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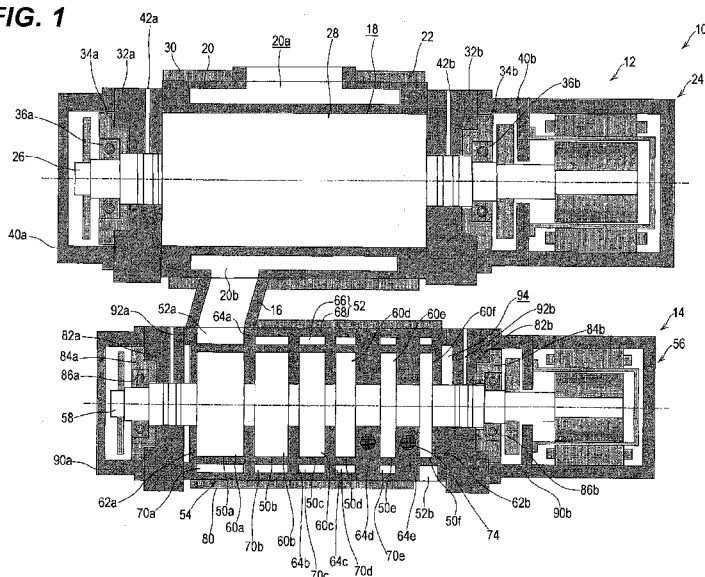
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(54) Title: VACUUM PUMP

FIG. 1



(57) Abstract: A vacuum pump (10) has a pump casing (54) including pump chambers (50a-50f) held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port (52a) and an outlet port (52b), a rotational shaft (58) rotatably supported at opposite ends thereof and extending in the longitudinal direction of the pump casing (54), and rotors (60a-60f) housed in the pump chambers (50a-50f) and coupled to the rotational shaft (58). The pump casing (54) includes a first thermally conductive member (72) extending parallel to the rotational shafts (58) substantially the full length of the pump casing (54) in the longitudinal direction thereof, and a second thermally conductive member (74) positioned near an end of the first thermally conductive member (72) at the outlet port (52b) and extending in a transverse direction of the pump casing (54).

DESCRIPTION**Title of Invention**

Vacuum pump

5 Technical Field

[0001] The present invention relates to a vacuum pump for use in a process such as a CVD process or an etching process which serves as part of fabrication methods for producing semiconductors, liquid crystals, solar cells, LEDs, etc., and more particularly to a vacuum pump for use in a process wherein a sublimable gas or a corrosive gas tends to flow into the interior of the vacuum pump.

Background Art

[0002] When a process gas introduced into a vacuum chamber is discharged under vacuum by using a vacuum pump, the inlet port region of the vacuum pump which is connected to the vacuum chamber is kept under a vacuum which is at the same level as the vacuum in the vacuum chamber and the outlet port region of the vacuum pump is kept substantially under the atmospheric pressure as it is vented to the atmosphere. When the vacuum pump is actuated to discharge the process gas from the vacuum chamber under vacuum, the heat of compression is generated in the vacuum pump because the process gas to be discharged is compressed by the vacuum pump.

[0003] Particularly, when a process gas in a vacuum chamber is discharged under vacuum by using a multistage vacuum pump, the pressure in the vacuum pump increases stepwise as the process gas flows through successive pump chambers, such as first, second, and third pump chambers, of the vacuum pump, and the heat of compression is generated as the process gas is compressed successively in the pump chambers. In the vacuum pump, therefore, the process gas flows through the pump chambers while being pressurized stepwise therein, and the temperature of the process gas also rises stepwise as it flows through the pump chambers. In each of the pump chambers, the process gas is higher in pressure and temperature at the outlet port thereof than at the inlet port thereof. Therefore, when the process gas is discharged from the vacuum chamber under vacuum by using the multistage vacuum pump, its temperature tends to be lower in a low-pressure region near the inlet port of the multistage vacuum pump, and tends to be higher locally

in a high-pressure region near the outlet port of the multistage vacuum pump which is kept nearly under the atmospheric pressure.

[0004] When a process gas containing a sublimable substance flows into a vacuum pump which is used to evacuate a vacuum chamber, for example, if the temperature in the vacuum pump is lower than the sublimation curve of the sublimable substance, then the sublimable substance contained in the process gas that has flowed into the vacuum pump is converted from a gas phase into a solid phase, and is deposited in the vacuum pump, tending to shut down the vacuum pump.

[0005] If local regions in the interior of a vacuum pump have high temperatures, on the other hand, they are likely to be corroded by a cleaning gas or an etching gas which flows into the vacuum pump.

[0006] There has been proposed a dry pump having a hollow thermally insulative intermediate chamber and a cooling passage for passing a refrigerant therethrough, between a pump chamber that is kept at a relatively high temperature and a lubricant chamber that is kept at a relatively low temperature, in order to minimize vaporization of the lubricant for thereby effectively keeping the lubricant in the lubricant chamber at a low temperature while at the same time keeping the pump chamber at a high temperature to lend itself to the discharging of a gas such as a condensable gas or a sublimable gas (see Japanese laid-open patent publication No. 2005-105829).

[0007] The applicant has proposed a rotor for use in rotary gas machinery which comprises a shaft body (rotor shaft) having an axial hole defined axially therein and a core embedded in the axial hole which is made of a material, such as aluminum, whose thermal conductivity is higher than the material of the shaft body, in order to reduce the temperature difference between inlet and outlet sides without sacrificing the corrosion resistance and mechanical strength of the rotor for thereby highly accurately managing clearances between rotors and the rotors and a casing in which the rotors are supported, to achieve a high discharging capability (see Japanese laid-open patent publication No. H11-230060).

Citation List

Patent Literature

[0008]

[PTL 1]

Japanese laid-open patent publication No. 2005-105829

[PTL 2]

Japanese laid-open patent publication No. 11-230060

5 **Summary of Invention**

Technical Problem

[0009] However, conventional vacuum pumps are not designed to keep the interior of the vacuum pump at a higher temperature over the entire vacuum pump for preventing local regions in the vacuum pump from being heated to a temperature higher than the corrosive
10 temperature while at the same time preventing products from being deposited in the vacuum pump due to a sublimable substance contained in a process gas that flows into the vacuum pump.

[0010] The present invention has been made in view of the above situation in the background art. It is therefore an object of the present invention to provide a vacuum
15 pump which is capable of preventing products from being generated and deposited in the vacuum pump, simply without the need for a heater or the like, by keeping the interior of the vacuum pump at a certain high temperature over the entire vacuum pump, i.e., uniformizing the temperature in the vacuum pump over the entire vacuum pump, while at the same time preventing local regions in the vacuum pump from being heated to a
20 temperature higher than the corrosive temperature.

