final stage of the roots pump is connected to an outlet port that communicates with the outside of the roots pump.

[0004] One rotary shaft is connected at one end thereof to a drive source and has a gear which is meshed with a gear mounted on the other rotary shaft. Thus, the rotary shafts are rotated synchronously in opposite directions. Although not described in the above-identified publication explicitly, the roots pump as embodied should be made so that each rotary shaft is prevented from moving in axial direction of the rotary shaft by any suitable means, such as locknut or press-fitting of the rotary shaft into the radial bearing provided at one end of the rotary shaft, for positioning the rotors in place in the pump chambers.

[0005] In the above-described roots pump, driving one rotary shaft to rotate, the other rotary shaft in engagement with the one rotary shaft is driven to rotate, thus rotating the paired rotors in each pump chamber. Gas drawn into the pump chamber at the first stage through the inlet port is transferred into its downstream pump chambers successively while being compressed by the rotation of the paired rotors. Such a compressed gas is discharged out of the pump chamber at the final stage through the outlet port.

[0006] The roots pump in operation generates high heat especially at the position adjacent to the outlet port, so that the housing, the rotors and the rotary shafts are thermally expanded. The roots pump at a stop generates no such heat and the housing is cooled by fresh air, so that the housing is thermally contracted together with the rotors and the rotary shafts. Although the housing is in direct contact with fresh air and therefore cooled easily, the rotors and the rotary shafts disposed within the housing are not directly cooled by fresh air. Therefore, the thermal expansion occurs differently between the housing on one hand and the rotors and the rotary shafts on the other. Specifically, the rotors and the rotary shafts are displaced more than the housing. Therefore, a large clearance is formed in the pump chamber at a position between the wall surface of the pump chamber as part of the housing and the wall surface of the rotor in thrust direction of the pump.

[0007] Fine particles present in the gas drawn into the pump chamber are easily accumulated in the clearance, thus forming a foreign matter in the clearance. When the roots pump is stopped and thermally contracted with the foreign matter present in the clearance, the rotors and the rotary shafts may fail to return to their original positions due to the presence of any foreign matter. In such a case, the rotors and the rotary shafts are pressed against the foreign matter. When the roots pump is restarted, there is a fear that the roots pump may not be operated properly due to large frictional resistance between the rotor and the foreign matter.

[0008] The present invention is directed to a rotary vacuum pump that reduces the frictional resistance due to foreign matter accumulated in the pump chamber of the rotary vacuum pump in restarting the rotary vacuum pump.

SUMMARY OF THE INVENTION

[0009] In accordance with an aspect of the present invention, the rotary vacuum pump includes a pump housing, a rotary shaft, a thrust movement restriction mechanism and a first elastic member. The pump housing has therein a pump chamber. The rotary shaft has thereon a rotor rotatably disposed in the pump chamber. When the rotor is rotated with the rotary shaft, gas in the pump chamber is pumped thereby to draw gas into the pump chamber. The thrust movement restriction mechanism is provided for allowing the rotor to displace in the pump chamber in one thrust direction due to thermal expansion thereof during the operation of the rotary vacuum pump. The first elastic member is provided for urging the rotary shaft in the other thrust direction opposite to the one thrust direction.

[0010] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWING

[0011] The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a front view in longitudinal section of a multistage roots pump according to a first embodiment of the present invention;

Fig. 2 is a plan view in longitudinal section of the multistage roots pump of Fig. 1;

Fig. 3 is a fragmentary plan view in longitudinal section of the multistage roots pump when thermally expanded;

Fig. 4 is a fragmentary plan view in longitudinal section of the multistage roots pump when thermally contracted;

Fig. 5 is a cross sectional view of the multistage roots pump as taken along the line 5-5 of Fig. 2;

Fig. 6 is a cross sectional view of the multistage roots pump as taken along the line 6-6 of Fig. 2;

Fig. 7 is a fragmentary sectional view of a multistage roots pump according to a second embodiment of the present invention; and

Fig. 8 is a fragmentary sectional view of a multistage roots pump according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] The following will describe the multistage roots pump according to the first embodiment of the present invention with reference to Figs. 1 to 6. The multistage roots pump will be referred to merely as roots pump hereinafter. It is noted that the left-hand side and the right-hand side of the roots pump as viewed in Figs. 1 to 4 correspond to the front and the rear of the roots pump, respectively. It is also noted that the upper side and the lower side of the roots pump as viewed in Figs. 1 to 4 correspond to the upper side and the lower side of the roots pump, respectively, when installed in place.

[0013] Referring to Fig. 1, the roots pump shown in its longitudinal sectional view has a pump housing indicated generally by reference numeral 1 and including a front housing 2, a rotor housing 3, a rear housing 4 and a gear housing 5 which are joined sealingly together by a plurality of bolts (not shown). As shown in Figs. 5 and 6, the rotor housing 3 is formed by two upper and lower halves joined together into a tubular body having therein a substantially elliptically-shaped space. The other housing components 2, 4 and 5 have substantially the same structure as the rotor housing 3. Such a two-piece structure is effective in assembling the roots pump. For example, after various parts and members which will be described later are mounted on the lower halves of the housing components 2-5, the upper halves of the housing components 2-5 may be assembled to the lower halves thereby to complete the roots pump. Since the above two-piece structure of the housing components 2-5 does not relate closely to the present invention, further description thereof will be omitted. The structure of the roots pump will be described with reference to an assembled roots pump shown in the drawings.

[0014] The rotor housing 3 has therein elliptically-shaped partitions 6-9 each formed by upper and lower partitions. As seen clearly in Fig. 1, the partitions 6-9 are arranged in the rotor housing 3 at spaced distances that decrease progressively toward the rear of the rotor housing 3. Thus, the rotor housing 3 has therein pump chambers 10-14 between the front housing 2 and the partition 6, between any two adjacent partitions 6-9, and between the partition 9 and the rear housing 4, respectively. That is, the partitions 6-9 are provided as part of the rotor housing 3 for forming the pump chambers 10-14. The pump chambers 10-14 have capacities that are reduced progressively toward the rear of the rotor housing 3.

