



(12) **EUROPEAN PATENT APPLICATION**
 published in accordance with Art. 153(4) EPC

(43) Date of publication:
09.09.2009 Bulletin 2009/37

(51) Int Cl.:
F04C 23/02 (2006.01) **F01C 13/04** (2006.01)
F01C 21/06 (2006.01) **F04C 29/04** (2006.01)
F25B 11/02 (2006.01)

(21) Application number: **07832306.0**

(22) Date of filing: **21.11.2007**

(86) International application number:
PCT/JP2007/072576

(87) International publication number:
WO 2008/062839 (29.05.2008 Gazette 2008/22)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

(72) Inventors:
 • **KUMAKURA, Eiji**
 Sakai-shi
 Osaka 591-8511 (JP)
 • **SAKITANI, Katsumi**
 Sakai-shi
 Osaka 591-8511 (JP)

(30) Priority: **24.11.2006 JP 2006317127**

(71) Applicant: **Daikin Industries, Ltd.**
 Osaka 530-8323 (JP)

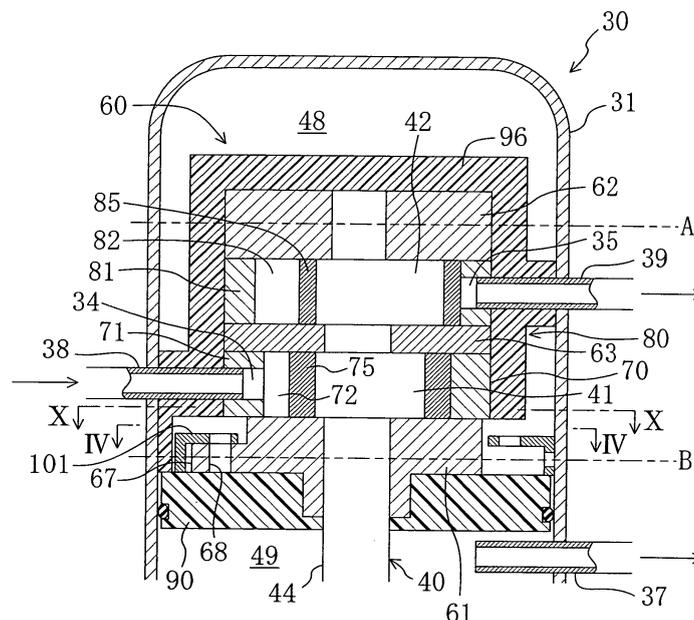
(74) Representative: **HOFFMANN EITL**
Patent- und Rechtsanwälte
 Arabellastrasse 4
 81925 München (DE)

(54) **FLUID MACHINE**

(57) A casing (31) contains a compression mechanism (50) for compressing refrigerant, an expansion mechanism (60) for expanding refrigerant, and a rotary

shaft (40) connecting the compression mechanism (50) and the expansion mechanism (60). The expansion mechanism (60) is fixed to the casing (31) by a mounting plate (101).

FIG. 3



Description

TECHNICAL FIELD

[0001] This invention relates to fluid machines in which a compression mechanism and an expansion mechanism are contained in a single casing.

BACKGROUND ART

[0002] Fluid machines are conventionally known in which an expansion mechanism, an electric motor and a compression mechanism are connected by a single rotary shaft. In such a fluid machine, the expansion mechanism generates power by expanding fluid introduced thereinto. The power generated by the expansion mechanism, together with power generated by the electric motor, is transmitted to the compression mechanism by the rotary shaft. Then, the compression mechanism is driven by the power transmitted from the expansion mechanism and the electric motor to suck the fluid and compress it.

[0003] In such a fluid machine, the expansion mechanism is heated by high-temperature fluid discharged from the compressor. Thus, when used for hot water supply, the fluid machine causes a decrease in the discharge gas temperature of the compressor, which decreases the hot water supply temperature. On the other hand, when used for air conditioning, the fluid machine causes a decrease in supply air temperature during heating operation and degrades the performance during cooling operation. Furthermore, the expansion mechanism itself causes an internal heat loss, whereby its power recovery effect is set off.

[0004] To prevent these problems of performance degradation and decrease in power recovery effect, Patent Document 1, for example, discloses a technique in which a heat insulator is attached to the expansion mechanism.

Patent Document 1: Published Japanese Patent Application No. 2005-106064

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005] However, it is not possible to prevent, with only the heat insulator as disclosed in Patent Document 1, heat flowing through the front head into the expansion mechanism from the casing sidewall raised to high temperature owing to transfer of heat produced in the compression mechanism, i.e., heat input to the expansion mechanism due to solid heat conduction. Specifically, the expansion mechanism, the casing and the member fixing them to each other (including the welded parts) are generally made of metallic materials and, therefore, have high heat conductivity. This causes a problem of occurrence of heat exchange due to heat conduction through the above metallic materials between low-temperature

refrigerant in the expansion mechanism and high-temperature refrigerant in the compression mechanism.

[0006] The present invention has been made in view of the foregoing points and, therefore, an object of the invention is that a fluid machine containing a compression mechanism and an expansion mechanism in a single casing prevents heat exchange between the casing and the expansion mechanism or the compression mechanism to prevent performance degradation and decrease in power recovery effect by devising the structure to which the compression mechanism or the expansion mechanism is fixed.

MEANS TO SOLVE THE PROBLEMS

[0007] To attain the above object, in the present invention, the compression mechanism (50) or the expansion mechanism (60) is fixed through a mounting plate (101) to the casing (31).

[0008] Specifically, a first aspect of the invention is directed to a fluid machine disposed in a refrigerant circuit (20) operating in a refrigeration cycle by circulating refrigerant therethrough.

[0009] The fluid machine includes: a casing (31); a compression mechanism (50) contained in the casing (31) and configured to compress the refrigerant; an expansion mechanism (60) contained in the casing (31) and configured to expand the refrigerant; a rotary shaft (40) disposed in the casing (31) and connecting the compression mechanism (50) and the expansion mechanism (60); and a mounting plate (101) fixing one of the compression mechanism (50) and the expansion mechanism (60) to the casing (31).

[0010] With the above structure, the refrigerant compressed by the compression mechanism (50) of the fluid machine (30), which is disposed in the refrigerant circuit (20), releases heat in a heat exchanger for heat release and then flows into the expansion mechanism (60) of the fluid machine (30). In the expansion mechanism (60), high-pressure refrigerant having flowed thereinto expands. Power recovered from the high-pressure refrigerant in the expansion mechanism (60) is transmitted to the compression mechanism (50) by the rotary shaft (40) and used to drive the compression mechanism (50). The refrigerant having expanded in the expansion mechanism (60) takes heat in a heat exchanger for heat absorption and is then sucked into the compression mechanism (50) of the fluid machine (30).

[0011] Since the compression mechanism (50) or the expansion mechanism (60) is firmly fixed to the casing (31) by the mounting plate (101), this prevents swelling of the casing (31) and excessive vibration of the compression mechanism (50) or the expansion mechanism (60).

[0012] In this case, the expansion mechanism (60) is kept at low temperature, while the compression mechanism (50) is kept at high temperature. Therefore, a temperature difference is produced between both the mech-

anisms. In view of this, comparison is made between the difference between the surface temperature of the compression mechanism (50) and the temperature of part of the casing (31) near to the compression mechanism (50) and the difference between the surface temperature of the expansion mechanism (60) and the temperature of part of the casing (31) near to the expansion mechanism (60), and one of the compression mechanism (50) and the expansion mechanism (60) having a greater temperature difference from the casing (31) is fixed to the casing (31) by the mounting plate (101). This prevents direct fixation between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) significantly different in temperature from the casing (31) that would conventionally be done. Therefore, if the mounting plate (101) is configured to have a high heat resistance, heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50) is reduced.

[0013] A second aspect of the invention is the fluid machine according to the first aspect of the invention, wherein the casing (31) has the shape of a cylindrical container, the mounting plate (101) is shaped in a ring and includes: mechanism-side mounting parts (104) which are formed at the inner periphery of the mounting plate (101) and to which one of the compression mechanism (50) and the expansion mechanism (60) is fixed; and casing-side mounting parts (105) formed at the outer periphery of the mounting plate (101) and fixed to the casing (31), the casing-side mounting parts (105) radially outwardly extend to provide a plate outside clearance (108) of given width from the inside surface of the casing (31) between each pair of the adjacent casing-side mounting parts (105), and the mechanism-side mounting parts (104) are circumferentially offset from the casing-side mounting parts (105).

[0014] With the above structure, since the plate outside clearances (108) are provided, the joints between the mounting plate (101) and the casing (31) are the casing-side mounting parts (105) only. Thus, the heat transfer area can be reduced as compared with the case where the mounting plate (101) is joined over the entire circumference to the casing (31). Furthermore, since the mechanism-side mounting parts (104) are circumferentially offset from the casing-side mounting parts (105), the heat transfer paths can be extended as compared with the case where each pair of mechanism- and casing-side mounting parts are arranged at the same circumferential angle. Thus, the heat resistance is increased, thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). For these reasons, heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50) is reduced.

[0015] A third aspect of the invention is the fluid machine according to the second aspect of the invention,

wherein the fluid machine is configured so that the refrigerant is introduced from the refrigerant circuit (20) directly into the compression mechanism (50) and the compressed refrigerant is discharged from the compression mechanism (50) to an internal space (49) of the casing (31) and then flows out of the internal space (49) to the outside of the casing (31), and the expansion mechanism (60) is fixed through the mounting plate (101) to the casing (31).

[0016] With the above configuration, the interior of the casing (31) is kept under high-temperature and high-pressure conditions, thereby providing a so-called high-pressure dome fluid machine. In this case, since the low-temperature expansion mechanism (60) significantly different in temperature from the atmosphere in the rest of the interior of the casing (31) is fixed through the mounting plate (101) to the casing (31), heat input due to heat conduction from the high-temperature casing (31) into the low-temperature expansion mechanism (60) is reduced by the effect of the mounting plate (101) reducing heat transfer.

[0017] A fourth aspect of the invention is the fluid machine according to the second aspect of the invention, wherein the fluid machine is configured so that the refrigerant is introduced from the refrigerant circuit (20) directly into the compression mechanism (50) and the compressed refrigerant is discharged directly to the outside of the casing (31), and the compression mechanism (50) is fixed through the mounting plate (101) to the casing (31).

[0018] With the above configuration, the interior of the casing (31) is kept under low-temperature and low-pressure conditions, thereby providing a so-called low-pressure dome fluid machine. In this case, since the high-temperature compression mechanism (50) significantly different in temperature from the atmosphere in the rest of the interior of the casing (31) is fixed through the mounting plate (101) to the low-temperature casing (31), heat input due to heat conduction from the high-temperature compression mechanism (50) into the low-temperature casing (31) is reduced by the effect of the mounting plate (101) reducing heat transfer.

[0019] A fifth aspect of the invention is the fluid machine according to the third aspect of the invention, wherein the mechanism-side mounting parts (104) are arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in surface temperature than the rest thereof.