Solution to Problem

[0011] In order to achieve the above object, the present invention provides a vacuum pump comprising a pump casing including a plurality of pump chambers held in fluid
25 communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side, a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing, and a plurality of rotors housed in the pump chambers and coupled to the
30 rotational shaft for rotation in unison with the rotational shaft. The pump casing includes a first thermally conductive member extending parallel to the rotational shaft substantially the full length of the pump casing in the longitudinal direction thereof, and a

second thermally conductive member positioned near an end of the first thermally conductive member on the outlet port side and extending in a transverse direction of the pump casing.

[0012] The pump chambers of a multistage vacuum pump that are closer to the outlet port have higher temperatures therein. The first-stage pump chamber has a lowest temperature therein, and the pump chambers near the outlet port have a highest temperature therein. In each of the pump chambers, a region positioned on the outlet side has a higher temperature than a region positioned on the upper inlet side. The first thermally conductive member that extends parallel to the rotational shaft substantially the full length of the pump casing, and the second thermally conductive member disposed in a position near the end of the first thermally conductive member near the outlet port serve to distribute the heat of the pump casing which define the pump chambers therein uniformly in the longitudinal and transverse directions of the pump casing, and also serve to transfer the heat efficiently from higher-temperature regions to lower-temperature regions, for thereby keeping the interior of the vacuum pump at a higher constant temperature over the entire vacuum pump, i.e., uniformizing the temperature in the vacuum pump over the entire vacuum pump, while at the same time preventing local regions in the vacuum pump from being heated to a temperature higher than the corrosive temperature. The first and second thermally conductive members are made of a material of good heat conductivity such as aluminum, aluminum alloy, copper, or the like.

[0013] The present invention also provides another vacuum pump comprising a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side, a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing, and a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft. The pump casing includes an intermediate chamber disposed adjacent to and outside of the one of the pump chambers which is held in fluid communication with the outlet port, and held in fluid communication with the one of the pump chambers, and a partition disposed in the intermediate chamber and

defining a passageway for guiding a process gas introduced into the intermediate chamber around the rotational shaft.

[0014] As described above, the pump chambers of a multistage vacuum pump that are closer to the outlet port have higher temperatures therein. In each of the pump chambers, a region positioned on the outlet side has a higher temperature than a region positioned on the upper inlet side. A portion of the high-temperature process gas that is discharged from the final stage pump chamber is introduced into the intermediate chamber and circulated in the intermediate chamber along the passageway to heat the inlet side of the final stage pump chamber, after which the high-temperature process gas discharged out of the outlet port. Therefore, the interior of the final stage pump chamber is made higher in temperature, without the need for a heater or the like, for preventing products from being deposited in the vacuum pump.

[0015] The present invention also provides yet another vacuum pump comprising a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side, a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing, and a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft. The pump casing includes an end wall disposed on an end thereof and separate from a side panel which is disposed adjacent to the end of the pump casing.

[0016] Since the pump casing includes the end wall disposed on the end thereof and separate from the side panel which is disposed adjacent to the end of the pump casing, all the rotors disposed in the pump chambers are enclosed by the pump casing. Therefore, the side panel, which is cooled by a lubricant that is supplied to cool the bearings, for example, cools the pump chambers and the process gas in the pump casing, preventing products from being deposited in the vacuum pump.

[0017] In a preferred aspect of the present invention, the pump casing includes an outer barrel which is of a double-walled structure with a gas passage defined therein.

[0018] Since the outer barrel is of the double-walled structure with the gas passage defined therein, the interiors of the pump chambers are reliably thermally insulated from

the exteriors thereof by the high-temperature process gas flowing through the gas passage, for thereby maintaining the interior of the vacuum pump at a low temperature to prevent a sublimable gas contained in the process gas from being converted into a solid substance and deposited in the vacuum pump, i.e., on the inner circumferential surface of the pump casing.

[0019] In a preferred aspect of the present invention, the pump casing includes a thermally insulative jacket surrounding an outer circumferential surface thereof.

[0020] The thermally insulative jacket surrounding the outer circumferential of the pump casing thermally insulates the interiors of the pump chambers to prevent the interior of the vacuum pump from becoming lower in temperature and hence to prevent a sublimable gas contained in the process gas from being converted into a solid substance and deposited in the vacuum pump, i.e., on the inner circumferential surface of the pump casing.

[0021] According to the present invention, the vacuum pump is capable of preventing products from being generated and deposited therein and also preventing the vacuum pump from being corroded, without the need for a heater or the like, by keeping the interior of the vacuum pump at a certain high temperature over the entire vacuum pump, i.e., uniformizing the temperature in the vacuum pump over the entire vacuum pump, for thereby making a vacuum pump process highly reliable.

Brief Description of Drawings

[0022]

[FIG. 1] FIG. 1 is a vertical sectional front view of a vacuum pump according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a vertical sectional side view of a first-stage pump chamber of a main pump of the vacuum pump shown in FIG. 1.

[FIG. 3] FIG. 3 is a perspective view of a pump casing of the main pump of the vacuum pump shown in FIG. 1.

[FIG. 4] FIG. 4 is a cross-sectional view taken along line X – X of FIG. 2.

[FIG. 5] FIG. 5 is a sectional perspective view of the first-stage pump chamber of the main pump of the vacuum pump shown in FIG. 1.

[FIG. 6] FIG. 6 is a view showing a sidewall, as viewed from an electric motor, which is positioned near an outlet port of the pump casing of the main pump of the vacuum pump shown in FIG. 1.

5 **Description of Embodiments**

[0023] Preferred embodiments of the present invention will now be described with reference to the drawings. FIG. 1 is a vertical sectional front view of a vacuum pump 10 according to an embodiment of the present invention. As shown in FIG. 1, the vacuum pump 10 includes a booster pump 12 disposed on a vacuum side and a main pump 14
10 disposed on an atmosphere side, which are connected to each other by a joint pipe 16. In this embodiment, the main pump 14 comprises a six-stage roots vacuum pump, and the booster pump 12 comprises a single-stage roots vacuum pump.