[0015] The partitions 6-9 have therein communicating spaces 15-18, respectively. As shown in Fig. 1, the communicating spaces 15-18 have on the lower side thereof discharge passages 19-22 opened forward and also on the upper side thereof suction passages 23-26 opened rearward, respectively.

[0016] Each of the pump chambers 10-14 has on the upper side thereof a suction region into which gas is drawn and also on the lower side thereof a discharge region from which gas is discharged. The suction region of the pump chamber 10 communicates with an inlet port 27 formed through the rotor housing 3 at the top thereof and connected to the outside of the roots pump. The discharge region of the pump chamber 10 communicates with the discharge passage 19 of the partition 6. The suction regions of the pump chambers 11-13 communicate with the suction passages 23-25 of the partitions 6-8, respectively. The discharge regions of the pump chambers 11-13 communicate with the discharge passages 20-22 of the partitions 7-9, respectively. The suction region of the pump chamber 14 communicates with the suction passage 26 of the partition 9. The discharge region of the pump chamber 14 communicates with an outlet port 28 formed through the rotor housing 3 at the bottom thereof and connected to the outside of the roots pump.

[0017] The inlet port 27 and the suction passages 23-26 serve as suction inlets for drawing gas into the pump chambers 10-14, respectively. The discharge passages 19-22 and the outlet port 28 serve as discharge outlets for discharging gas from the pump chambers 10-14, respectively.

[0018] The pump housing 1 has therein two parallel rotary shafts 29, 30 that extend through the pump housing 1 horizontally. Rotors 31-35 are fixedly mounted on the rotary shaft 29 for rotation therewith. As shown in Fig. 5, each of the rotors 31-35 has a cross shape as viewed in axial direction of the rotary shaft 29. Similarly, rotors 36-40 are fixedly mounted on the rotary shaft 30 for rotation therewith. As shown in Fig. 5, each of the rotors 36-40 also has a cross shape as viewed in axial direction of the rotary shaft 30. As shown in Fig. 2, a pair of rotors 31 and 36 are rotatably disposed in the pump chamber 10 in engagement with each other. The same is true of the other pairs of rotors 32, 37, 33, 38, 34, 39 and 35, 40 in the pump chambers 11,12, 13 and 14.

[0019] The rotary shaft 29 is rotatably supported at the front end thereof by a bearing 41 provided in the front housing 2. The bearing 41 is movable relative to the front housing 2 in the thrust direction thereof. An annular member 43 is fixedly mounted on the rotary shaft 29. A disc spring 45 is interposed between the rear end of the annular member 43 and the front housing 2 and located around the rotary shaft 29 for urging the rotary shaft 29 forward via the bearing 41 and the annular member 43. The disc spring 45 serves as the second elastic member of the present invention. A sealing member 47 is interposed between the outer peripheral surface of the annular member 43 and the inner surface of the front housing 2 for preventing gas in the pump chamber 10 from leaking out of the pump hosing 1 in a similar way, the rotary shaft 30 is rotatably supported at the front end thereof by a bearing 42 provided in the front housing 2. The bearing 42 is movable relative to the front housing 2 in the thrust direction thereof. An annular member 44 is fixedly mounted on the rotary shaft 30. A disc spring 46 is interposed between the rear end of the annular member 44 and the front housing 2 and located around the rotary shaft 30 for urging the rotary shaft 30 forward via the bearing 42 and the annular member 44. The disc spring 46 also serves as the second elastic member of the present invention. A sealing member 48 is interposed between the outer peripheral surface of the annular member 44 and the inner surface of the front housing 2 for preventing gas in the pump chamber 10 from leaking out of the pump housing 1. The front housing 2 is provided with a cover 65 that covers the front ends of the rotary shafts 29 and 30.

[0020] The rotary shaft 29 is rotatably supported at the rear end thereof by a bearing 51 held by the holder 49 fixedly mounted on the inner surface of the rear housing 4. A spring seat 53 is fixedly screwed on the rotary shaft 29 behind the bearing 51. The spring seat 53 is adjusted for its mounting position and then fixedly mounted on the rotary shaft 29 by any suitable means, such as using double nut that simplifies the fixing procedure. Similarly, the rotary shaft 30 is rotatably supported at the rear end thereof by a bearing 52 held by the holder 50 fixedly mounted on the inner surface of the rear housing 4. A spring seat 54 is fixedly screwed on the rotary shaft 30 behind the bearing 52. The spring seat 54 is adjusted for its mounting position and then fixedly mounted on the rotary shaft 30 by any suitable means, such as using double nut that simplifies the fixing procedure.

[0021] A helical compression spring 55 is interposed between the inner ring of the bearing 51 and the spring seat 53 and located around the rotary shaft 29 for urging the rotary shaft 29 rearward. Thus, the rotary shaft 29 is movable relative to the bearing 51 in the thrust direction of the rotary shaft 29. The helical compression spring 55 serves as the first elastic member of the present invention. In a similar manner, a helical compression spring 56 is interposed between the inner ring of the bearing 52 and the spring seat 54 and located around the rotary shaft 30 for urging the rotary shaft 30 rearward. Thus, the rotary shaft 30 is movable relative to the bearing 52 in the thrust direction of the rotary shaft 30. The helical compression spring 56 also serves as the first elastic member of the present invention. The rotary shafts 29, 30 are positioned most rearward by the helical compression springs 55, 56 having larger elastic force than the disc springs 45, 46. Thus, the rotors 31-40 are positioned in the pump chambers 10-14 so as to be allowed to displace in one thrust direction as described later with the urging force of the disc spring 45 and the helical compression spring 55 and also the urging force of the disc spring 46 and the helical compression spring 56.

[0022] Labyrinth seals 57, 58 are provided on the rotary shafts 29, 30 at positions in the rear housing 4 adjacently to the bearings 51, 52 for providing a seal between the pump chamber 14 and the area of the rear housing 4, in which the bearings 51, 52 are provided. The rotary shafts 29, 30 have at the rear end thereof gears 59, 60 which are meshed with each other in the gear housing 5. An electric motor M is fixedly mounted on the rear end face of the gear housing 5 and the output shaft 61 of the electric motor M is coupled to the rotary shaft 29 through a coupling 62. Thus, drive force of the electric motor M is transmitted to the rotary shafts 29 and 30.