[0020] With this structure, the mechanism-side mounting parts (104) located at one ends of the heat transfer paths in the mounting plate (101) are arranged to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60). Therefore, the temperature differences between the mechanism-side mounting parts (104) and the casing-side mounting parts

(105) are reduced, whereby heat input from the high-temperature casing (31) to the low-temperature expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0021] A sixth aspect of the invention is the fluid machine according to the third aspect of the invention, wherein the casing-side mounting parts (105) are arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in surface temperature than the rest thereof.

[0022] With this structure, the casing-side mounting parts (105) located at one ends of the heat transfer paths in the mounting plate (101) are arranged to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60). Therefore, the temperature differences between the mechanism-side mounting parts (104) and the casing-side mounting parts (105) are reduced, whereby heat input from the high-temperature casing (31) to the low-temperature expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0023] A seventh aspect of the invention is the fluid machine according to any one of the second to sixth aspects of the invention, wherein a sector of the mounting plate (101) lying between each of the mechanism-side mounting parts (104) and the adjacent casing-side mounting part (105) has a smaller cross-sectional area across the circumference than a sector of the mounting plate (101) lying within each of the casing-side mounting parts (105).

[0024] With the above structure, the heat transfer areas of the heat transfer paths in the mounting plate (101) are reduced, whereby heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0025] An eighth aspect of the invention is the fluid machine according to any one of the second to seventh aspects of the invention, wherein the mounting plate (101) has a sheet metal structure.

[0026] With the above structure, since the mounting plate (101) has a sheet metal structure formed of a thin metal sheet, the heat transfer areas of the heat transfer paths are reduced, whereby heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is reduced. This reduces the

amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0027] A ninth aspect of the invention is the fluid machine according to any one of the second to eighth aspects of the invention, wherein the mounting plate (10) has a plurality of through holes (106, 107) formed therein.

[0028] With the above structure, since the mounting plate (101) has through holes (106, 107) formed therein, the heat transfer areas of the heat transfer paths are reduced, whereby heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0029] A tenth aspect of the invention is the fluid machine according to any one of the second to ninth aspects of the invention, further including a heat insulator (90, 96) that is disposed in the internal space of the casing (31), covers the entire exposed surface of one of the compression mechanism (50) and the expansion mechanism (60) within the casing (31) and is passed through by the rotary shaft (40).

[0030] With the above structure, since the heat insulator (90, 96) covers the entire exposed surface of the compression mechanism (50) or the expansion mechanism (60) within the casing (31), this prevents heat exchange between the internal space of the casing (31) and the compression mechanism (50) or the expansion mechanism (60) covered with the heat insulator (90, 96). Therefore, heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is further reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0031] An eleventh aspect of the invention is the fluid machine according to the tenth aspect of the invention, wherein the heat insulator (90, 96) is divided in the axial direction of the rotary shaft (40) into a first heat insulator (90) and a second heat insulator (96) that are bounded by each other in line with the mounting plate (101).

[0032] With the above structure, although the compression mechanism (50) or the expansion mechanism (60) is fixed through the mounting plate (101) to the casing (31), the heat insulator (90, 96) is easily assembled with them by dividing it into the first heat insulator (90) and the second heat insulator (96).

[0033] A twelfth aspect of the invention is the fluid machine according to the tenth or eleventh aspect of the invention, wherein the heat insulator (90, 96) extends into the plate outside clearances (108).

[0034] With the above structure, since the mounting plate (101) is also covered with the heat insulator (90,

96), this prevents heat exchange between refrigerant and the mounting plate (101), whereby heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is further reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0035] A thirteenth aspect of the invention is the fluid machine according to any one of the second to twelfth aspects of the invention, wherein at least one of each pair of the mechanism-side mounting part (104) and a joint part (67) of one of the compression mechanism (50) and the expansion mechanism (60) joined to the mechanism-side mounting part (104) is protruded to reduce the contact area therebetween.

[0036] With the above structure, the heat transfer areas of the heat transfer paths between the mounting plate (101) and the compression mechanism (50) or the expansion mechanism (60) are reduced as compared with the case where each pair of the mechanism-side mounting part (104) and the joint part (67) are joined to each other in face-to-face contact between the mounting plate (101) and the counterpart. Thus, heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0037] A fourteenth aspect of the invention is the fluid machine according to any one of the second to thirteenth aspects of the invention, wherein a heat insulating spacer (110) made of a heat insulating material is disposed between each pair of the mechanism-side mounting part (104) and a joint part (67) of one of the compression mechanism (50) and the expansion mechanism (60) joined to the mechanism-side mounting part (104).

[0038] With the above structure, since a heat insulating spacer (110) having a small coefficient of heat transfer is disposed between each pair of the mechanism-side mounting part (104) and the joint part (67), the heat resistance between the mounting plate (101) and the compression mechanism (50) or the expansion mechanism (60) is increased. Thus, heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0039] A fifteenth aspect of the invention is the fluid machine according to any one of the second to fourteenth aspects of the invention, wherein the refrigerant circuit (20) uses carbon dioxide as the refrigerant to operate in a supercritical refrigeration cycle.

[0040] With the above configuration, carbon dioxide as the refrigerant circulates through the refrigerant circuit

(20) in which the fluid machine (30) is connected. The compression mechanism (50) of the fluid machine (30) compresses sucked refrigerant to the critical pressure or higher and then discharges it. The high-pressure refrigerant of critical pressure or higher is introduced into the expansion mechanism (60) of the fluid machine (30) and expands therein.

EFFECTS OF THE INVENTION

[0041] As described above, in the present invention, the compression mechanism (50) or the expansion mechanism (60) significantly different in temperature from the casing (31) is not fixed directly to the casing (31) but fixed to the casing (31) through the mounting plate (101), thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). Thus, the fluid machine containing the compression mechanism (50) and the expansion mechanism (60) in a single casing can prevent performance degradation and decrease in power recovery effect.

[0042] According to the second aspect of the invention, since a plate outside clearance (108) is formed from the casing (31) between each pair of adjacent casing-side mounting parts (105) extending from the mounting plate (101), this reduces the joint area between the mounting plate (101) and the casing (31) and thereby reduces the heat transfer area. Furthermore, since the mechanism-side mounting parts (104) of the ring-shaped mounting plate (101) are circumferentially offset from the casing-side mounting parts (105) thereof to extend the heat transfer paths and thereby increase the heat resistance, this further prevents performance degradation and decrease in power recovery effect.

[0043] According to the third aspect of the invention, in the high-pressure dome fluid machine, the low-temperature expansion mechanism (60) significantly different in temperature from the atmosphere of the rest of the interior of the casing (31) is fixed to the casing (31) through the mounting plate (101), thereby reducing heat exchange due to heat conduction between the high-temperature casing (31) and the low-temperature expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0044] According to the fourth aspect of the invention, in the low-pressure dome fluid machine, the high-temperature compression mechanism (50) significantly different in temperature from the atmosphere in the rest of the interior of the casing (31) is fixed through the mounting plate (101) to the low-temperature casing (31), thereby reducing heat exchange due to heat conduction between the low-temperature casing (31) and the high-temperature compression mechanism (50). This further prevents performance degradation and decrease in power recovery effect.

[0045] According to the fifth aspect of the invention, the mechanism-side mounting parts (104) are arranged

to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60), thereby reducing heat input from the high-temperature side to the low-temperature side. This further prevents performance degradation and decrease in power recovery effect.

[0046] According to the sixth aspect of the invention, the casing-side mounting parts (105) are arranged to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60), thereby reducing heat input from the high-temperature side to the low-temperature side. This further prevents performance degradation and decrease in power recovery effect.

[0047] According to the seventh aspect of the invention, the cross-sectional area of the mounting plate (101) across the circumference is reduced to reduce the heat transfer areas of the heat transfer paths, thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0048] According to the eighth aspect of the invention, the mounting plate (101) has a sheet metal structure formed of a thin metal sheet to reduce the heat transfer areas of the heat transfer paths, thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0049] According to the ninth aspect of the invention, a plurality of through holes (106, 107) are formed in the mounting plate (101) to reduce the heat transfer areas of the heat transfer paths, thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0050] According to the tenth aspect of the invention, the heat insulator (90, 96) covers the entire exposed surface of the compression mechanism (50) or the expansion mechanism (60) within the casing (31), thereby preventing heat exchange between the internal space of the casing (31) and the compression mechanism (50) or the expansion mechanism (60) covered with the heat insulator (90, 96). This prevents performance degradation and decrease in power recovery effect.

[0051] According to the eleventh aspect of the invention, since the heat insulator (90, 96) is divided in the axial direction of the rotary shaft (40) into two parts bounded by each other in line with the mounting plate (101), the heat insulator (90, 96) can be easily assembled with the other components, which reduces the production cost.

[0052] According to the twelfth aspect of the invention, the heat insulator (90, 96) extends also in the plate outside clearances (108) to prevent heat exchange between the mounting plate (101) and refrigerant and thereby re-

duce heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0053] According to the thirteenth aspect of the invention, at least one of each pair of the mechanism-side mounting part (104) and the joint part (67) of the compression mechanism (50) or the expansion mechanism (60) is protruded to reduce the contact area therebetween, thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0054] According to the fourteenth aspect of the invention, a heat insulating spacer (110) made of a heat insulating material is disposed between each pair of the mechanism-side mounting part (104) and the joint part (67) of the compression mechanism (50) or the expansion mechanism (60) to increase the heat resistance between the mounting plate (101) and the compression mechanism (50) or the expansion mechanism (60), thereby reducing heat exchange between the casing (31) and the compression mechanism (50) or the expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

BRIEF DESCRIPTION OF DRAWINGS

[0055]

[FIG. 1] FIG. 1 is a piping diagram showing the configuration of a refrigerant circuit in Embodiment 1.

[FIG. 2] FIG. 2 is a longitudinal cross-sectional view showing a schematic structure of a compression/expansion unit according to Embodiment 1.

[FIG. 3] FIG. 3 is a longitudinal cross-sectional view showing an expansion mechanism and heat insulators in Embodiment 1.

[FIG. 4] FIG. 4 is a cross-sectional view taken along the line IV-IV in FIG. 3.

[FIG. 5] FIG. 5 is a cross-sectional view taken along the line V-V in FIG. 4.

[FIG. 6] FIG. 6 is a cross-sectional view taken along the line VI-VI in FIG. 4.

[FIG. 7] FIG. 7 is an enlarged view showing an essential part of the expansion mechanism in Embodiment 1.

[FIG. 8] FIG. 8 is schematic transverse cross-sectional views of the expansion mechanism in Embodiment 1, showing the states of the expansion mechanism at every 90° of angle of rotation of a rotary shaft.

[FIG. 9] FIG. 9 is a corresponding view of FIG. 4, showing Modification 1 of Embodiment 1.

[FIG. 10] FIG. 10 is a cross-sectional view taken along the line X-X in FIG. 3.

[FIG. 11] FIG. 11 is a perspective view showing the temperature distribution in the inside surface of a

casing.

[FIG. 12] FIG. 12 is a corresponding view of FIG. 4, showing Modification 2 of Embodiment 1.

[FIG. 13] FIG. 13 is a corresponding view of FIG. 6, showing Modification 3 of Embodiment 1.