[0024] The booster pump 12 includes a pump casing 22 having a substantially cylindrical outer barrel 20 with a pump chamber 18 defined therein, and a pair of rotational shafts 26
15 extending in the pump casing 22 and synchronously rotatable about their own axes in respective opposite directions by energizing an electric motor 24. The pump chamber 18 houses a pair of rotors 28, such as two-lobed rotors, rotatably therein with a predetermined clearance therebetween. The rotors 28 are fixedly mounted respectively on the rotational shafts 26. The outer barrel 20 of the pump casing 20 has an inlet port
20 20a defined in its wall and connected to a discharge pipe (not shown) extending from a vacuum chamber or the like that is to be evacuated by the vacuum pump 10, and an outlet port 20b defined in its wall and connected to the joint pipe 16. When the rotors 28 are synchronously rotated about their own axes in the respective opposite directions by the electric motor 24, a process gas from the vacuum chamber or the like flows through the
25 inlet port 20a into the pump chamber 18, is compressed by the rotors 28 in the pump chamber 18, and is then discharged through the outlet port 20b into the joint pipe 16. In FIG. 1, only one of the rotational shafts 26, one of the rotors 28, and one of mechanisms for actuating the rotational shafts 26 based on the drive power from the electric motor 24 are illustrated. The other rotational shaft, the other rotor, and the other mechanism are
30 positioned behind away from the viewer of FIG. 1.

[0025] In this embodiment, the outer circumferential surface of the outer barrel 20 of the pump casing 20, except the inlet port 20a and the outlet port 20b, is surrounded by a thermally insulative jacket 30 which is of a substantially hollow cylindrical shape. The

thermally insulative jacket 30 thermally insulates the interior of the pump chamber 18 from the exteriors thereof, thereby keeping the interior of the pump chamber 18 constant in temperature.

[0026] Two side panels 32a, 32b are disposed respectively on the axial ends of the pump casing 22. The rotational shafts 26 are rotatably supported at their outer ends by bearings 36a, 36b housed in bearing housings 34a, 34b that are mounted respectively on the side panels 32a, 32b. Two lubricant housings 40a, 40b for holding a lubricant therein are disposed on respective outer side surfaces of the side panels 32a, 32b. The electric motor 24 has a motor housing coupled to one of the lubricant housings 40b.

[0027] The side panels 32a, 32b have respective purge gas passages 42a, 42b for supplying a purge gas, such as an N₂ gas or the like, to the portions of the rotational shafts 26 in the side panels 32a, 32b to prevent the process gas from flowing out of the pump chamber 18 into the bearings 36a, 36b.

[0028] The booster pump 12 is generally kept at a high vacuum level (low pressure level) therein, and has low generated heat as it does not produce much heat of compression. Therefore, it is desirable to positively heat the booster pump 12 with a heating means, such as a heater or the like, mounted on or in the booster pump 12. The thermally insulative jacket 30, which surrounds the outer circumferential surface of the outer barrel 20 of the pump casing 22, except the inlet port 20a and the outlet port 20b, is effective to prevent the temperature in the pump chamber 18 from dropping due to ambient air.

[0029] The main pump 14 of this embodiment comprises a six-stage roots vacuum pump, and includes a pump casing 54 having a substantially cylindrical outer barrel 52 with six pump chambers 50a-50f, i.e., first- through sixth-stage pump chambers 50a-50f, defined therein, and a pair of rotational shafts 58 extending in the pump casing 54 and synchronously rotatable about their own axes in respective opposite directions by energizing an electric motor 56. The first-stage pump chamber 50a, which is disposed on a suction side of the main pump 14, houses a pair of rotors 60a, such as three-lobed rotors, rotatably therein, as shown FIG. 2. Similarly, the second-stage pump chamber 50b houses a pair of rotors 60b, such as three-lobed rotors, rotatably therein, and the third-stage pump chamber 50c houses a pair of rotors 60c, such as three-lobed rotors, rotatably therein. The fourth-stage pump chamber 50d houses a pair of rotors 60d, such as three-lobed rotors, rotatably therein, the fifth-stage pump chamber 50e houses a pair of rotors 60e, such as three-lobed rotors, rotatably therein, and the sixth-stage pump chamber 50f,

which is disposed on a discharge side of the main pump 14, houses a pair of rotors 60f, such as three-lobed rotors, rotatably therein. One linear array of rotors 60a-60f is fixedly mounted on one of the rotational shafts 58, whereas the other linear array of rotors 60a-60f is fixedly mounted on the other rotational shaft 58.

5 [0030] The pump casing 54 has a pair of end walls 62a, 62b closing the respective opposite ends of the outer barrel 52 and five, i.e., first through fifth, partition walls 64a-64e that partition the interior of the outer barrel 52. The end wall 62a and the first partition wall 64a define the first-stage pump chamber 50a therebetween in the outer barrel 52. The first partition wall 64a and the second partition wall 64b define the
10 second-stage pump chamber 50b therebetween in the outer barrel 52. The second partition wall 64b and the third partition wall 64c define the third-stage pump chamber 50c therebetween in the outer barrel 52. The third partition wall 64c and the fourth partition wall 64d define the fourth-stage pump chamber 50d therebetween in the outer barrel 52. The fourth partition wall 64d and the fifth partition wall 64e define the fifth-
15 stage pump chamber 50e therebetween in the outer barrel 52. The fifth partition wall 64e and the end wall 62b define the sixth-stage pump chamber 50f therebetween in the outer barrel 52.

[0031] When the rotors 60a are synchronously rotated about their own axes in the respective opposite directions by the electric motor 56, a process gas is introduced into
20 the first-stage pump chamber 50a from an upper inlet side thereof which is connected to the joint pipe 16, is compressed by the rotors 60a in the first-stage pump chamber 50a, and is then discharged from the first-stage pump chamber 50a out of a lower outlet side thereof, as shown in FIG. 2. The process gas is subsequently compressed similarly in the second- through sixth-stage pump chambers 50b-50f.

25 [0032] The outer barrel 52 of the pump casing 54 has an inlet port 52a defined in its sidewall which is connected to the joint pipe 16 and held in fluid communication with the upper inlet side of the first-stage pump chamber 50a, and an outlet port 52b defined in its sidewall which is held in fluid communication with the lower outlet side of the sixth-stage (final stage) pump chamber 50f. The outer barrel 52 of the pump casing 54 is of a
30 double-walled structure including an inner wall 66 and an outer wall 68 disposed outside of and spaced a certain distance from the inner wall 66, with first through fifth gas passages 70a-70e being defined therebetween. Specifically, the first gas passage 70a extends around the first-stage pump chamber 50a, and the second gas passage 70b

extends around the second-stage pump chamber 50b. The third gas passage 70c extends around the third-stage pump chamber 50c, the fourth gas passage 70d extends around the fourth-stage pump chamber 50d, and the fifth gas passage 70e extends around the fifth-stage pump chamber 50e. The fifth gas passage 70e also extends around the sixth-stage pump chamber 50f.