[0023] The outlet port 28, which communicates with the discharge region of the pump chamber 14 at the final stage of the roots pump, is connected to a muffler 63 and an exhaust mechanism 64. Thus, the gas discharged from the pump chamber 14 is delivered to exhaust-gas treatment equipment (not shown) through the exhaust mechanism 64,

[0024] The following will describe the general operation of the roots pump. When the drive force of the electric motor M causes the rotary shaft 29 to rotate, the rotary shaft 30 is driven to rotate through the gears 59 and 60. The rotors 31-35 on the rotary shaft 29 and the 36-40 on the rotary shaft 30 are rotated in the pump chambers 10-14 in engagement with each other. With the rotation of the rotors 31-35 and 36-40, gas is drawn into the pump chamber 10 through the inlet port 27.

[0025] The gas drawn into the suction region of the pump chamber 10 at the first stage of the roots pump is transferred into the discharge region of the pump chamber 10 by the rotation of the rotors 31 and 36. The gas in the discharge region of the pump chamber 10 is drawn further into the suction region of the next pump chamber 11 at the second stage of the roots pump through the discharge passage 19, the communicating space 15 and the suction passage 23 of the partition 6. The gas drawn into the suction region of the pump chamber 11 is transferred into the discharge region of the pump chamber 11 by the rotation of the rotors 32 and 37. The gas in the discharge region of the pump chamber 11 is drawn into the suction region of the pump chamber 12 at the third stage of the roots pump through the discharge passage 20, the communicating space 16 and the suction passage 24 of the partition 7. Similarly, the gas in the pump chamber 12 is transferred into the pump chamber 13 at the fourth stage of the roots pump and further into the pump chamber 14 at the final stage of the roots pump successively.

[0026] The gas drawn into the pump chamber 10 through the inlet port 27 is transferred through the pump chambers 11-14 while being compressed into a high-temperature and high-pressure gas to be discharged through the outlet port 28. Therefore, the rotor housing 3 with the partitions 6-9 and the rotary shafts 29, 30 with the rotors 31-40 are thermally expanded and displaced in both thrust and radial directions, accordingly. The rotary shafts 29, 30 are mounted in the rotor housing 3 and the rear housing 4 so as to be allowed to displace in the thrust direction due to the thermal expansion. Flanges 29A, 30A of the rotary shafts 29, 30 located in the rear housing 4 are in contact at the rear thereof with the front end faces of the labyrinth seals 57, 58, respectively. Each of the flanges 29A, 30A serves as a stepped portion of the present invention. The rear end faces of the labyrinth seals 57, 58 are in contact with the inner rings of the bearings 51, 52, respectively. Therefore, the rotary shafts 29, 30 are prevented from moving rearward by the bearings 51, 52 which respectively support the rotary shafts 29, 30 at a position adjacent to one end thereof. The flange 29A of the rotary shaft 29, the labyrinth seal 57 and the bearing 51 cooperate to form a thrust movement restriction mechanism of the present invention. The flange 30A of the rotary shaft 30. the labyrinth seal 58 and the bearing 52 also cooperate to form a thrust movement restriction mechanism of the present invention. The flanges 29A, 30A of the rotary shafts 29, 30 may be provided by circlips. The roots pump is formed so that the pump housing 1 is fixedly mounted to a mounting base (not shown) through a vibration proof rubber (not shown) with the electric motor M hung on the rear end face of the pump housing 1. Thus, the thermal expansion of the pump housing 1 is absorbed by the vibration proof rubber.

[0027] The following will describe the operation of the roots pump in connection with the effects of the present invention, For the sake of convenience, the description is made with reference to Figs. 3 and 4 showing the rotors 36-40 of the rotary shaft 30. While the roots pump is in operation, the gas drawn into the pump chamber 10 at the first stage is transferred toward the pump chamber 14 at the final stage while being compressed. Thus, the gas under a high temperature and a high pressure is discharged from the pump chamber 14. Accordingly, the rotor housing 3 with the partitions 6-9 and the rotary shaft 30 with the rotors 36-40 are thermally expanded and displaced in both thrust and radial directions.

[0028] Since the displacement of the rotors 36-40 in thrust direction thereof is allowed to take place in a single direction, as indicated by the leftward arrow at the bottom in Fig. 3, the rotors 36-40 are displaced forward. The largest displacement due to the thermal expansion takes place around the pump chamber 14. However, the rotor housing 3 which is exposed to fresh air at its outer periphery is constantly cooled together with the partitions 6-9. On the other hand, the rotary shaft 30 with the rotors 36-40, which is located away from and disposed in the rotor housing 3, is not cooled by fresh air. Therefore, as indicated by the upper and lower arrows having different lengths in Fig. 3, the thermal expansion a of the rotor housing 3 is smaller than that β of the rotary shaft 30.

[0029] In operation of the roots pump, a large clearance 66 is formed between the front surface of the rear housing 4 forming the pump chamber 14 and the rear surface of the rotor 40 due to the thermal expansion. Fine particles present in the gas transferred through the pump chambers 10-14 tend to be accumulated in a large clearance such as 66, thereby forming a mass of foreign matter 67 in the clearance 66 (refer to Fig. 4). While the roots pump is in operation, there is no problem with the foreign matter 67 because the clearance 66 is relatively large. When the roots pump is stopped, however, the source of heat due to the high-temperature gas disappears and the entire roots pump is rapidly cooled, accordingly.

[0030] When the roots pump is at a stop as shown in Fig. 4 and cooled, the rotor housing 3 with the partitions 6-9 and the rotary shaft 30 with the rotors 36-40 are thermally contracted and displaced rearward so as to return to their original positions. The rotary shaft 30 with the rotors 36-40, which was thermally expanded to a larger extent, is thermally contracted also to a larger extent. As indicated by the difference in the length of the upper and lower arrows in Fig. 4, the thermal contraction γ of the rotor housing 3 is smaller than that δ of the rotary shaft 30. When the roots pump is cooled, the foreign matter 67, which has been accumulated in the clearance 66 of the pump chamber 14 in operation, remains in the clearance 66.