LIST OF REFERENCE NUMERALS

[0056]

20	refrigerant circuit
30	compression/expansion unit
31	casing
40	rotary shaft
49	second space (internal space)
50	compression mechanism
60	expansion mechanism
90	first heat insulator
96	second heat insulator
101	mounting plate
104	mechanism-side mounting part
105	casing-side mounting part
106, 107	through hole
108	plate outside clearance

BEST MODE FOR CARRYING OUT THE INVENTION

[0057] Embodiments of the present invention will be described below in detail with reference to the drawings. This embodiment is directed to an air conditioner including a compression/expansion unit that is a fluid machine according to the present invention.

<GENERAL STRUCTURE OF AIR CONDITIONER>

[0058] As shown in FIG. 1, the air conditioner (1) according to this embodiment includes a refrigerant circuit (20). Connected in the refrigerant circuit (20) are the compression/expansion unit (30), an outdoor heat exchanger (23), an indoor heat exchanger (24), a first four-way selector valve (21) and a second four-way selector valve (22). Furthermore, the refrigerant circuit (20) is filled with carbon dioxide (CO₂) as refrigerant.

[0059] The compression/expansion unit (30) includes a casing (31) formed in the shape of a vertically long, cylindrical, closed container. The casing (31) contains a compression mechanism (50), an expansion mechanism (60) and an electric motor (45). Inside the casing (31), the compression mechanism (50), the electric motor (45) and the expansion mechanism (60) are arranged in bottom to top order. The details of the compression/expansion unit (30) will be described later.

[0060] In the refrigerant circuit (20), the compression mechanism (50) is connected at its discharge side (a discharge pipe (37)) to the first port of the first four-way selector valve (21) and connected at its suction side (suction pipes (36)) to the fourth port of the first four-way selector valve (21). On the other hand, the expansion

mechanism (60) is connected at its outflow side (an outlet pipe (39)) to the first port of the second four-way selector valve (22) and connected at its inflow side (an inlet pipe (38)) to the fourth port of the second four-way selector valve (22).

[0061] Furthermore, in the refrigerant circuit (20), the outdoor heat exchanger (23) is connected at one end to the second port of the second four-way selector valve (22) and connected at the other end to the third port of the first four-way selector valve (21). On the other hand, the indoor heat exchanger (24) is connected at one end to the second port of the first four-way selector valve (21) and connected at the other end to the third port of the second four-way selector valve (22).

[0062] The first four-way selector valve (21) and the second four-way selector valve (22) are each configured to be switchable between a position in which the first and second ports are communicated with each other and the third and fourth ports are communicated with each other (the position shown in the solid lines in FIG. 1) and a position in which the first and third ports are communicated with each other and the second and fourth ports are communicated with each other (the position shown in the broken lines in FIG. 1).

<STRUCTURE OF COMPRESSION/EXPANSION UNIT>

[0063] As shown in FIG. 2, the compression/expansion unit (30) includes a casing (31) that is a vertically long, cylindrical, closed container. Inside the casing (31), the compression mechanism (50), the electric motor (45) and the expansion mechanism (60) are arranged in bottom to top order. Furthermore, refrigerating machine oil serving as lubricating oil is accumulated at the bottom of the casing (31). In other words, inside the casing (31), refrigerating machine oil is accumulated towards the compression mechanism (50).

[0064] The internal space of the casing (31) is partitioned into upper and lower spaces by a later-described first heat insulator (90) disposed under a front head (61) of the expansion mechanism (60). The upper space constitutes a first space (48) and the lower space constitutes a second space (49). In the first space (48) the expansion mechanism (60) is disposed, while in the second space (49) the compression mechanism (50) and the electric motor (45) are disposed.

[0065] Attached to the casing (31) is the discharge pipe (37). The discharge pipe (37) is disposed between the electric motor (45) and the expansion mechanism (60) and communicated with the second space (49) in the casing (31). Furthermore, the discharge pipe (37) is formed in the shape of a relatively short, straight tube and placed in an approximately horizontal position.

[0066] The electric motor (45) is disposed in a longitudinally middle part of the casing (31). The electric motor (45) is composed of a stator (46) and a rotor (47). The stator (46) is fixed to the casing (31), such as by shrink

fitting. The rotor (47) is placed inside the stator (46). The rotor (47) is coaxially passed through by a main spindle (44) of a rotary shaft (40).

[0067] The rotary shaft (40) constitutes a rotation axis. The rotary shaft (40) includes two lower eccentric parts (58, 59) formed towards its lower end and two large-diameter eccentric parts (41, 42) formed towards its upper end. A lower end part of the rotary shaft (40) having the lower eccentric parts (58, 59) formed thereat is engaged with the compression mechanism (50), while an upper end part thereof having the large-diameter eccentric parts (41, 42) formed thereat is engaged with the expansion mechanism (60).

[0068] The two lower eccentric parts (58, 59) are formed with a larger diameter than the main spindle (44), in which the lower of the two constitutes a first lower eccentric part (58) and the upper constitutes a second lower eccentric part (59). The first lower eccentric part (58) and the second lower eccentric part (59) have opposite directions of eccentricity with respect to the axis of the main spindle (44).

[0069] The two large-diameter eccentric parts (41, 42) are formed with a larger diameter than the main spindle (44), in which the lower of the two constitutes a first large-diameter eccentric part (41) and the upper constitutes a second large-diameter eccentric part (42). The first large-diameter eccentric part (41) and the second large-diameter eccentric part (42) have the same direction of eccentricity. The second large-diameter eccentric part (42) has a larger outer diameter than the first large-diameter eccentric part (41). Furthermore, in terms of degree of eccentricity with respect to the axis of the main spindle (44), the second large-diameter eccentric part (42) is larger than the first large-diameter eccentric part (41).

[0070] Although not shown, the rotary shaft (40) has an oil feeding channel formed therein. The oil feeding channel extends along the rotary shaft (40). Its beginning opens at the lower end of the rotary shaft (40) and its end opens at the upper part of the rotary shaft (40). Through the oil feeding channel refrigerating machine oil is fed to the compression mechanism (50) and the expansion mechanism (60). However, refrigerating machine oil fed to the expansion mechanism (60) is at a minimum, and refrigerating machine oil having lubricated the expansion mechanism (60) does not flow out into the first space (48) but is discharged through the outlet pipe (39).

[0071] The compression mechanism (50) is constituted by a so-called oscillating piston rotary compressor. The compression mechanism (50) includes two cylinders (51, 52) and two pistons (57). In the compression mechanism (50), a rear head (55), the first cylinder (51), a middle plate (56), the second cylinder (52) and a front head (54) are stacked in bottom to top order.

[0072] The first and second cylinders (51, 52) contain their respective cylindrical pistons (57) disposed, one in the interior of each cylinder. Although not shown, a plate-shaped blade extends from the side surface of each piston (57) and is supported through a swing bush to the

associated cylinder (51, 52). The piston (57) in the first cylinder (51) engages with the first lower eccentric part (58) of the rotary shaft (40). On the other hand, the piston (57) in the second cylinder (52) engages with the second lower eccentric part (59) of the rotary shaft (40). Each of the pistons (57, 57) is in slidable contact at its inner periphery with the outer periphery of the associated lower eccentric part (58, 59) and in slidable contact at its outer periphery with the inner periphery of the associated cylinder (51, 52). Thus, a compression chamber (53) is defined between the outer periphery of each of the pistons (57, 57) and the inner periphery of the associated cylinder (51, 52).

[0073] The first and second cylinders (51, 52) have their respective suction ports (32) formed, one in each cylinder. Each suction port (32) radially passes through the associated cylinder (51, 52) and its distal end opens on the inner periphery of the cylinder (51, 52). Furthermore, each suction port (32) is extended to the outside of the casing (31) by the associated suction pipe (36).

[0074] The front head (54) and rear head (55) have their respective discharge ports formed, one in each head. The discharge port in the front head (54) brings the compression chamber (53) in the second cylinder (52) into communication with the second space (49). The discharge port in the rear head (55) brings the compression chamber (53) in the first cylinder (51) into communication with the second space (49). Furthermore, each discharge port is provided at its distal end with a discharge valve composed of a lead valve, and configured to be opened and closed by the discharge valve. In FIG. 2, the discharge ports and discharge valves are not given. The gas refrigerant discharged from the compression mechanism (50) into the second space (49) is sent through the discharge pipe (37) out of the compression/expansion unit (30).

[0075] As also shown in magnified form in FIG. 3, the expansion mechanism (60) is constituted by a so-called oscillating piston rotary expander. The expansion mechanism (60) includes two cylinders (71, 72) and two pistons (75, 85) in two cylinder-piston pairs. The expansion mechanism (60) further includes the front head (61), a middle plate (63) and a rear head (62).

[0076] In the expansion mechanism (60), the front head (61), the first cylinder (71), the middle plate (63), the second cylinder (81) and the rear head (62) are stacked in bottom to top order. In this state, the first cylinder (71) is closed at the lower end surface by the front head (61) and closed at the upper end surface by the middle plate (63). On the other hand, the second cylinder (81) is closed at the lower end surface by the middle plate (63) and closed at the upper end surface by the rear head (62). Furthermore, the second cylinder (81) has a larger inner diameter than the first cylinder (71).

[0077] The expansion mechanism (60) is fixed through a mounting plate (101) to the inside surface of the casing (31). As shown in FIGS. 4 and 5, the mounting plate (101) has a ring-shaped sheet metal structure and includes a

disc-shaped plate body (102) and a bent part (103) bent approximately 90 degrees downward from the plate body (102) over the entire circumference. The mounting plate (101) further includes: mechanism-side mounting parts (104) formed at the inner periphery of the mounting plate (101) and fixed to the expansion mechanism (60); and casing-side mounting parts (105) formed at the outer periphery of the mounting plate (101) and fixed to the casing (31).

[0078] On the expansion mechanism (60), joint parts (67) joined to the respective mechanism-side mounting parts (104) are formed to extend outward from the outer periphery of the front head (61). In this embodiment, the joint parts (67) are formed at three points along the circumference of the front head (61) at equally spaced 120° intervals. As shown in FIG. 6, each joint part (67) has a bolt hole (68) formed in the center thereof. The rim of the bolt hole (68) is formed to protrude upward. Likewise, each mechanism-side mounting part (104) has a bolt hole (104a) formed in the center thereof. The rim of the bolt hole (104a) is formed to protrude downward. This reduces the contact area between the mechanism-side mounting parts (104) and the joint parts (67).

[0079] The casing-side mounting parts (105) are formed to extend radially outward from the outer periphery of the mounting plate (101). In this embodiment, the casing-side mounting parts (105) are formed at three points along the circumference of the mounting plate (101) at equally spaced 120° intervals. The casing-side mounting parts (105) are welded to the inside surface of the casing (31). Between each pair of adjacent casing-side mounting parts (105), a plate outside clearance (108) from the casing (31) is formed to have a given width.

[0080] Furthermore, a sector of the mounting plate (101) lying between each mechanism-side mounting part (104) and the adjacent casing-side mounting part (105) has a smaller cross-sectional area across the circumference than a sector of the mounting plate (101) lying within the casing-side mounting part (105). The mounting plate (101) has a plurality of through holes (106, 107) for reducing the cross-sectional area across the circumference.