[0033] The gas passages 70a-70e have respective portions held in fluid communication with the respective pump chambers 50a-50e through the respective lower outlet sides thereof, and also have respective portions held in fluid communication with the respective pump chambers 50b-50f through the respective upper inlet sides thereof. As shown in FIG. 2, the process gas that has flowed from the inlet port 52a into the first-stage pump chamber 50a through its upper inlet side is compressed in the first-stage pump chamber 50a, and then flows from the first-stage pump chamber 50a through its lower outlet side into the first gas passage 70a. Then, the process gas flows upwardly in the first gas passage 70a and reaches the upper inlet side of the second-stage pump chamber 50b. The process gas flows into the second-stage pump chamber 50b through its upper inlet side and is compressed in the second-stage pump chamber 50b, and then flows from the second-stage pump chamber 50b through its lower outlet side into the second gas passage 70b. Then, the process gas flows upwardly in the second gas passage 70b and reaches the upper inlet side of the third-stage pump chamber 50c. Subsequently, the process gas is compressed in and flows through the third- through sixth-stage pump chambers 50c-50f. Thereafter, the process gas is discharged from the lower outlet side of the sixth-stage pump chamber 50f through the outlet port 52b out of the main pump 14.

[0034] A thermally conductive member (first thermally conductive member) 72 in the form of a rod, for example, is embedded longitudinally in a lower portion of the pump casing 54 which is positioned below the lower outlet sides of the pump chambers 50a-50e. The thermally conductive member 72 is positioned substantially centrally in the transverse direction of the pump casing 54 and extends parallel to the rotational shafts 58 substantially the full length of the pump casing 54. The thermally conductive member 72 has an end exposed out of the pump casing 54 below the inlet port 52a, as shown in FIG. 3. In addition, thermally conductive members (second thermally conductive members) 74, each in the form of a rod, for example, are embedded, in this embodiment, in the fourth partition wall 64d between the fourth-stage pump chamber 50d and the fifth-stage pump chamber 50e and the fifth partition wall 64e between the fifth-stage pump chamber

50e and the fifth-stage pump chamber 50f near the end of the thermally conductive member 72 on the outlet port 52b side. The thermally conductive members 74 are positioned beneath the lower outlet sides of the pump chambers 50d-50f and extend substantially the full width of the pump casing 54. The thermally conductive member 74 has opposite ends exposed out of the pump casing 54, as shown in FIG. 3.

[0035] The thermally conductive members 72, 74 are made of a material of good heat conductivity such as aluminum, aluminum alloy, copper, or the like. The thermally conductive members 72, 74 may be machined parts separate from the pump casing 54 or may be cast of aluminum integrally with the pump casing 54 which may be made of a corrosion-resistant material.

[0036] The pump chambers of the multistage vacuum pump that are closer to the outlet port 52b have higher temperatures therein. According to this embodiment, specifically, the first-stage pump chamber 50a has a lowest temperature therein, and the fifth- and sixth-stage pump chambers 50e, 50f near the outlet port 52b have a highest temperature therein. In each of the pump chambers, a region (lower region) positioned on the lower outlet side has a higher temperature than a region (upper region) positioned on the upper inlet side. Specifically, the region positioned on the lower outlet side of the fifth-stage pump chamber 50e and the region positioned on the lower outlet side of the sixth-stage pump chamber 50f have a highest temperature therein.

[0037] In this embodiment, the thermally conductive members 74 disposed in the fourth partition wall 64d and the fifth partition wall 64e serve to distribute the heat of the regions having the highest temperature, i.e., the region positioned on the lower outlet side of the fifth-stage pump chamber 50e and the region positioned on the lower outlet side of the sixth-stage pump chamber 50e, uniformly in the transverse directions of the pump casing 54. The thermally conductive member 72 that extends parallel to the rotational shafts 58 substantially the full length of the pump casing 54 serves to transfer the heat from regions having higher temperatures to regions having lower temperatures for thereby keeping the interior of the main pump 14 at a higher constant temperature over the entire main pump 14, i.e., uniformizing the temperature in the main pump 14 over the entire main pump 14, while at the same time preventing local regions in the main pump 14 from being heated to a temperature higher than the corrosive temperature. With the thermally conductive members 72, 74 being thus disposed in the pump casing 54, therefore, it is possible to keep the temperature over the entire pump casing 54 in a

necessary temperature range from a temperature of 110°C, for example, at which products are deposited in the pump casing 54, to a corrosive temperature of 200°C, for example, at which the main pump 14 is subject to corrosion.

[0038] Since the outer barrel 52 of the pump casing 54 is of the double-walled structure having the gas passages 70a-70e defined therein, the interiors of the pump chambers 50a-50f are reliably thermally insulated from the exteriors thereof by the high-temperature process gas flowing through the gas passages 70a-70e, for thereby maintaining the interior of the main pump 14 at a high temperature to prevent a sublimable gas contained in the process gas from being converted into a solid substance and deposited in the main pump 14, i.e., on the inner circumferential surface of the pump casing 54. Particularly, the high-temperature process gas which flows through the gas passages 70a-70e from the lower outlet sides of the pump chambers 50a-50e to the upper inlet sides of the pump chambers in the next stages is effective to heat the pump chambers 50a-50f.

[0039] In this embodiment, the outer circumferential surface of the outer barrel 52 of the pump casing 54, except the inlet port 52a and the outlet port 52b, is surrounded by a thermally insulative jacket 80 which is of a substantially hollow cylindrical shape. The thermally insulative jacket 80 thermally insulates the interiors of the pump chambers 50a-50f from the exteriors thereof, thereby keeping the interiors of the pump chambers 50a-50f constant in temperature.

[0040] Two side panels 82a, 82b are disposed respectively outside of the end walls 62a, 62b of the pump casing 54. The rotational shafts 58 are rotatably supported at their outer ends by bearings 86a, 86b housed in bearing housings 84a, 84b that are mounted respectively on the side panels 82a, 82b. Two lubricant housings 90a, 90b for holding a lubricant therein are disposed on respective outer side surfaces of the side panels 82a, 82b. The electric motor 56 has a motor housing coupled to one of the lubricant housings 90b. The side panels 82a, 82b have respective purge gas passages 92a, 92b for supplying a purge gas, such as an N₂ gas or the like, to the portions of the rotational shafts 58 in the side panels 82a, 82b to prevent the process gas from flowing out of the pump chambers 50a-50f into the bearings 86a, 86b.