[0031] Due to the contraction force of the rotor 40 in returning to its original position and the elastic force of the helical compression spring 56, the foreign matter 67 may be held in the pump chamber 14 at the position between the rear surface of the rotor 40 and the front surface of the rear housing 4. In such a case, the presence of such foreign matter 67 causes a large rotational resistance to the rotor 40. In the present embodiment, however, the rotary shaft 30 is maintained at a position displaced slightly forward by virtue of the deformation of the helical compression spring 56. Thus, the thrust against the foreign matter 67 due to the thermal contraction of the rotor 40 is merely urged by the elastic force. Therefore, the thrust is considerably lessened in comparison with the thermal contraction force being applied to the foreign matter 67. Consequently, holding the foreign matter 67 firmly between the rotor 40 and the rear housing 4 due to the thermal contraction of the rotor 40 is prevented. If any foreign matter 67 is accumulated in any clearance of the pump chambers 10-13, holding the foreign matter 67 firmly among the rotors 36-39, the partitions 6-9 and the front housing 2 due to the thermal contraction of the rotors 36-39 is similarly prevented.

[0032] When the roots pump is set in operation again, the thrust of the rotor 40 against the foreign matter 67 is relatively small and the frictional resistance is also small, so that the roots pump is started smoothly. It is expected that the foreign matter 67 is gradually removed from the clearance 66 by the pressure of the gas and the rotation of the rotor 40 while the roots pump is operating. If the foreign matter 67 remains in the clearance 66, the rotor 40 is not pressed firmly against the foreign matter 67 by virtue of the deformation of the helical compression spring 56, so that the operation of the roots pump is not hindered.

[0033] The above-described first embodiment of the roots pump offers the following advantageous effects.

(1) The helical compression springs 55, 56 are interposed between the bearings 51, 52 and the spring seats 53, 54 for urging the rotary shafts 29, 30 rearward or in the other thrust direction so that the displacement of the rotors 31-40 is allowed only in one axial direction of the rotary shafts 29, 30. The roots pump having such a simple structure makes possible prevention of frictional resistance due to the foreign matter 67.

(2) The original positions of the rotors 36-40 in the pump chambers 10-14 are easily set by disposing the disc spring 46 and the helical compression spring 56 in the front and in the rear of the pump housing 1. Similarly, the original positions of the rotors 31-35 in the pump chambers 10-14 are easily set by disposing the disc spring 45 and the helical compression spring 55 in the front and in the rear of the pump housing 1.

(3) Since the rotary shafts 29, 30 are prevented from displacing in the rearward direction thereof by bringing the flanges 29A, 30A into contact with the bearings 51, 52 indirectly through the labyrinth seals 57, 58, respectively, the object of the present invention is achieved by a simple structure.

(4) Since each of the helical compression springs 55, 56 and the disc spring 45, 46 is provided by a spring, the object of the present invention is achieved by a simple structure.

(5) Since the gas is transferred in the rearward direction of the rotary shafts 29, 30 and the thrust movement restriction mechanisms are located at a position adjacent to the final stage of the multistage roots pump, the thrust movement of the rotary shafts 29, 30 are restricted at a position adjacent to the final stage of the multistage roots pump. Thus, leakage of the gas in the pump chamber 14 at the final stage is effectively prevented.

[0034] The present invention is not limited to above-described first embodiment, but it may be variously modified as exemplified below.

[0035] The first elastic member of the present invention is not limited to the helical compression spring 55 or 56. Any other elastic member such as disc spring, resin or rubber may be used.

[0036] In the above-described first embodiment, the helical compression springs 55, 56 are disposed in the rear of the pump housing 1. However, such first elastic members may be disposed in the front of the pump housing 1 or at any intermediate position of the pump housing 1.

[0037] In the above-described first embodiment, the helical compression springs 55, 56 are disposed around the rotary shafts 29, 30, respectively. However, such first elastic members may be disposed in any other suitable positions as long as the rotary shafts 29, 30 are urged in axial direction of the rotary shafts 29, 30.

[0038] In the following description of the second and third embodiments of the present invention, the reference numerals in parentheses denote the components of the rotary shaft 30 shown in Fig. 2. The second embodiment of the present invention will be described with reference to Fig. 7. The bearing 51 (52) is slidable together with the rotary shaft 29 (30), and the bearing 51 (52) is placed in contact at the outer ring thereof with the retainer plate 68 (69) mounted to the holder 49 (50). Thus, while the rearward movement (rightward in Fig. 7) of the rotary shaft 29 (30) and the bearing 51 (52) is restricted, the forward movement thereof (leftward in Fig. 7) due to the thermal expansion is allowed. The coil spring 70 (71) as the first elastic member of the present invention is interposed between the radially inward projection 72 (73) of the holder 49 (50) and the outer ring of the bearing 51 (52) for urging the rotary shaft 29 (30) and the bearing 51 (52) in the direction (rightward in Fig. 7) opposite to the direction in which the rotary shaft 29 (30) is moved due to the thermal expansion. The second embodiment offers substantially the same advantageous effects as the first embodiment.

[0039] The third embodiment of the present invention will be now described with reference to Fig. 8. The bearing 51 (52) and the holder 49 (50) are slidable together with the rotary shaft 29 (30). While the rearward movement (rightward in Fig. 8) of the rotary shaft 29 (30), the bearing 51 (52) and the holder 49 (50) is restricted by the contact of the flange 29A (30A) of the rotary shaft 29

(30) (shown in Figs. 1, 2) with the labyrinth seal 57 (58), the forward movement thereof (leftward in Fig. 8) due to the thermal expansion is allowed. The coil spring 74 (75) as the first elastic member of the present invention is interposed between the radially outward projection 76 (77) of the holder 49 (50) and the cutout portion 78 (79) of the rear housing 4 for urging the rotary shaft 29 (30), the bearing 51 (52) and the holder 49 (50) in the direction (rightward in Fig. 8) opposite to the direction in which the rotary shaft 29 (30) is moved due to the thermal expansion. The third embodiment offers substantially the same advantageous effects as the first embodiment.

[0040] Instead of the disc springs 45, 46 as the second elastic members, rigid members may be used for restricting the rearward movement of the rotary shafts 29, 30 caused by the helical compression springs 55, 56, respectively.