[0081] As shown in FIG. 4, the mechanism-side mounting parts (104) are circumferentially offset from the casing-side mounting parts (105). In other words, in this embodiment, each casing-side mounting part (105) is arranged in the circumferential middle between the two adjacent mechanism-side mounting parts (104).

[0082] The rotary shaft (40) passes through the front head (61), the first cylinder (71), the middle plate (63) and the second cylinder (81) that are stacked. The rear head (62) has a center hole formed in the center and passing through the rear head (62) in the thickness direction. Inserted into the center hole of the rear head (62) is the upper end of the rotary shaft (40). Furthermore, the first large-diameter eccentric part (41) of the rotary shaft (40) is located inside the first cylinder (71) and the second large-diameter eccentric part (42) thereof is lo-

cated inside the second cylinder (81).

[0083] As also shown in FIGS. 7 and 8, the first piston (75) and the second piston (85) are placed in the first cylinder (71) and the second cylinder (81), respectively.

5 The first and second pistons (75, 85) are each formed in an annular or cylindrical shape. The outer diameters of the first piston (75) and the second piston (85) are equal to each other. The inner diameter of the first piston (75) is approximately equal to the outer diameter of the first large-diameter eccentric part (41), and the inner diameter of the second piston (85) is approximately equal to the outer diameter of the second large-diameter eccentric part (42). The first piston (75) and the second piston (85) are passed through by the first large-diameter eccentric part (41) and the second large-diameter eccentric part (42), respectively.

[0084] The first piston (75) is slidably engaged at the outer periphery with the inner periphery of the first cylinder (71), is in slidable contact at one end surface thereof with the front head (61) and is in slidable contact at the other end surface with the middle plate (63). In the first cylinder (71), its inner periphery defines a first expansion chamber (72) together with the outer periphery of the first piston (75). On the other hand, the second piston (85) is slidably engaged at the outer periphery with the inner periphery of the second cylinder (81), is in slidable contact at one end surface thereof with the rear head (62) and is in slidable contact at the other end surface with the middle plate (63). In the second cylinder (81), its inner periphery defines a second expansion chamber (82) together with the outer periphery of the second piston (85).

[0085] The first and second pistons (75, 85) are integrally formed with blades (76, 86), one for each piston. Each blade (76, 86) is formed in the shape of a plate extending in a radial direction of the associated piston (75, 85) and extends outward from the outer periphery of the piston (75, 85). The blade (76) of the first piston (75) and the blade (86) of the second piston (85) are inserted into a bush hole (78) in the first cylinder (71) and a bush hole (88) in the second cylinder (81), respectively. The bush hole (78, 88) of each cylinder (71, 81) passes through the associated cylinder (71, 81) in a thickness direction and opens on the inner periphery of the cylinder (71, 81). These bush holes (78, 88) constitute through holes.

[0086] The cylinders (71, 81) are provided with pairs of bushes (77, 87), each cylinder with one pair of bushes. Each bush (77, 87) is a small piece formed so that its inside surface is flat and its outside surface is arcuate. In each cylinder (71, 81), the pair of bushes (77, 87) are inserted into the associated bush hole (78, 88) to sandwich the associated blade (76, 86) therebetween. Each bush (77, 87) slides with the inside surface on the associated blade (76, 86) and slides with the outside surface on the associated cylinder (71, 81). Each blade (76, 86) integral with the piston (75, 85) is supported through the associated bushes (77, 87) to the associated cylinder (71, 81) and is free to angularly move with respect to and

free to enter and retract from the cylinder (71, 81).

[0087] The first expansion chamber (72) in the first cylinder (71) is partitioned by the first blade (76) integral with the first piston (75); a region thereof to the left of the first blade (76) in FIGS. 7 and 8 provides a first high-pressure chamber (73) of relatively high pressure, while a region thereof to the right of the first blade (76) provides a first low-pressure chamber (74) of relatively low pressure. The second expansion chamber (82) in the second cylinder (81) is partitioned by the second blade (86) integral with the second piston (85); a region thereof to the left of the second blade (86) in FIGS. 7 and 8 provides a second high-pressure chamber (83) of relatively high pressure, while a region thereof to the right of the second blade (86) provides a second low-pressure chamber (84) of relatively low pressure.

[0088] The first cylinder (71) and the second cylinder (81) are arranged in postures in which the circumferential relative positions between their associated pairs of bushes (77, 87) coincide with each other. In other words, the angle of displacement of the second cylinder (81) relative to the first cylinder (71) is 0°. As described previously, the first large-diameter eccentric part (41) and the second large-diameter eccentric part (42) have the same direction of eccentricity with respect to the axis of the main spindle (44). Therefore, when the first blade (76) comes to a most retracted position towards the outside of the first cylinder (71), the second blade (86) concurrently comes to a most retracted position towards the outside of the second cylinder (81).

[0089] The first cylinder (71) has an inlet port (34) formed therein. The inlet port (34) opens on the inner periphery of the first cylinder (71) slightly to the left of the bushes (77) in FIGS. 7 and 8. The inlet port (34) can be communicated with the first high-pressure chamber (73). On the other hand, the second chamber (81) has an outlet port (35) formed therein. The outlet port (35) opens on the inner periphery of the second cylinder (81) slightly to the right of the bushes (87) in FIGS. 7 and 8. The outlet port (35) can be communicated with the second low-pressure chamber (84).

[0090] The middle plate (63) has a communicating channel (64) formed therein. The communicating channel (64) passes through the middle plate (63) in the thickness direction. In the surface of the middle plate (63) facing the first cylinder (71), one end of the communicating channel (64) opens at a position to the right of the first blade (76). In the other surface of the middle plate (63) facing the second cylinder (81), the other end of the communicating channel (64) opens at a position to the left of the second blade (86). Furthermore, as shown in FIG. 7, the communicating channel (64) extends obliquely with respect to the thickness direction of the middle plate (63) and brings about communication between the first low-pressure chamber (74) and the second high-pressure chamber (83).

[0091] In the expansion mechanism (60) in this embodiment configured as described above, a first rotary

mechanism (70) is constituted by the first cylinder (71), and the bushes (77), the first piston (75) and the first blade (76) that are provided in association with the first cylinder (71). Furthermore, a second rotary mechanism (80) is constituted by the second cylinder (81), and the bushes (87), the second piston (85) and the second blade (86) that are provided in association with the second cylinder (81).

[0092] As shown in FIG. 3, the internal space of the casing (31) contains a heat insulator (90, 96) covering the entire exposed surface of the expansion mechanism (60) within the casing (31) and passed through by the rotary shaft (40). The heat insulator (90, 96) is divided in the axial direction of the rotary shaft (40) into a first heat insulator (90) and a second heat insulator (96) that are bounded by each other in line with the mounting plate (101).

[0093] The lower first heat insulator (90) is disposed to abut on the side of the expansion mechanism (60) near to the compression mechanism (50) and cover the expansion mechanism (60) from the surroundings of the rotary shaft (40) to the inner periphery of the casing (31). Thus, the first heat insulator (90) separates the first space (48), which is located around the low-temperature expansion mechanism (60) and has a significant temperature difference from the atmosphere in the rest of the interior of the casing (31), from the second space (49).

[0094] Specifically, the first heat insulator (90) is shaped in a disc having a center hole through which the rotary shaft (40) is inserted, and disposed to abut on the under surface of the front head (61) of the expansion mechanism (60). A minimum clearance is provided between the outer periphery of the rotary shaft (40) and the inner periphery of the first heat insulator (90) so as not to interfere with the rotation of the rotary shaft (40).

[0095] As shown in FIG. 3, the upper second heat insulator (96) has a substantially cylindrical shape having a top wall and covers all of the exposed side and top surfaces of the expansion mechanism (60) within the casing (31). More specifically, the second heat insulator (96) is passed through by the inlet pipe (38) and the outlet pipe (39). Preferably, the outer peripheries of the inlet pipe (38) and outlet pipe (39) are also covered with the second heat insulator (96).

[0096] Furthermore, as shown in FIG. 4, the heat insulator (90, 96) extends also into the plate outside clearances (108) from the casing (31) between the adjacent casing-side mounting parts (105). More specifically, the side surface of the mounting plate (101) is covered with extensions from the under surface of the second heat insulator (96). Alternatively, the side surface of the mounting plate (101) may be covered with extensions from the top surface of the first heat insulator (90).

[0097] The first and second heat insulators (90, 96) are made of resin moldings. Concrete examples of the resin moldings include super engineering plastics having high heat-resistance (of 240°C to 250°C). Examples of such super engineering plastics include polyphenylene

sulfide (PPS), polyether ether ketone (PEEK) and polyimide (PI).

- OPERATIONAL ACTIONS -

[0098] Actions of the air conditioner (10) will be described below. Here, a description is given first of the action of the air conditioner (10) in cooling operation, then the action thereof in heating operation and then the action of the expansion mechanism (60).

<COOLING OPERATION>

[0099] In cooling operation, the first four-way selector valve (21) and the second four-way selector valve (22) are switched to the positions shown in the broken lines in FIG. 1. When in this state the electric motor (45) of the compression/expansion unit (30) is energized, refrigerant circulates through the refrigerant circuit (20) so that the refrigerant circuit (20) operates in a vapor compression refrigeration cycle.

[0100] The refrigerant compressed by the compression mechanism (50) is discharged through the discharge pipe (37) out of the compression/expansion unit (30). In this state, the refrigerant pressure is higher than the critical pressure. The discharged refrigerant is sent to the outdoor heat exchanger (23) and therein releases heat to the outdoor air. The high-pressure refrigerant having released heat in the outdoor heat exchanger (23) passes through the inlet pipe (38) and then flows into the expansion mechanism (60). In the expansion mechanism (60), the high-pressure refrigerant expands and power is recovered from the high-pressure refrigerant. The low-pressure refrigerant obtained by expansion is sent through the outlet pipe (39) to the indoor heat exchanger (24). In the indoor heat exchanger (24), the refrigerant having flowed therein takes heat from room air to evaporate, thereby cooling the room air. The low-pressure gas refrigerant having flowed out of the indoor heat exchanger (24) passes through the suction pipes (36) and is then sucked through the suction ports (32) into the compression mechanism (50). The compression mechanism (50) compresses the sucked refrigerant and discharges it.

<HEATING OPERATION>

[0101] In heating operation, the first four-way selector valve (21) and the second four-way selector valve (22) are switched to the positions shown in the solid lines in FIG. 1. When in this state the electric motor (45) of the compression/expansion unit (30) is energized, refrigerant circulates through the refrigerant circuit (20) so that the refrigerant circuit (20) operates in a vapor compression refrigeration cycle.

[0102] The refrigerant compressed by the compression mechanism (50) is discharged through the discharge pipe (37) out of the compression/expansion unit (30). In

this state, the refrigerant pressure is higher than the critical pressure. The discharged refrigerant is sent to the indoor heat exchanger (24). In the indoor heat exchanger (24), the refrigerant having flowed therein releases heat to room air, thereby heating the room air. The refrigerant having released heat in the indoor heat exchanger (24) passes through the inlet pipe (38) and then flows into the expansion mechanism (60). In the expansion mechanism (60), the high-pressure refrigerant expands and power is recovered from the high-pressure refrigerant. The low-pressure refrigerant obtained by expansion is sent through the outlet pipe (39) to the outdoor heat exchanger (23) and therein takes heat from the outdoor air to evaporate. The low-pressure gas refrigerant having flowed out of the outdoor heat exchanger (23) passes through the suction pipes (36) and is then sucked through the suction ports (32) into the compression mechanism (50). The compression mechanism (50) compresses the sucked refrigerant and discharges it.