[0041] In this embodiment, the end wall 62a of the pump casing 54, which defines the first-stage pump chamber 50a, is positioned between the rotors 60a housed in the first-stage pump chamber 50a and the side panel 82a that is disposed outside of the rotors 60a. The end wall 62b of the pump casing 54, which defines the sixth-stage pump chamber

50f, is positioned between the rotors 60f housed in the sixth-stage pump chamber 50f and the side panel 82b that is disposed outside of the rotors 60f. Therefore, all the rotors 60a-60f disposed in the pump chambers 50a-50f are enclosed in the pump casing 54. Thus, the side panels 82a, 82b, which are cooled by the lubricant that is supplied to cool the bearings 86a, 86b, for example, cool the pump chambers 50a-50f and the process gas in the pump casing 54, thereby preventing products from being deposited in the vacuum pump 10.

[0042] In this embodiment, an intermediate chamber 94 is defined between the end wall 62b of the pump casing 54, which defines the sixth-stage (final stage) pump chamber 50f, and the side panel 82b that is disposed outside of the end wall 62b. As shown in FIGS. 4 and 6, the end wall 62b has a discharge hole 96 defined substantially centrally therein in the transverse directions thereof and positioned near the lower outlet side of the sixth-stage (final stage) pump chamber 50f. As shown in FIG. 6, the end wall 62b also has two reverse-flow holes 98 defined therein, one on each side of the discharge hole 96. Two partitions 100 are positioned in the intermediate chamber 94 between the discharge hole 96 and the reverse-flow holes 98, respectively, and extend from the respective rotational shafts 58 to the bottom of the intermediate chamber 94. The partitions 100 serve to prevent the process gas discharged from the discharge hole 96 from directly flowing into the reverse-flow holes 98. With this structure, the partitions 100 is configured to define gas passageways 102 in the intermediate chamber 94 which extend upwardly from the discharge hole 96 to positions above the rotational shafts 58, then around the rotational shafts 58, and downwardly toward the reverse-flow holes 98, as shown in FIG. 6.

[0043] In this embodiment, the partitions 100 are in the form of plates separate from the pump casing 54 and fixed to the pump casing 54. However, the partitions 100 may be integrally formed with the pump casing 54.

[0044] As described above, the pump chambers of the multistage vacuum pump near the final stage have a highest temperature, and the region near the outlet side of each of those pump chambers has a higher temperature than the region near the inlet side thereof. According to this embodiment, therefore, a portion of the high-temperature process gas that is discharged from the sixth-stage (final stage) pump chamber 50f is introduced through the discharge hole 96 into the intermediate chamber 94 and circulated in the intermediate chamber 94 along the gas passageways 102 to heat the inlet side of the sixth-stage pump chamber 50f through the end wall 62b, after which the high-

temperature process gas is discharged through the reverse-flow holes 98 out of the outlet port 52b. Therefore, the interior of the sixth-stage (final stage) pump chamber 50f is made higher in temperature.

[0045] The vacuum pump 10 thus constructed operates by energizing the electric motor 24 of the booster pump 12 and the electric motor 56 of the main pump 14 to actuate the booster pump 12 and the main pump 14 to discharge the process gas, which is introduced into, e.g., a vacuum chamber, from the vacuum chamber.

[0046] At this time, the interior of the vacuum pump 10 is kept at a higher temperature over the entire vacuum pump 10 for preventing local regions in the vacuum pump 10 from being heated to a temperature higher than the corrosive temperature while at the same time preventing products from being deposited in the vacuum pump 10 due to a sublimable substance contained in a process gas that flows into the vacuum pump 10.

[0047] While the present invention has been described with reference to preferred embodiments, it is understood that the present invention is not limited to the embodiments described above, but is applicable to vacuum pumps of different types, e.g., a claw vacuum pump, a screw vacuum pump, etc., within the scope of the inventive concept as expressed herein.

Industrial Applicability

[0048] The present invention is applicable to a vacuum pump for use in a process wherein a sublimable gas or a corrosive gas tends to flow into the interior of the vacuum pump.

CLAIMS

[Claim 1]

A vacuum pump comprising:

5 a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side;

10 a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft;

wherein the pump casing includes:

15 a first thermally conductive member extending parallel to the rotational shaft substantially the full length of the pump casing in the longitudinal direction thereof; and

a second thermally conductive member positioned near an end of the first thermally conductive member on the outlet port side and extending in a transverse direction of the pump casing.

20 [Claim 2]

A vacuum pump according to claim 1, wherein the pump casing includes an outer barrel which is of a double-walled structure with a gas passage defined therein.

[Claim 3]

25 A vacuum pump according to claim 1, wherein the pump casing includes a thermally insulative jacket surrounding an outer circumferential surface thereof.

[Claim 4]

A vacuum pump comprising:

5 a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side;

a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

10 a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft;

wherein the pump casing includes:

15 an intermediate chamber disposed adjacent to and outside of the one of the pump chambers which is held in fluid communication with the outlet port, and held in fluid communication with the one of the pump chambers; and

a partition disposed in the intermediate chamber and defining a passageway for guiding a process gas introduced into the intermediate chamber around the rotational shaft.

20 [Claim 5]

A vacuum pump according to claim 4, wherein the pump casing includes an outer barrel which is of a double-walled structure with a gas passage defined therein.

[Claim 6]

25 A vacuum pump according to claim 4, wherein the pump casing includes a thermally insulative jacket surrounding an outer circumferential surface thereof.

[Claim 7]

A vacuum pump comprising:

5 a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side;

a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

10 a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft;

wherein the pump casing includes:

an end wall disposed on an end thereof and separate from a side panel which is disposed adjacent to the end of the pump casing.