[0041] Although in the first embodiment the rotor housing 3 with the partitions 6-9 and the rotary shafts 29-30 with the rotors 31-40 are displaced toward the suction side of the roots pump due to the thermal expansion, it may be so arranged that they are displaced only toward the discharge side of the roots pump.

[0042] The pump housing 1 is not limited to the two-piece structure, but it may be an integrated housing. Alternatively, the pump housing 1 may be of a three-piece structure or any other multiple-structure,

[0043] Although in the first embodiment the roots pump has two rotary shafts 29 and 30, it may have one rotary shaft. Alternatively, the roots pump may have three or more rotary shafts.

[0044] The rotary vacuum pump of the present invention is not limited to a multistage roots pump, but it may be a single-stage roots pump having a single pump chamber.

[0045] Although in the above-described embodiment the flanges 29A, 30A of the rotary shafts 29, 30 are in contact with the inner rings of the bearings 51, 52 indirectly through the labyrinth seals 57, 58, respectively, the flanges 29A, 30A of the rotary shafts 29, 30 may be in contact with the inner rings of the bearings 51, 52 directly, respectively.

[0046] The rotary vacuum pump of the present invention is not limited to a roots pump, but it may be a screw pump or a gear pump.

Claims

1. A rotary vacuum pump comprising:

   a pump housing (1) having therein a pump chamber (10-14); and
   a rotary shaft (29, 30) having thereon a rotor (31-40) rotatably disposed in the pump chamber (10-14), wherein when the rotor (31-40) is rotated with the rotary shaft (29, 30), gas in the pump chamber (10-14) is pumped thereby to draw gas into the pump chamber (10-14),
   characterized in that
   a thrust movement restriction mechanism (29A, 30A, 57, 58, 51, 52) is provided for allowing the rotor (31-40) to displace in the pump chamber (10-14) in one thrust direction due to thermal expansion thereof during the operation of the rotary vacuum pump,

   wherein a first elastic member (55, 56, 70, 71, 74, 75) is provided for urging the rotary shaft (29, 30) in the other thrust direction opposite to the one thrust direction.

2. The rotary vacuum pump according to claim 1, **characterized in that** the thrust movement restriction mechanism (29A, 30A, 57, 58, 51, 52) has a stepped portion (29A, 30A) that is formed on the rotary shaft (29, 30) and a bearing (51, 52) that supports the rotary shaft (29, 30), wherein the rotary shaft (29, 30) is prevented from displacing in the other thrust direction which is opposed to the one thrust direction by bringing the stepped portion (29A, 30A) into contact with the bearing (51, 52) directly or indirectly.

3. The rotary vacuum pump according to claim 1 or 2, **characterized in that** the rotary shaft (29, 30) having the rotor (31-40) is provided in plurality, wherein the rotors (31-40) are engaged with each other in the pump chamber (10-14).

4. The rotary vacuum pump according to claim 3, **characterized in that** the first elastic member (55, 56, 70, 71, 74, 75) is located around one end of each rotary shaft (29, 30).

5. The rotary vacuum pump according to claim 4, **characterized in that** a second elastic member (45, 46) is provided for urging each rotary shaft (29, 30) in the one thrust direction.

6. The rotary vacuum pump according to claim 5, **characterized in that** the first and second elastic members (45, 46, 55, 56, 70, 71, 74, 75) are respectively located around opposite ends of the rotary shafts (29, 30).

7. The rotary vacuum pump according to claim 5 or 6, **characterized in that** each of the first elastic members (55, 56, 70, 71, 74, 75) and the second elastic members (45, 46) is provided by a spring.

8. The rotary vacuum pump according to claim 4, **characterized in that** the first elastic member (70, 71) is located between the stepped portion (29A, 30A) and the bearing (51, 52).

9. The rotary vacuum pump according to any one of

claims 1 through 8, **characterized in that** the rotary vacuum pump is a multistage roots pump.

10. The rotary vacuum pump according to claim 9, wherein the gas is transferred in the one thrust direction of the rotary shaft (29, 30), wherein the thrust movement restriction mechanism (55, 56, 70, 71, 74, 75) is located at a position adjacent to the final stage of the multistage roots pump.