<ACTION OF EXPANSION MECHANISM>

[0103] The action of the expansion mechanism (60) is described with reference to FIG. 8.

[0104] First, a description is given of the course of flow of supercritical high-pressure refrigerant into the first high-pressure chamber (73) of the first rotary mechanism (70). When the rotary shaft (40) rotates slightly from an angle of rotation of 0°, the contact point between the first piston (75) and the first cylinder (71) passes through the opening of the inlet port (34), so that high-pressure refrigerant begins to flow through the inlet port (34) into the first high-pressure chamber (73). Then, as the angle of rotation of the rotary shaft (40) gradually increases to 90°, 180° and 270°, high-pressure refrigerant flows more into the first high-pressure chamber (73). The flow of the high-pressure refrigerant into the first high-pressure chamber (73) continues until the angle of rotation of the rotary shaft (40) reaches 360°.

[0105] Next, a description is given of the course of refrigerant expansion in the expansion mechanism (60). When the rotary shaft (40) rotates slightly from an angle of rotation of 0°, the first low-pressure chamber (74) and the second high-pressure chamber (83) are communicated through the communicating channel (64) with each other, so that the refrigerant begins to flow from the first low-pressure chamber (74) into the second high-pressure chamber (83). Then, as the angle of rotation of the rotary shaft (40) gradually increases to 90°, 180° and 270°, the first low-pressure chamber (74) gradually decreases its volume and, concurrently, the second high-pressure chamber (83) gradually increases its volume, resulting in gradually increasing volume of the expansion chamber (66). The increase in the volume of the expansion chamber (66) continues until just before the angle of rotation of the rotary shaft (40) reaches 360°. The refrigerant in the expansion chamber (66) expands during the increase in the volume of the expansion chamber

(66). The expansion of the refrigerant causes the rotary shaft (40) to be driven into rotation. Thus, the refrigerant in the first low-pressure chamber (74) flows through the communicating channel (64) into the second high-pressure chamber (83) while expanding.

[0106] Next, a description is given of the course of flow of refrigerant out of the second low-pressure chamber (84) of the second rotary mechanism (80). The second low-pressure chamber (84) starts to be communicated with the outlet port (35) at a point of time when the rotary shaft (40) is at an angle of rotation of 0°. In other words, the refrigerant starts to flow out of the second low-pressure chamber (84) to the outlet port (35). Then, during the period when the angle of rotation of the rotary shaft (40) gradually increases to 90°, 180° and 270° and until it reaches 360°, low-pressure refrigerant obtained by expansion flows out of the second low-pressure chamber (84).

- ASSEMBLY PROCEDURE OF MOUNTING PLATE -

[0107] A description is given of the assembly procedure of the expansion mechanism (60), the mounting plate (101) and the heat insulator (90, 96).

[0108] First, bolts (not shown) are inserted into the bolt holes (68) in the front head (61) and the bolt holes (104a) in the mechanism-side mounting parts (104) and then tightened.

[0109] Next, the first heat insulator (90) is mounted to the expansion mechanism (60) from below the mounting plate (101), and the second heat insulator (96) is mounted to the expansion mechanism (60) from above. Since in this manner the heat insulator (90, 96) is divided into the first heat insulator (90) and the second heat insulator (96), the heat insulator (90, 96) can be easily assembled.

[0110] Finally, the outside end surfaces of the casing-side mounting parts (105) are welded to the inside surface of the casing (31).

<ACTION OF MOUNTING PLATE>

[0111] Since the first heat insulator (90) partitions the internal space of the casing (31) into the first space (48) in which the expansion mechanism (60) is placed and the second space (49) in which the compression mechanism (50) is placed, the first space (48) is kept at low temperature and high density and the second space (49) is kept at high temperature and low density. Thus, the interior of the casing (31) is kept under high-temperature and high-pressure conditions, thereby providing a so-called high-pressure dome fluid machine.

[0112] Since the expansion mechanism (60) is firmly fixed to the casing (31) by the mounting plate (101), this prevents high-pressure refrigerant from swelling the casing (31) and prevents excessive vibration of the expansion mechanism (60).

[0113] Since the low-temperature expansion mechanism (60) significantly different in temperature from the

atmosphere in the rest of the interior of the casing (31) is fixed through the mounting plate (101) to the casing (31), this prevents direct fixation between the casing (31) and the expansion mechanism (60) significantly different in temperature from the casing (31) that would conventionally be done. Furthermore, since the joints between the mounting plate (101) and the casing (31) are the casing-side mounting parts (105) only, the heat transfer area is reduced as compared with the case where the mounting plate (101) is joined over the entire circumference to the casing (31). This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

[0114] Furthermore, since the mechanism-side mounting parts (104) are circumferentially offset from the casing-side mounting parts (105), the heat transfer paths can be extended as compared with the case where each pair of mechanism- and casing-side mounting parts are arranged at the same circumferential angle. Thus, the heat resistance is increased, thereby reducing heat exchange between the expansion mechanism (60) and the casing (31).

[0115] Since a sector of the mounting plate (101) lying between each mechanism-side mounting part (104) and the adjacent casing-side mounting part (105) has a smaller cross-sectional area across the circumference than a sector of the mounting plate (101) lying within the casing-side mounting part (105), this reduces the heat transfer areas of the heat transfer paths in the mounting plate (101). Furthermore, since the mounting plate (101) has a sheet metal structure formed of a thin metal sheet, the heat transfer areas of the heat transfer paths are further reduced. Moreover, since the mounting plate (101) has through holes (106, 107) formed therein, the heat transfer areas of the heat transfer paths are further reduced. In addition, since the rims of the bolt holes (68) are formed to protrude upward and the rims of the bolt holes (104a) are formed to protrude downward, the contact area between each mechanism-side mounting part (104) and the joint part (67) is reduced. Since the heat transfer areas of the heat transfer paths between the mounting plate (101) and the expansion mechanism (60) are thus reduced, this reduces heat exchange between the expansion mechanism (60) and the casing (31).

[0116] Since the first heat insulator (90) isolates the first space (48) located around the low-temperature expansion mechanism (60) and having a significant temperature difference from the atmosphere in the rest of the interior of the casing (31), this effectively prevents occurrence of refrigerant convection.

[0117] Since the heat insulator (90, 96) covers the entire exposed surface of the expansion mechanism (60) within the casing (31), this prevents heat exchange between the internal space of the casing (31) and the expansion mechanism (60) covered with the heat insulator (90, 96). Therefore, heat exchange between the expan-

sion mechanism (60) and the casing (31) is further reduced.

[0118] Since the mounting plate (101) is also covered with the heat insulator (90, 96), heat exchange between the mounting plate (101) and refrigerant is prevented, whereby heat exchange between the expansion mechanism (60) and the casing (31) is further reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50).

- EFFECTS OF EMBODIMENT 1 -

[0119] In the compression/expansion unit (30) according to this embodiment, the low-temperature expansion mechanism (60) significantly different in temperature from the atmosphere of the rest of the interior of the casing (31) is not fixed directly to the casing (31) but only the casing-side mounting parts (105) are fixed to the casing (31) through the mounting plate (101) welded to the casing (31), thereby reducing heat exchange due to heat conduction between the high-temperature casing (31) and the low-temperature expansion mechanism (60). This further prevents performance degradation and decrease in power recovery effect.

[0120] Since the mechanism-side mounting parts (104) of the ring-shaped mounting plate (101) are circumferentially offset from the casing-side mounting parts (105) thereof to extend the heat transfer paths and thereby increase the heat resistance, this further prevents performance degradation and decrease in power recovery effect.

[0121] Since the heat transfer areas of the heat transfer paths in the mounting plate (101) are reduced to reduce heat exchange between the expansion mechanism (60) and the casing (31), such as by forming the mounting plate (101) in a sheet metal structure formed of a thin metal sheet, forming a plurality of through holes (106, 107) in the mounting plate (101) and protruding the mechanism-side mounting parts (104) and the joint parts (67), this further prevents performance degradation and decrease in power recovery effect.

[0122] Since the heat insulator (90, 96) covers the entire exposed surface of the expansion mechanism (60) within the casing (31), this prevents heat exchange between the second space (48) in the casing (31) and the expansion mechanism (60) covered with the heat insulator (90, 96) and thereby prevents performance degradation and decrease in power recovery effect.

[0123] Since the heat insulator (90, 96) extends also in the plate outside clearances (108) to prevent heat exchange between the mounting plate (101) and refrigerant and thereby reduce heat exchange between the expansion mechanism (60) and the casing (31), this further prevents performance degradation and decrease in power recovery effect.

[0124] Since the heat insulator (90, 96) is divided in

the axial direction of the rotary shaft (40) into two parts bounded by each other in line with the mounting plate (101), the heat insulator (90, 96) can be easily assembled with the other components, which reduces the production cost.

- MODIFICATION 1 OF EMBODIMENT 1 -

[0125] As shown in FIG. 9, the mechanism-side mounting parts (104) may be arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in surface temperature than the rest thereof. For simplicity, the through holes (106, 107) are not given in the figure.

[0126] Specifically, as shown in FIG. 10, the expansion mechanism (60) has a generally circumferential, surface temperature distribution in which the surface temperature decreases in order from Region A to Region F when viewed in the axial direction. To give examples of the actual temperatures, Region A is at 30°C that is a suction temperature, and Region F is at 0°C that is a discharge temperature.

[0127] On the other hand, as shown in FIG. 11, the casing (31) has a generally circumferential, surface temperature distribution in which the surface temperature decreases in order from Region A to Region F. To give examples of the actual temperatures, Region A is at 90°C that is a discharge temperature of the compression mechanism (50), and Region F is at a low temperature (approximately 0°C) that is a discharge temperature of the expansion mechanism (60).

[0128] Therefore, it is desirable to arrange the mechanism-side mounting parts (104) to avoid regions of the expansion mechanism (60) having low surface temperatures and regions of the casing (31) having high surface temperatures. With this structure, the mechanism-side mounting parts (104) located at one ends of the heat transfer paths in the mounting plate (101) are arranged to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60). Therefore, heat input from the high-temperature side to the low-temperature side is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50). Hence, performance degradation and decrease in power recovery effect of the compression/expansion unit (30) can be prevented.

- MODIFICATION 2 OF EMBODIMENT 1 -

[0129] As shown in FIG. 12, the casing-side mounting parts (105) may be arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in sur-

face temperature than the rest thereof. For simplicity, the through holes (106, 107) are not given in the figure.

[0130] Specifically, the expansion mechanism (60) is kept at low temperatures as a whole. Therefore, it is desirable to arrange the casing-side mounting parts (105) to avoid Region A of the casing (31) having the highest surface temperature. Furthermore, the casing (31) naturally has a low-temperature region between the inlet pipe (38) and the outlet pipe (39). Therefore, it is desirable to dispose a casing-side mounting part (105) in this region. With this structure, the casing-side mounting parts (105) located at one ends of the heat transfer paths in the mounting plate (101) are arranged to reduce the surface temperature differences between the expansion mechanism (60) and regions of the casing (31) near to the expansion mechanism (60). Therefore, heat input from the high-temperature side to the low-temperature side is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50). Hence, performance degradation and decrease in power recovery effect of the compression/expansion unit (30) can be prevented.