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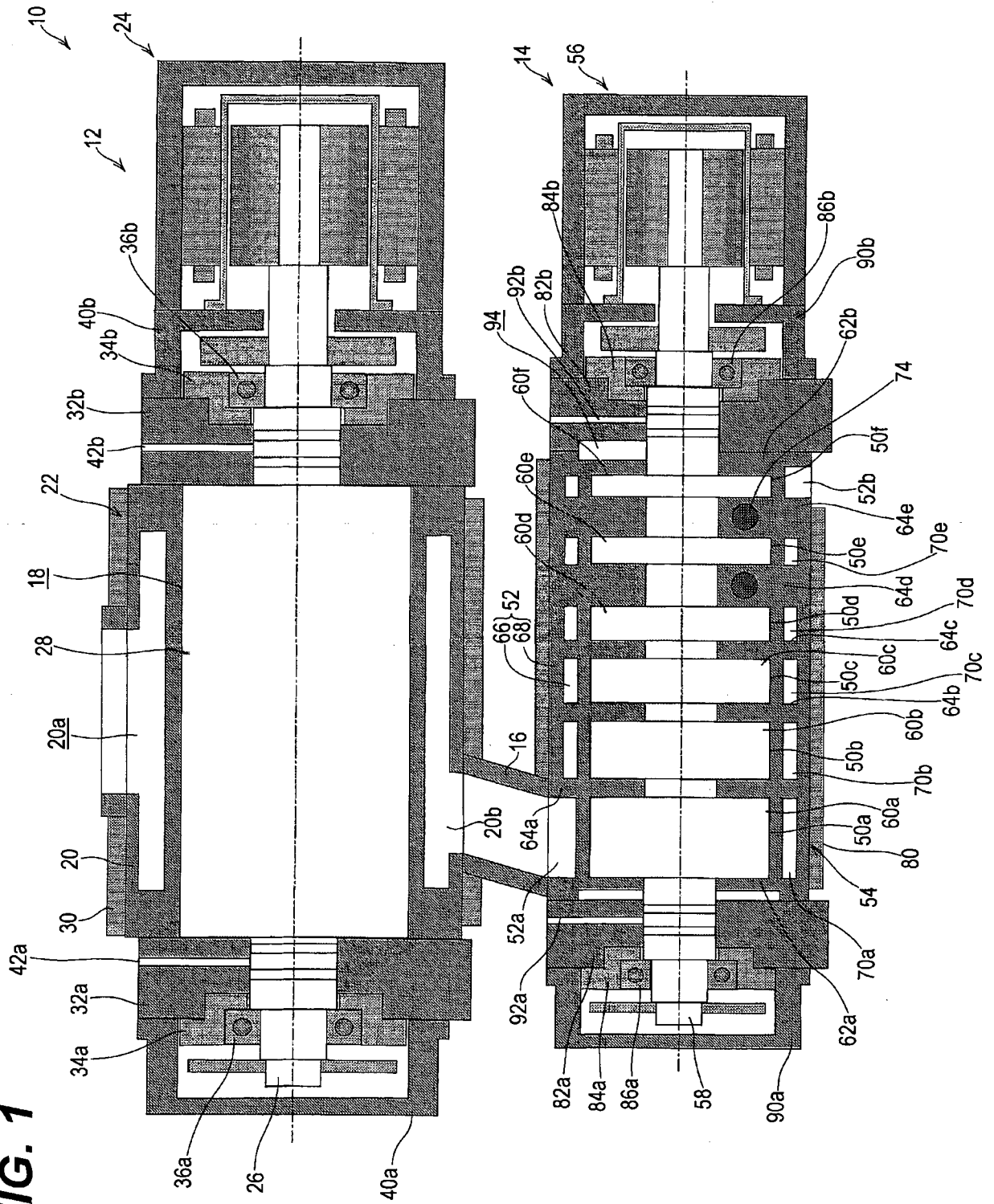
[Claim 8]

A vacuum pump according to claim 7, wherein the pump casing includes an outer barrel which is of a double-walled structure with a gas passage defined therein.

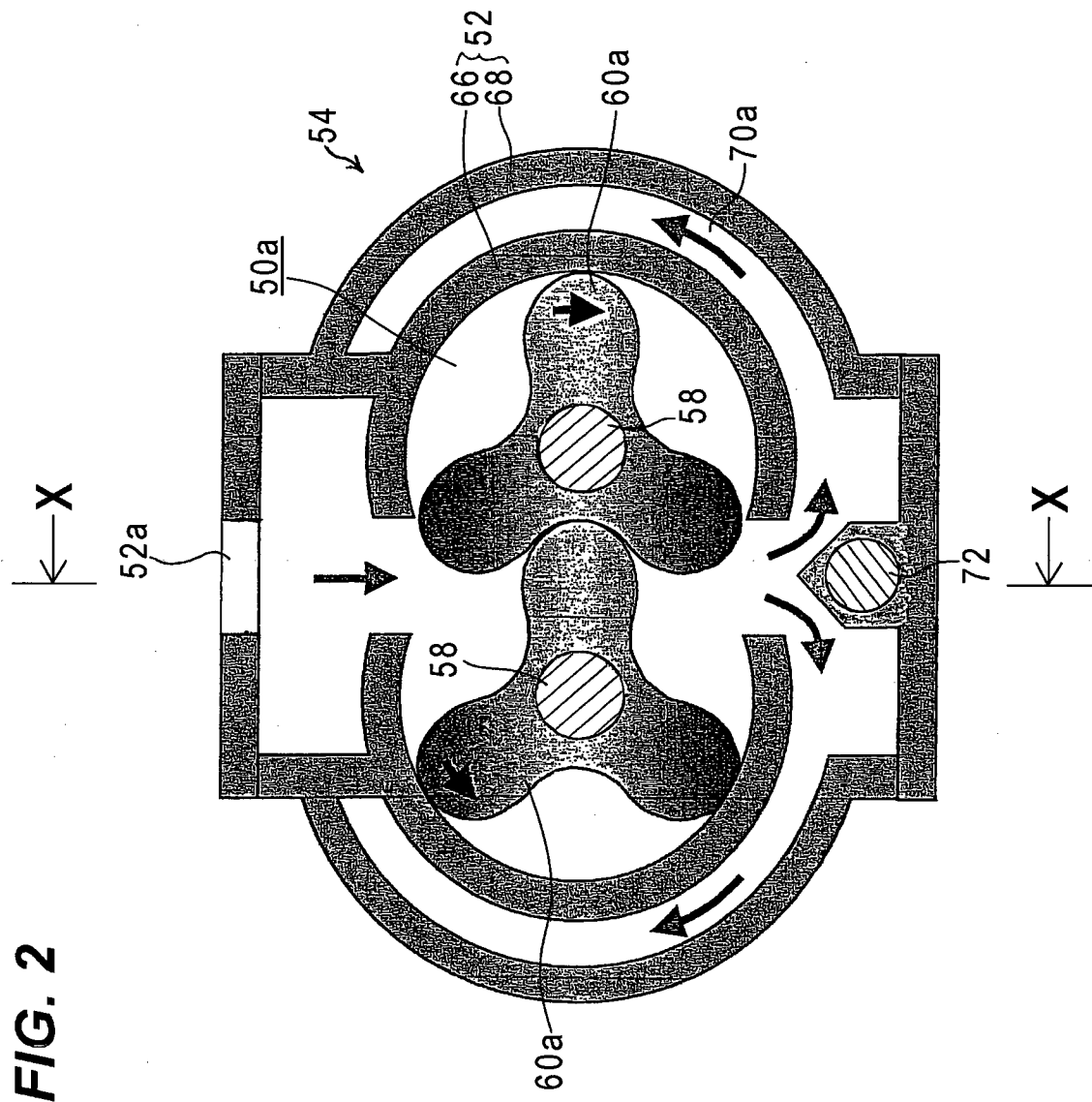
20 [Claim 9]

A vacuum pump according to claim 7, wherein the pump casing includes a thermally insulative jacket surrounding an outer circumferential surface thereof.