FIG. 1

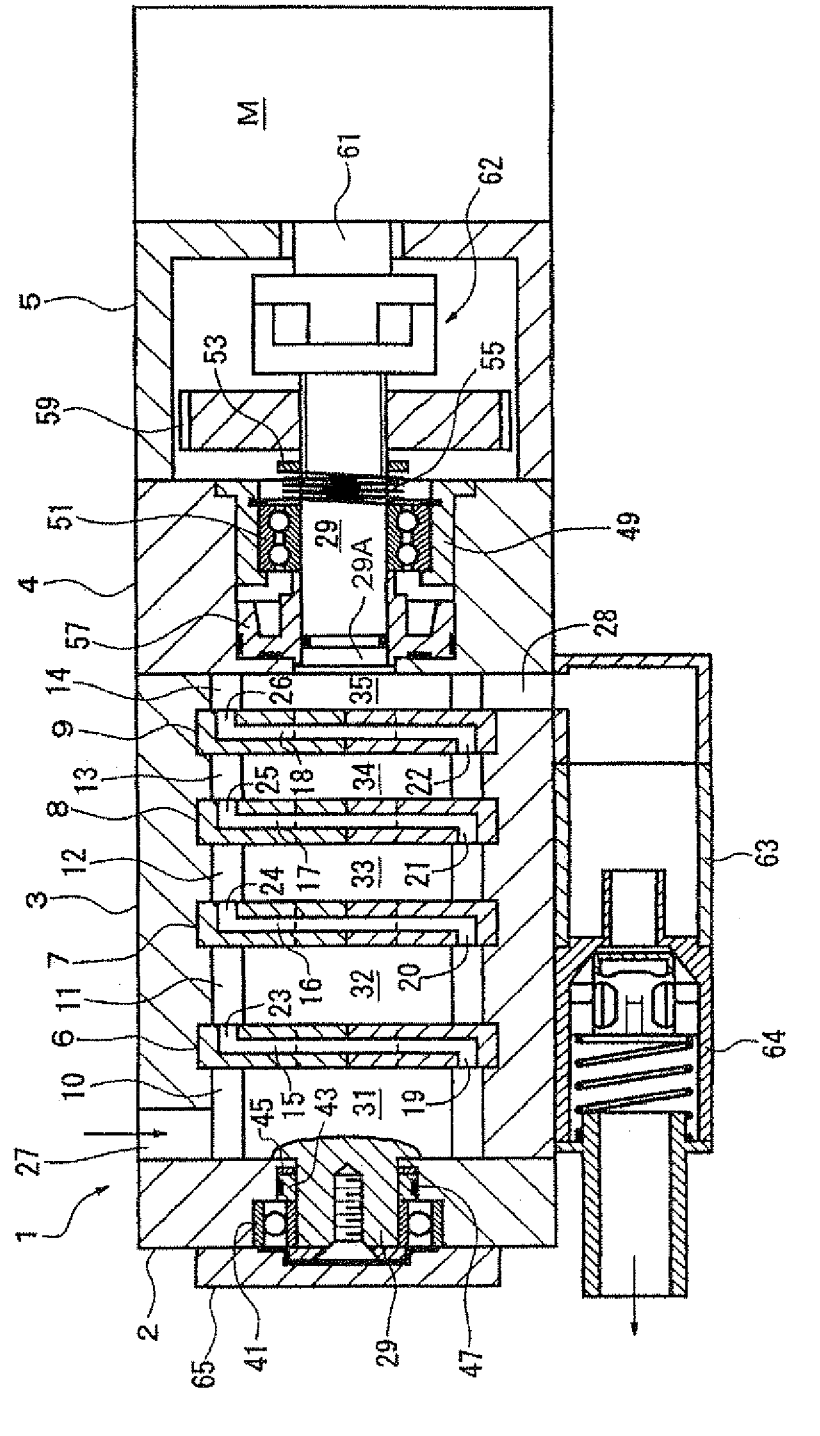

M
61
62
5
53
55
59
51
29
29A
49
4
57
28
14
26
35
9
13
25
18
34
22
8
12
24
17
33
21
3
63
7
11
23
16
32
20
6
64
10
45
15
43
31
19
27
1
2
65
41
29
47

FIG. 2

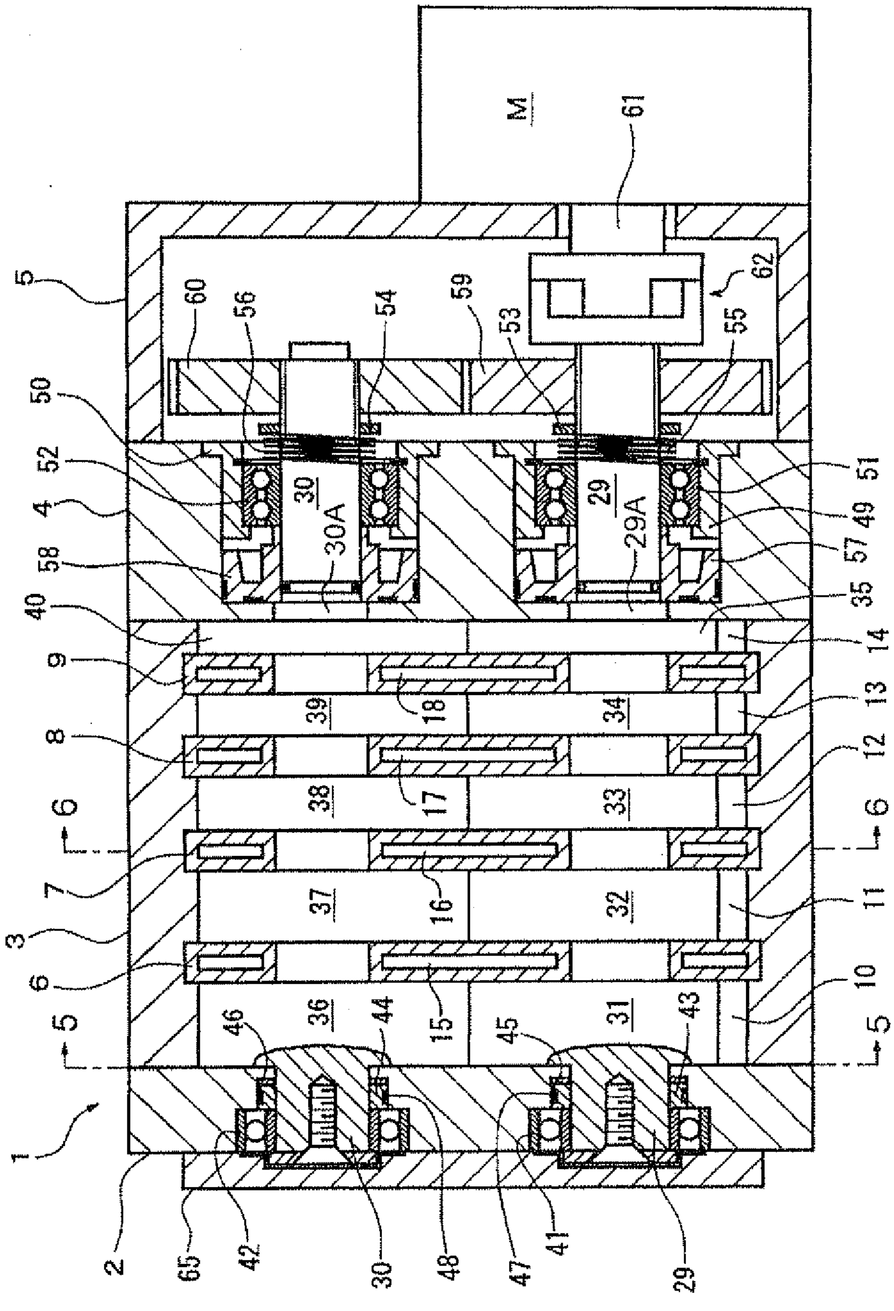

M
61
62
5
60
56
54
59
53
55
50
52
4
58
40
9
8
7
6
3
5
30
30A
29
29A
51
49
57
35
14
13
12
11
10
39
38
37
36
34
33
32
31
18
17
16
15
46
44
45
43
1
2
65
42
30
48
47
41
29