- MODIFICATION 3 OF EMBODIMENT 1 -

[0131] As shown in FIG. 13, a heat insulating spacer (110) made of a heat insulating material may be disposed between each pair of the mechanism-side mounting part (104) and the joint part (67) of the expansion mechanism (60) joined to the mechanism-side mounting part (104). Since the heat insulating spacers (110) are disposed in the vicinity of the expansion mechanism (60) always kept at relatively low temperatures, they may be made of a low heat-resistance material. Therefore, the freedom of choice of materials is high.

[0132] With the above structure, since the heat resistance between the mounting plate (101) and the expansion mechanism (60) is increased, heat exchange between the expansion mechanism (60) and the casing (31) is reduced. This reduces the amount of heat exchange due to heat conduction between low-temperature refrigerant in the expansion mechanism (60) and high-temperature refrigerant in the compression mechanism (50). Hence, performance degradation and decrease in power recovery effect of the compression/expansion unit (30) can be prevented.

<OTHER EMBODIMENTS>

[0133] The above embodiment of the present invention may have the following configurations.

[0134] Although in the above embodiment the fluid machine is a high-pressure dome compression/expansion unit (30), it may be a so-called low-pressure dome compression/expansion unit (30) in which the interior of the casing (31) is at low pressure. In this case, the fluid ma-

chine is configured so that the refrigerant is introduced from the refrigerant circuit (20) directly into the compression mechanism (50) and the compressed refrigerant is discharged directly to the outside of the casing (31). The compression mechanism (50) is fixed to the casing (31) through a mounting plate (101) having a similar shape to that in the above embodiment and thereby having a high heat resistance. Since the high-temperature compression mechanism (50) significantly different in temperature from the atmosphere in the rest of the interior of the casing (31) is fixed through the mounting plate (101) to the low-temperature casing (31), this reduces heat exchange due to heat conduction between the low-temperature casing (31) and the high-temperature expansion mechanism (60). Hence, performance degradation and decrease in power recovery effect can be prevented.

[0135] Although in the above embodiment the expansion mechanism (60) is constituted by an oscillating piston rotary expander, the expansion mechanism (60) may be constituted by a rolling piston rotary expander. In this expansion mechanism (60), the blade (76, 86) in each of the rotary mechanisms (70, 80) is formed separately from the associated piston (75, 85). Thus, the distal end of the blade (76, 86) is pushed against the outer periphery of the associated piston (75, 85), whereby the blade (76, 86) moves forward and backward with movement of the associated piston (75, 85).

[0136] Although in the above embodiment the compression mechanism (50) is constituted by an oscillating piston rotary compressor and the expansion mechanism (60) is constituted by an oscillating piston rotary expander, the mechanisms may be constituted by a scroll compressor and a scroll expander.

[0137] In the above embodiment, if the plate outside clearances (108) between the mounting plate (101) and the casing (31) are at a certain width (for example, 5 mm) or more and the refrigerant accumulates in the plate outside clearance (108), there is no need to extend the heat insulator (90, 96) into the clearances. Specifically, the resin-based material making up a common heat insulator (90, 96) has a heat conductivity of 0.3 w/m-k, while carbon dioxide refrigerant in the space around the expansion mechanism (60) has a heat conductivity of 0.07 w/m-k. Therefore, carbon dioxide refrigerant has a one-order lower heat conductivity than the resin-based material. Since thus the coefficient of heat transfer of gas refrigerant is smaller than that of the heat insulator (90, 96), heat exchange is not increased but rather reduced.

[0138] Although in the above embodiment a set of three mechanism-side mounting parts (104) and a set of three casing-side mounting parts (105) are arranged with each set of mounting parts spaced at circumferentially equal intervals, each set of mounting parts may be composed of two, four, or more mounting parts. Also in such cases, the mechanism-side mounting parts (104) are preferably circumferentially offset from the casing-side mounting parts (105).

[0139] In the above embodiment, the first and second heat insulators (90, 96) are made of high heat-resistant super engineering plastics. However, if the heat insulators (90, 96) are disposed on the relatively low-temperature expansion mechanism (60) as in Embodiment 1, they may be made of low heat-resistant general-purpose engineering plastics because the refrigerant temperature is at 100°C or less. Examples of such general-purpose engineering plastics include polyacetal (POM). Alternatively, epoxy resin or FRP may be used instead as a material for the heat insulator. However, FRP has the disadvantage that if it contains carbon fibers, glass fibers or the like, the heat conductivity is increased.

[0140] Although in the above embodiment carbon dioxide is used as refrigerant, R410A, R407C or isobutane may be used instead as refrigerant.

[0141] Although in the above embodiment the electric motor (45) is disposed above the compression mechanism (50) in the second space (49), it may be disposed below the compression mechanism (50).

[0142] The above embodiments are merely preferred embodiments in nature and are not intended to limit the scope, applications and use of the invention.

INDUSTRIAL APPLICABILITY

[0143] As can be seen from the above description, the present invention is useful for a fluid machine in which a compression mechanism and an expansion mechanism are contained in a single casing.

Claims

1. A fluid machine disposed in a refrigerant circuit (20) operating in a refrigeration cycle by circulating refrigerant therethrough, the fluid machine comprising:
 - a casing (31);
 - a compression mechanism (50) contained in the casing (31) and configured to compress the refrigerant;
 - an expansion mechanism (60) contained in the casing (31) and configured to expand the refrigerant;
 - a rotary shaft (40) disposed in the casing (31) and connecting the compression mechanism (50) and the expansion mechanism (60); and
 - a mounting plate (101) fixing one of the compression mechanism (50) and the expansion mechanism (60) to the casing (31).
2. The fluid machine of claim 1, wherein the casing (31) has the shape of a cylindrical container, the mounting plate (101) is shaped in a ring and includes: mechanism-side mounting parts (104) which are formed at the inner periphery of the mounting

plate (101) and to which one of the compression mechanism (50) and the expansion mechanism (60) is fixed; and casing-side mounting parts (105) formed at the outer periphery of the mounting plate (101) and fixed to the casing (31), the casing-side mounting parts (105) radially outwardly extend to provide a plate outside clearance (108) of given width from the inside surface of the casing (31) between each pair of the adjacent casing-side mounting parts (105), and the mechanism-side mounting parts (104) are circumferentially offset from the casing-side mounting parts (105).

3. The fluid machine of claim 2, wherein the fluid machine is configured so that the refrigerant is introduced from the refrigerant circuit (20) directly into the compression mechanism (50) and the compressed refrigerant is discharged from the compression mechanism (50) to an internal space (49) of the casing (31) and then flows out of the internal space (49) to the outside of the casing (31), and the expansion mechanism (60) is fixed through the mounting plate (101) to the casing (31).
4. The fluid machine of claim 2, wherein the fluid machine is configured so that the refrigerant is introduced from the refrigerant circuit (20) directly into the compression mechanism (50) and the compressed refrigerant is discharged directly to the outside of the casing (31), and the compression mechanism (50) is fixed through the mounting plate (101) to the casing (31).
5. The fluid machine of claim 3, wherein the mechanism-side mounting parts (104) are arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in surface temperature than the rest thereof.
6. The fluid machine of claim 3, wherein the casing-side mounting parts (105) are arranged to connect regions of the expansion mechanism (60) higher in surface temperature than the rest thereof to regions of the casing (31) near to the expansion mechanism (60) and lower in surface temperature than the rest thereof.
7. The fluid machine of claim 2, wherein a sector of the mounting plate (101) lying between each of the mechanism-side mounting parts (104) and the adjacent casing-side mounting part (105) has a smaller cross-sectional area across the circumference than a sector of the mounting plate (101) lying within each of the casing-side mounting parts (105).

8. The fluid machine of claim 2, wherein the mounting plate (101) has a sheet metal structure.
9. The fluid machine of claim 2, wherein the mounting plate (10) has a plurality of through holes (106, 107) formed therein. 5
10. The fluid machine of claim 2, further comprising a heat insulator (90, 96) that is disposed in the internal space of the casing (31), covers the entire exposed surface of one of the compression mechanism (50) and the expansion mechanism (60) within the casing (31) and is passed through by the rotary shaft (40). 10
11. The fluid machine of claim 10, wherein the heat insulator (90, 96) is divided in the axial direction of the rotary shaft (40) into a first heat insulator (90) and a second heat insulator (96) that are bounded by each other in line with the mounting plate (101). 15
20
12. The fluid machine of claim 10, wherein the heat insulator (90, 96) extends into the plate outside clearances (108).
13. The fluid machine of claim 2, wherein at least one of each pair of the mechanism-side mounting part (104) and a joint part (67) of one of the compression mechanism (50) and the expansion mechanism (60) joined to the mechanism-side mounting part (104) is protruded to reduce the contact area therebetween. 25
30
14. The fluid machine of claim 2, wherein a heat insulating spacer (110) made of a heat insulating material is disposed between each pair of the mechanism-side mounting part (104) and a joint part (67) of one of the compression mechanism (50) and the expansion mechanism (60) joined to the mechanism-side mounting part (104). 35
15. The fluid machine of claim 2, wherein the refrigerant circuit (20) uses carbon dioxide as the refrigerant to operate in a supercritical refrigeration cycle. 40