FIG. 1



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FIG. 3

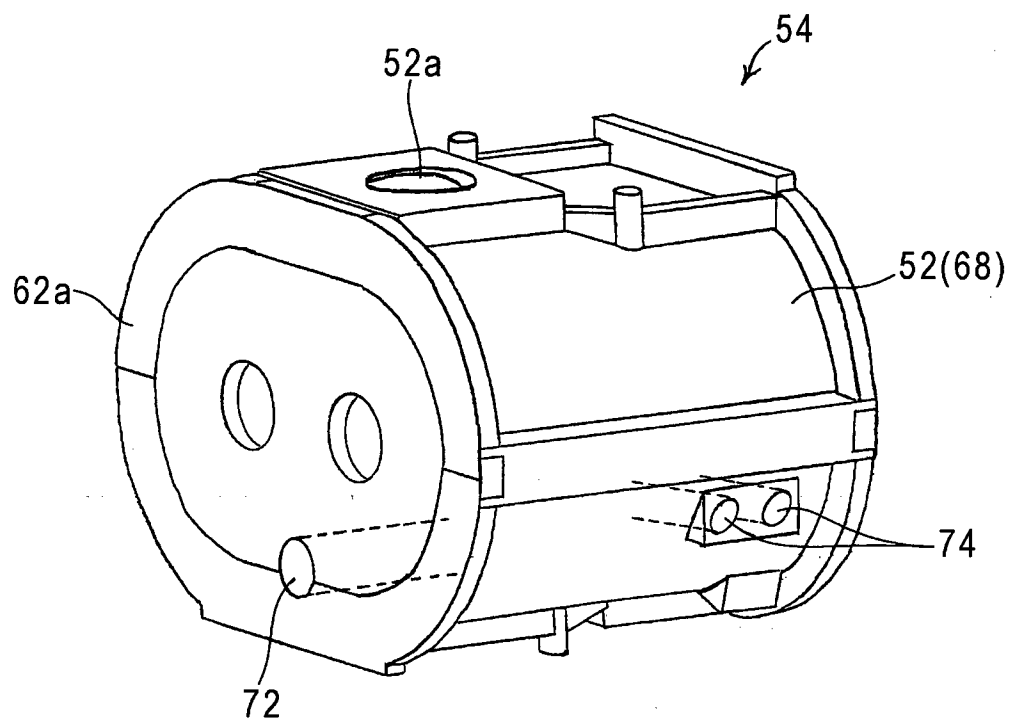
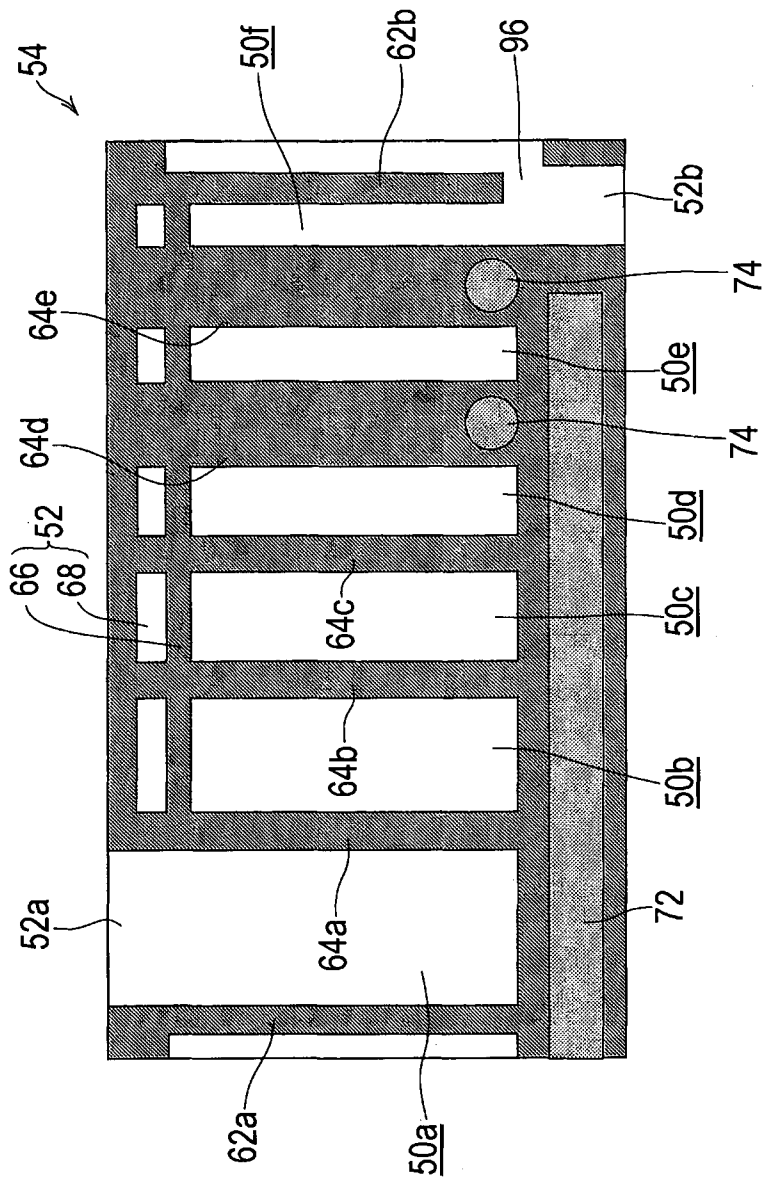
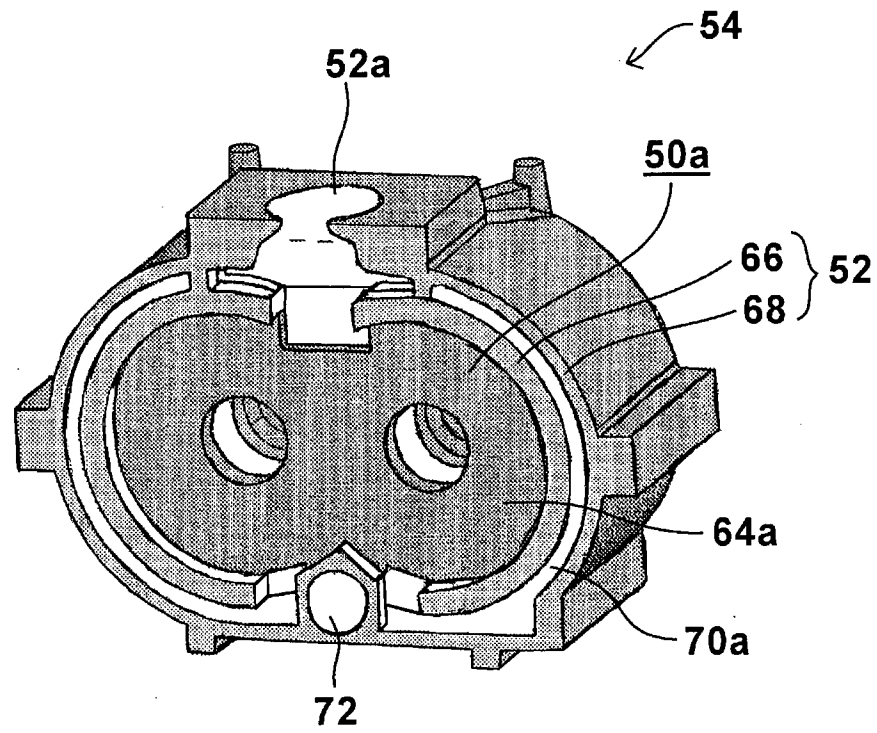