FIG. 3

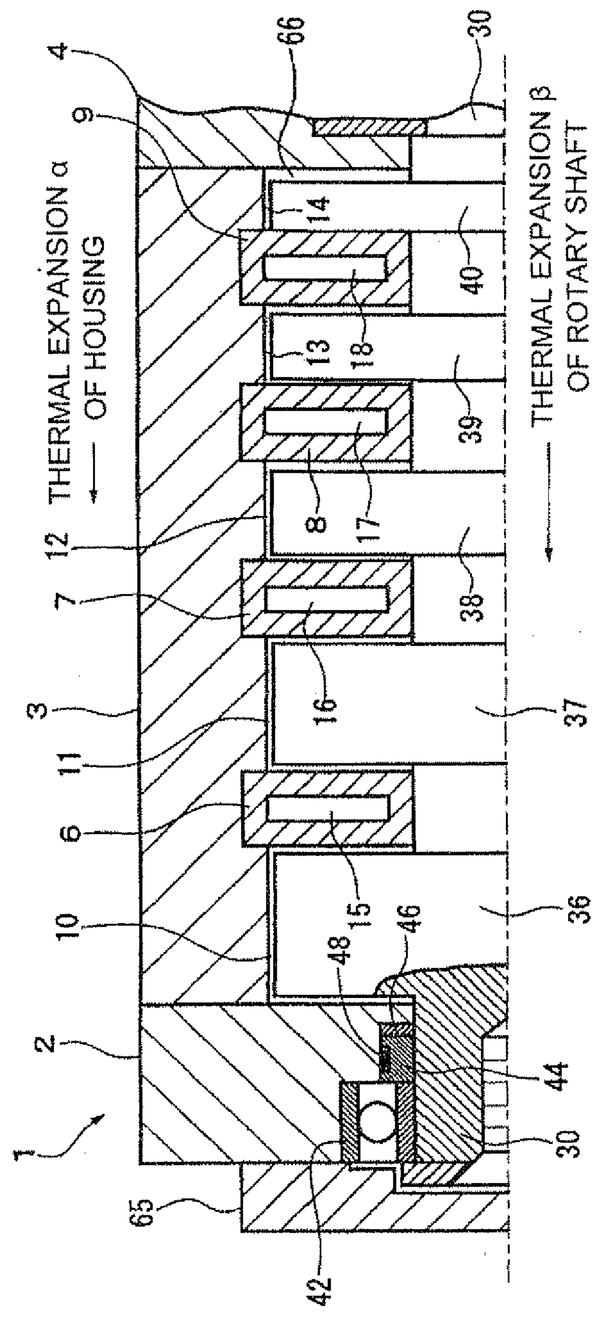

THERMAL EXPANSION α OF HOUSING
THERMAL EXPANSION β OF ROTARY SHAFT
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
30
36
37
38
39
40
42
44
46
48
65
66

FIG. 4

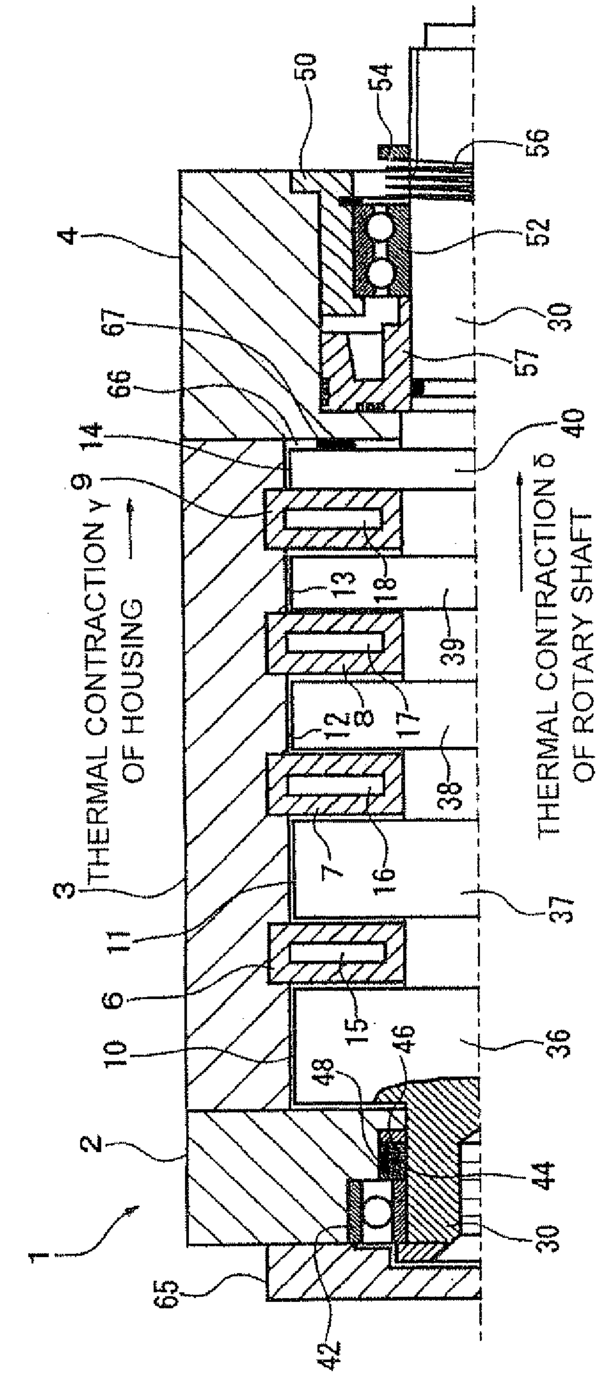

THERMAL CONTRACTION γ OF HOUSING
THERMAL CONTRACTION δ OF ROTARY SHAFT
1
2
3
4
6
7
8
9
10
11
12
13
14
15
16
17
18
30
36
37
38
39
40
42
44
46
48
50
52
54
56
57
65
66
67