45

50

55

FIG. 1

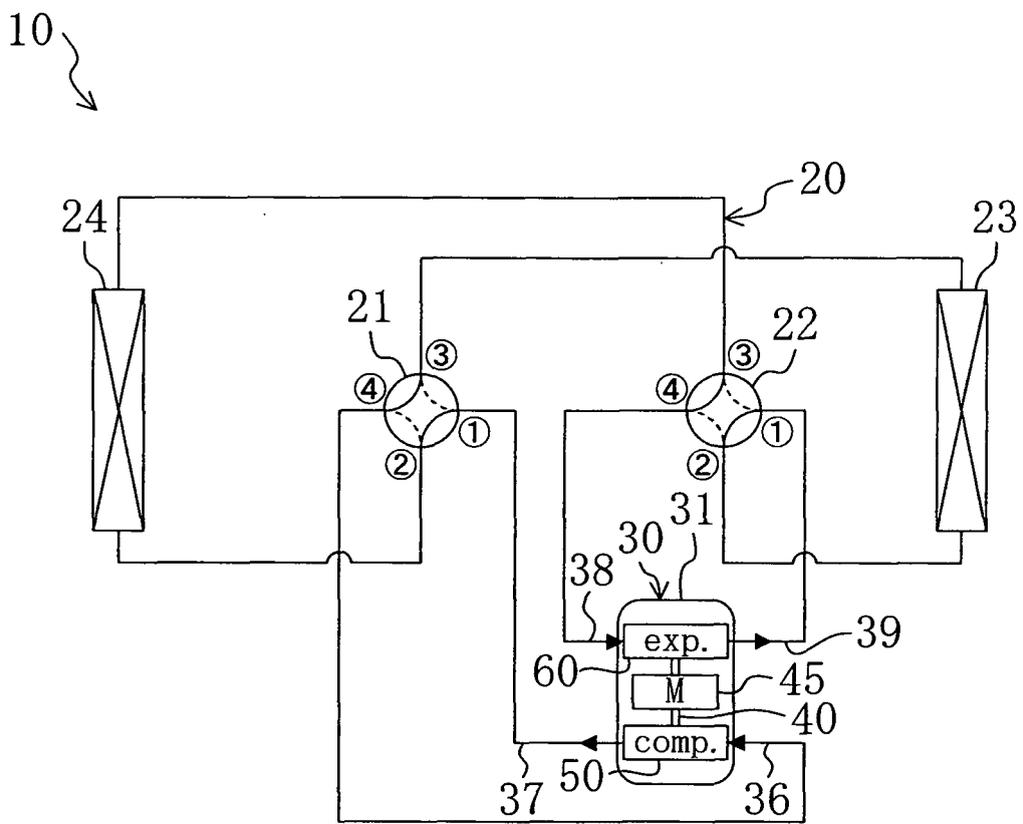


FIG. 2

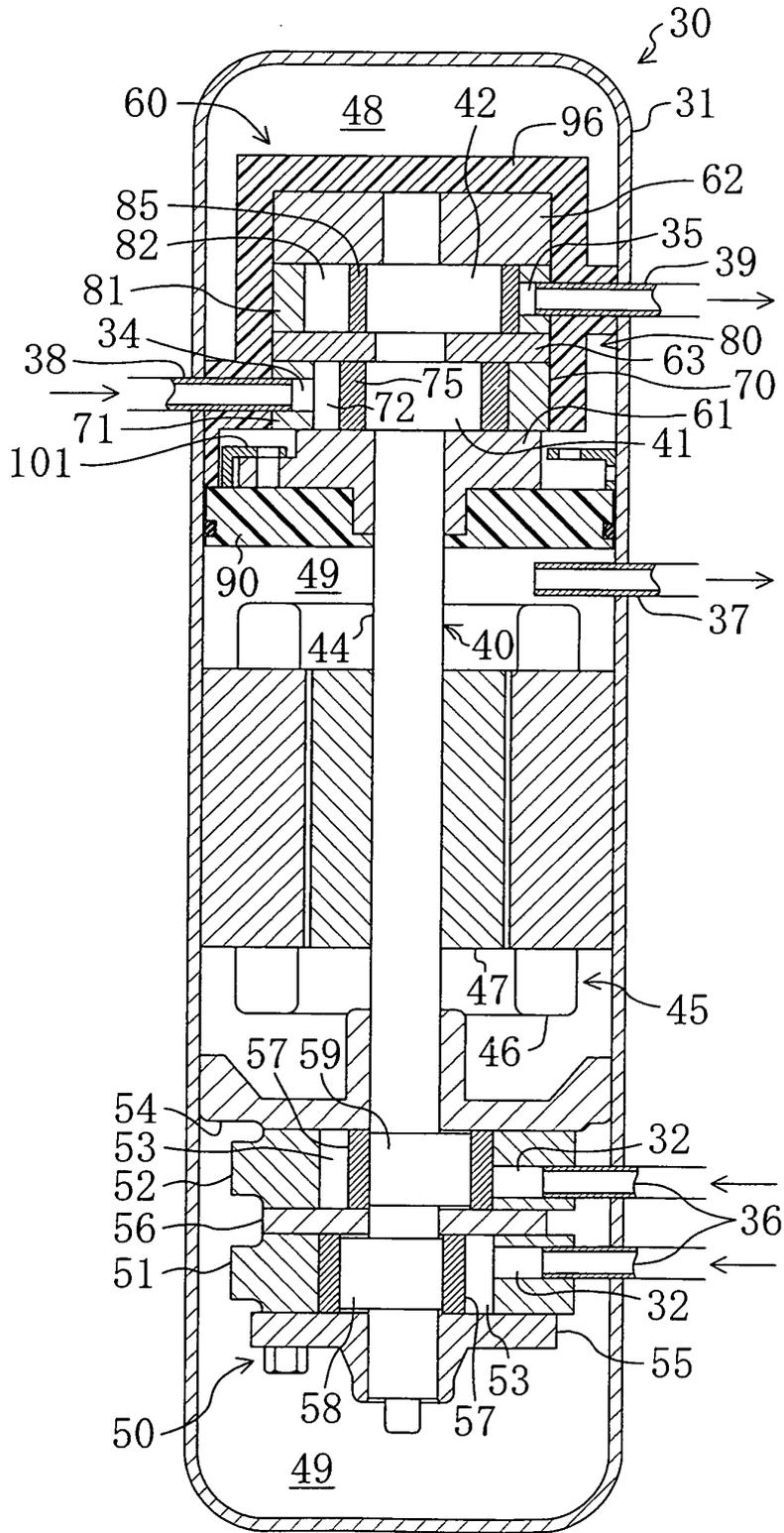


FIG. 3

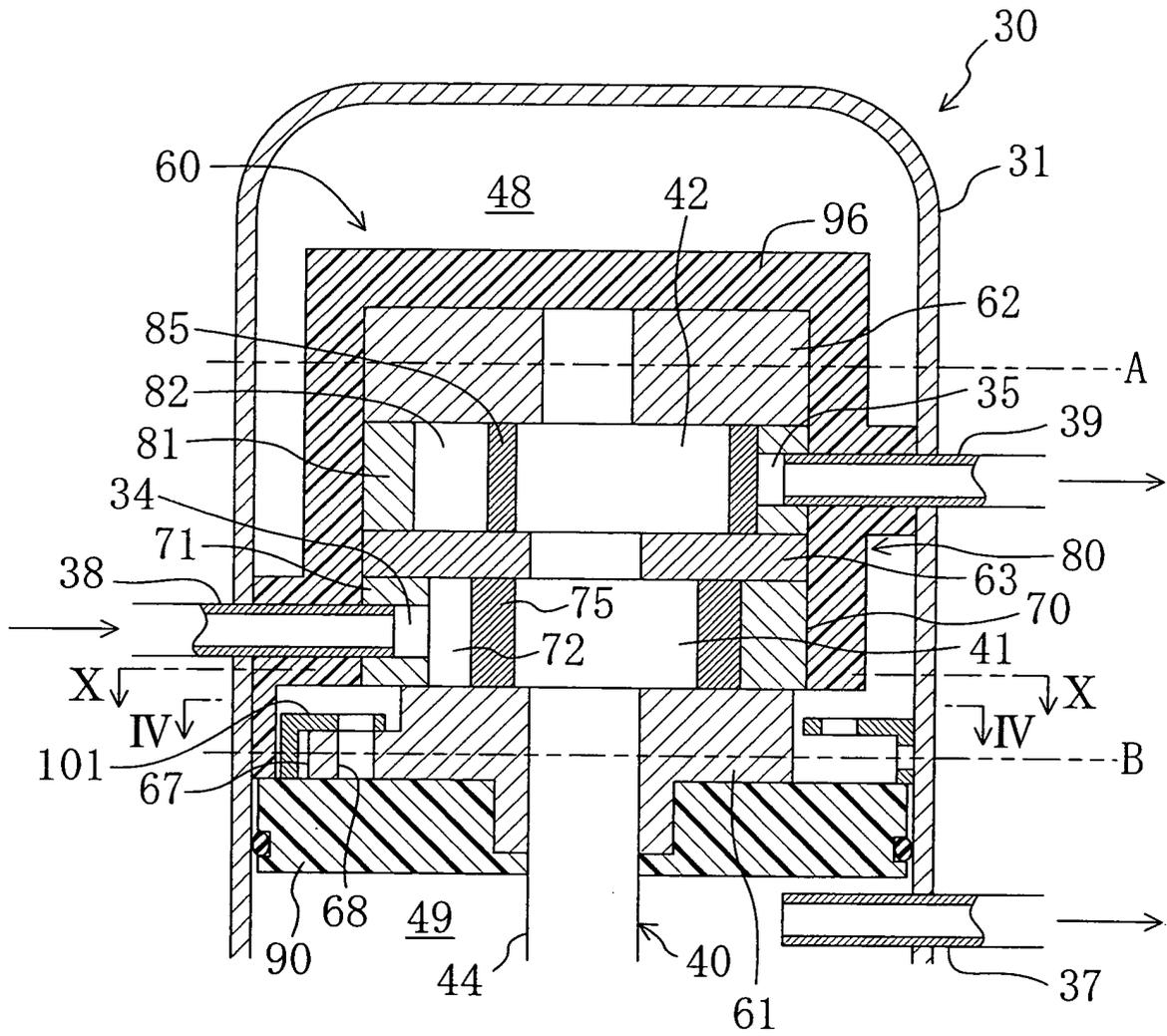


FIG. 4

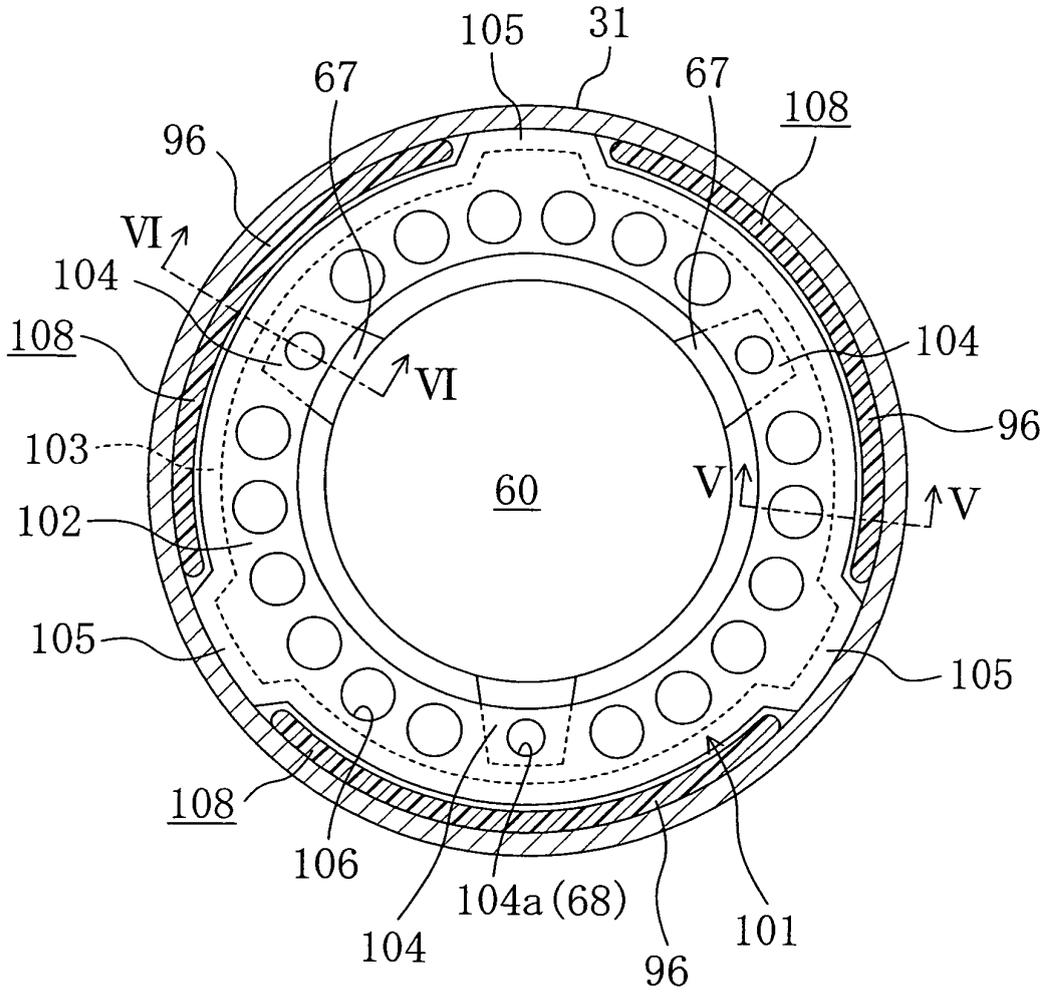


FIG. 5