FIG. 4



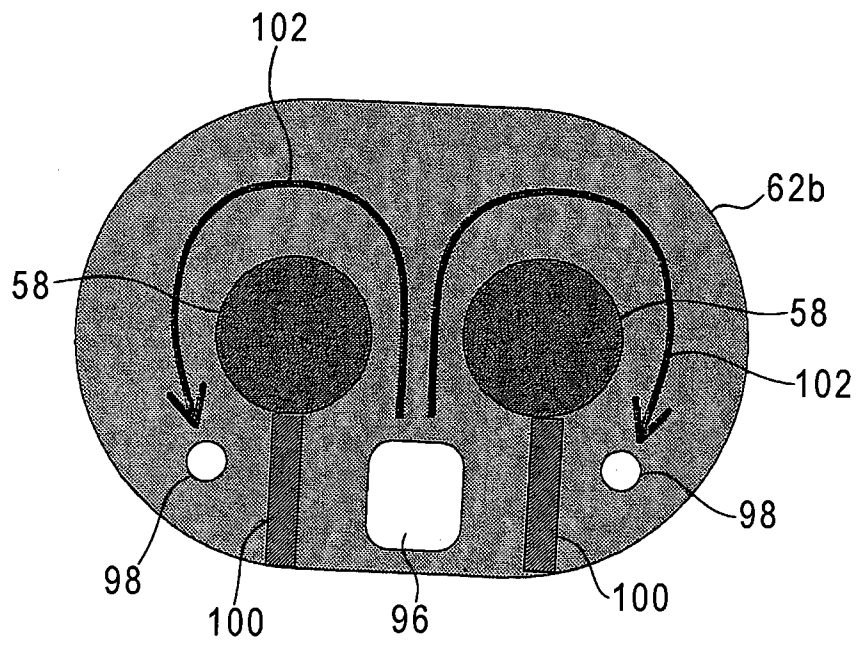
5/6

FIG. 5



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FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/064347

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F04C25/02 (2006.01) i, F04C18/18 (2006.01) i, F04C23/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. F04C25/02, F04C18/18, F04C23/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2012
 Registered utility model specifications of Japan 1996-2012
 Published registered utility model applications of Japan 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2010-270657 A (MITSUBISHI HEAVY INDUSTRIES, LTD., ULVAC, INC.) 2010.12.02, [0026]-[0029], [0039]-[0040], Fig.2-5 & WO 2010/134427 A1	7 8-9 1-6
Y	JP 2004-293434 A (AISIN SEIKI CO., LTD.) 2004.10.21, [0024]-[0025], [0031], [0035]-[0036], Fig.1-3 (No Family)	8-9
A	JP 2005-36814 A (NABTESCO CO., LTD.) 2005.02.10, [0004]-[0010], [0028]-[0031], Fig. 5-6 (No Family)	1-9 1-9
A	JP 10-318168 A (T. D. ENGINEERING CO., LTD.) 1998.12.02, [0002]-[0005], [0018]-[0022], Fig. 5-6 & US 6126425 A & EP 879964 A1	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

07.08.2012

Date of mailing of the international search report

21.08.2012

Name and mailing address of the ISA/JP

Japan Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/064347

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-129978 A (AISIN SEIKI CO., LTD.) 2003.05.08, [0002]-[0011], [0039]-[0040], Fig. 4 & US 2003/0077182 A1	1-9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/064347

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The inventions of claims 1-3, claims 4-6 and claims 7-9 have a common technical feature in that,

a vacuum pump comprising: a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side;

a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft.

(Continued on the extra page.)

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

However, the abovementioned technical feature is described in D1 (JP 2005-36814 A (NABTESCO CO., LTD.) 2005.02.10, [0004]-[0010], [0028]-[0031], Fig. 5-6) and D2 (JP 10-318168 A (T. D. ENGINEERING CO., LTD.) 1998.12.02, [0002]-[0005], [0018]-[0022], Fig. 5-6), and is not a special technical feature.

Accordingly, there is not a special technical feature between claims 1-3, claims 4-6 and claims 7-9 within the meaning of PCT Rule 13.2 at the time of the instruction of additional fees.

Therefore, the claims include the inventions of the following three groups.

Group 1. Claim 1-3

A vacuum pump comprising: a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side; a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft; wherein the pump casing includes:

a first thermally conductive member extending parallel to the rotational shaft substantially the full length of the pump casing in the longitudinal direction thereof; and

a second thermally conductive member positioned near an end of the first thermally conductive member on the outlet port side and extending in a transverse direction of the pump casing.

Group 2. Claim 4-6

A vacuum pump comprising: a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side; a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft; wherein the pump casing includes:

an intermediate chamber disposed adjacent to and outside of the one of the pump chambers which is held in fluid communication with the outlet port, and held in fluid communication with the one of the pump chambers; and

a partition disposed in the intermediate chamber and defining a passageway for guiding a process gas introduced into the intermediate chamber around the rotational shaft.

(Continued on next extra page.)

Group 3. Claim 7-9

A vacuum pump comprising: a pump casing including a plurality of pump chambers held in fluid communication with each other and arrayed in a longitudinal direction thereof, an inlet port held in fluid communication with one of the pump chambers which is positioned on a suction side, and an outlet port held in fluid communication with one of the pump chambers which is positioned on a discharge side; a rotational shaft rotatably supported at opposite ends thereof by bearings and extending in the longitudinal direction of the pump casing; and

a plurality of rotors housed in the pump chambers and coupled to the rotational shaft for rotation in unison with the rotational shaft; wherein the pump casing includes:

an end wall disposed on an end thereof and separate from a side panel which is disposed adjacent to the end of the pump casing.