FIG. 5

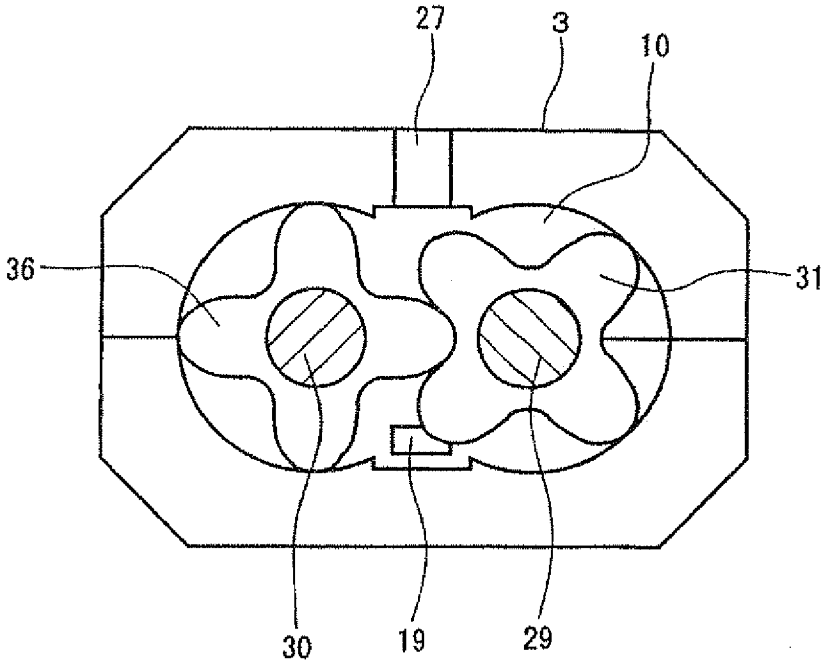


FIG. 6

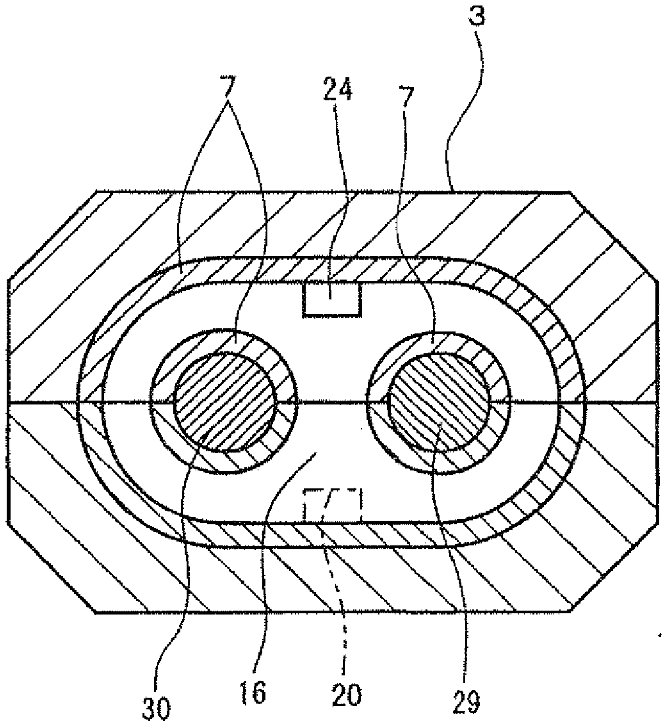


FIG. 7

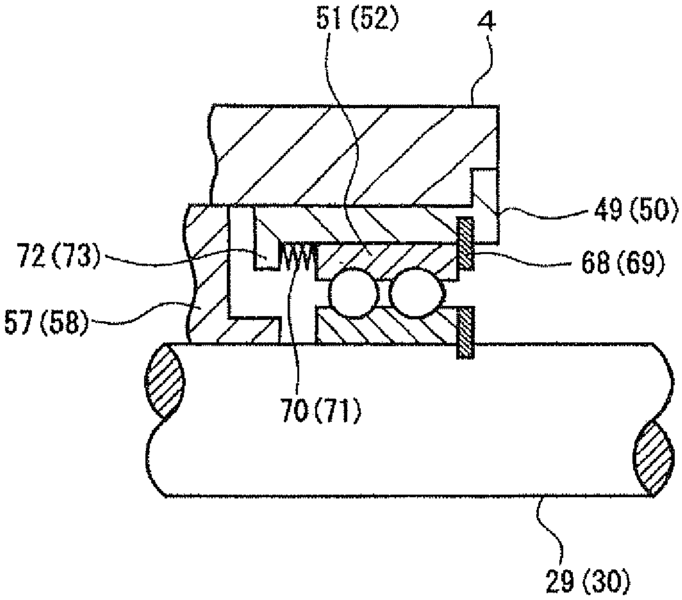
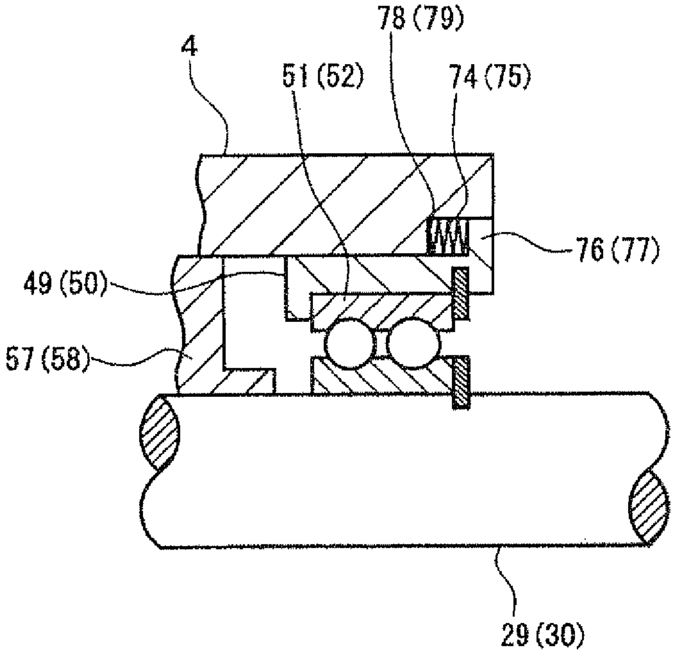

51 (52)
4
49 (50)
72 (73)
68 (69)
57 (58)
70 (71)
29 (30)

FIG. 8


78 (79)
4
51 (52)
74 (75)
76 (77)
49 (50)
57 (58)
29 (30)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2008051116 A **[0002]**