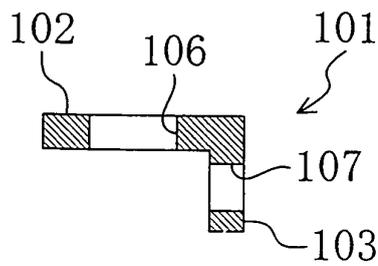


FIG. 6

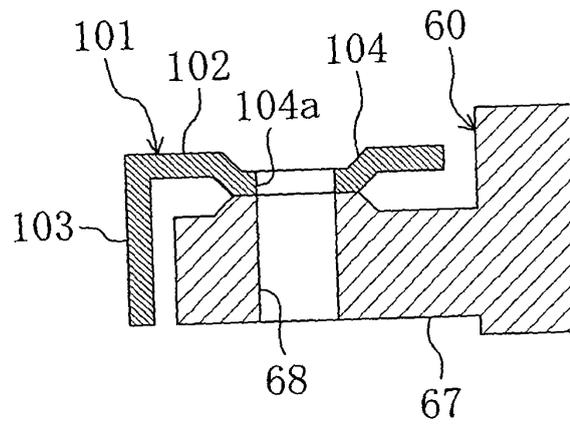


FIG. 7

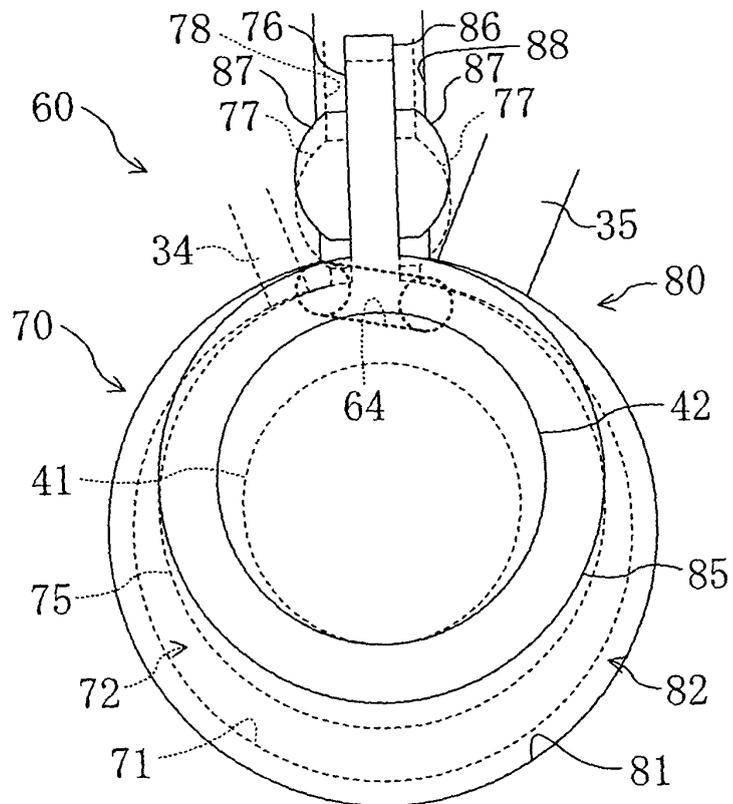


FIG. 8

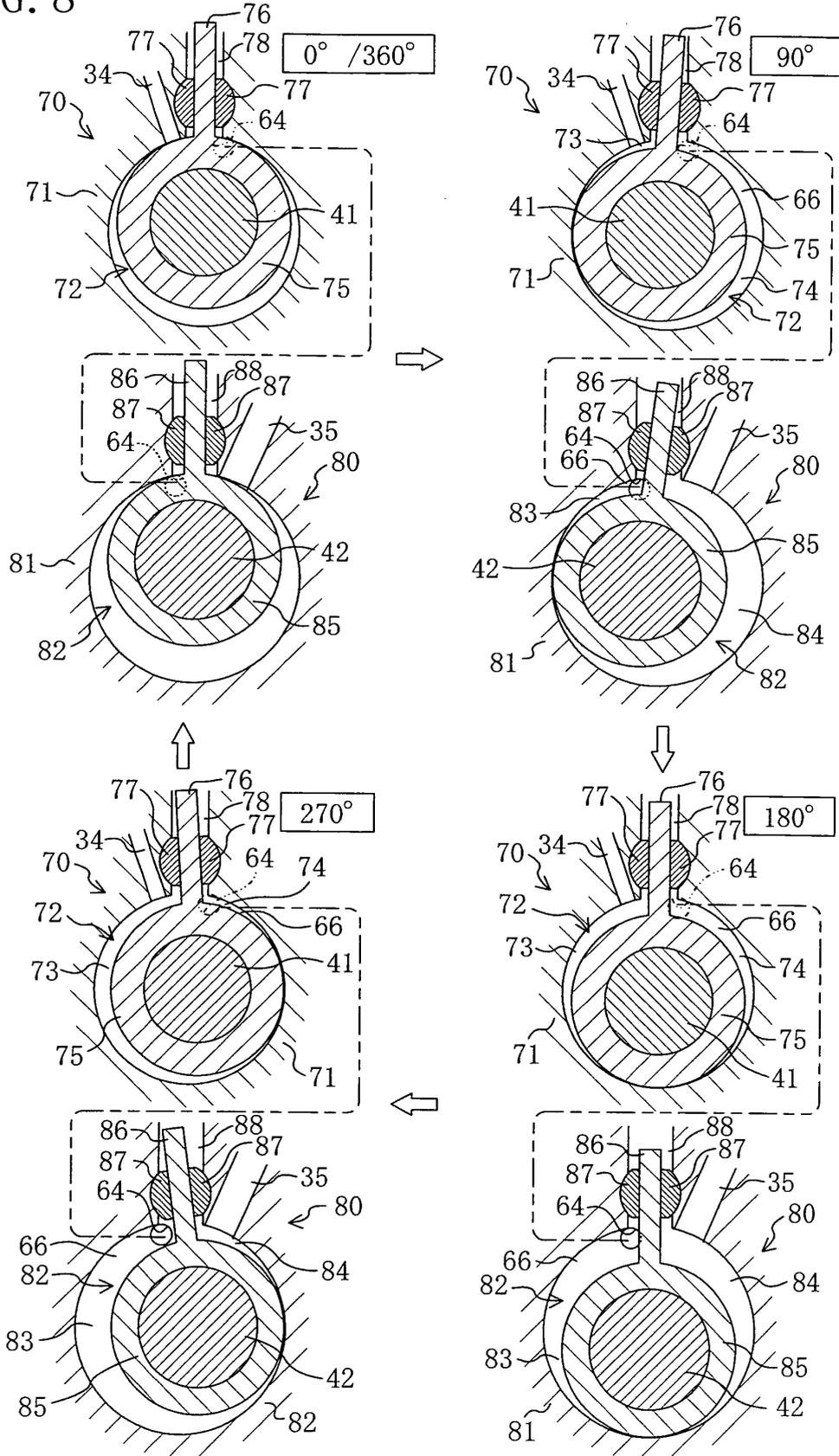


FIG. 9

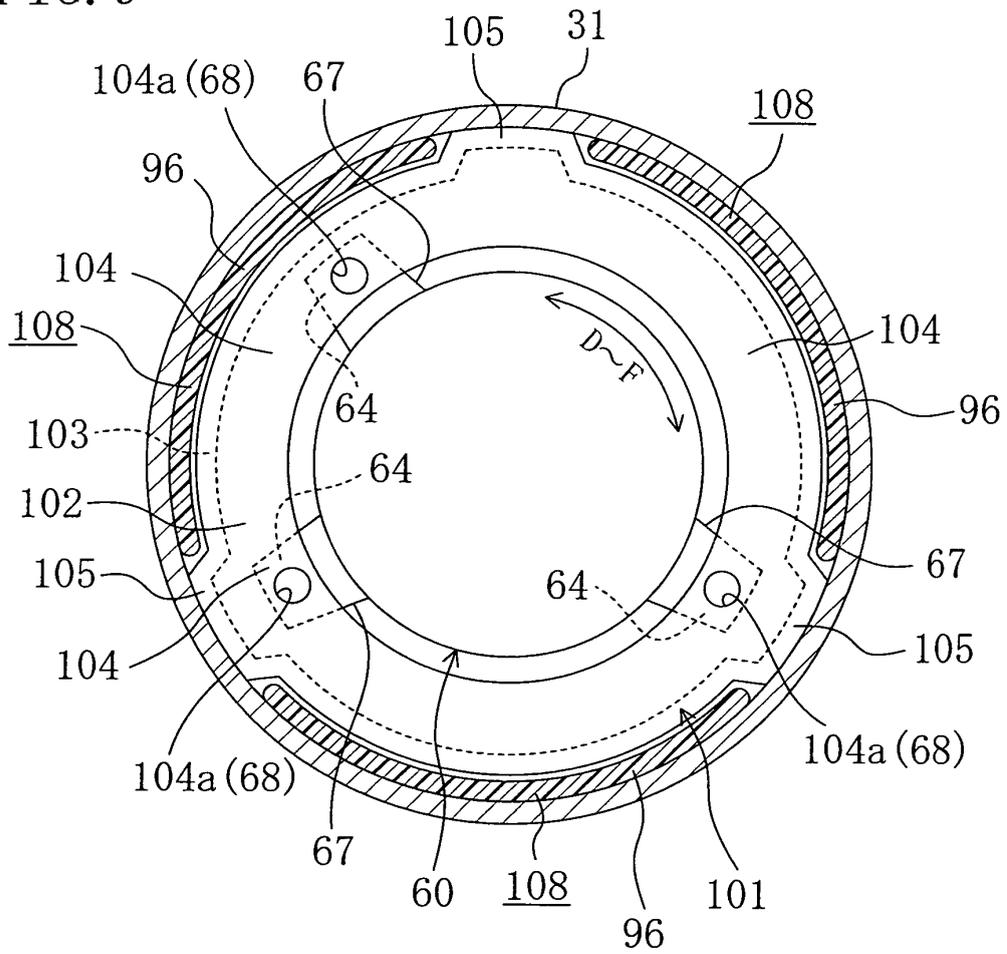


FIG. 10

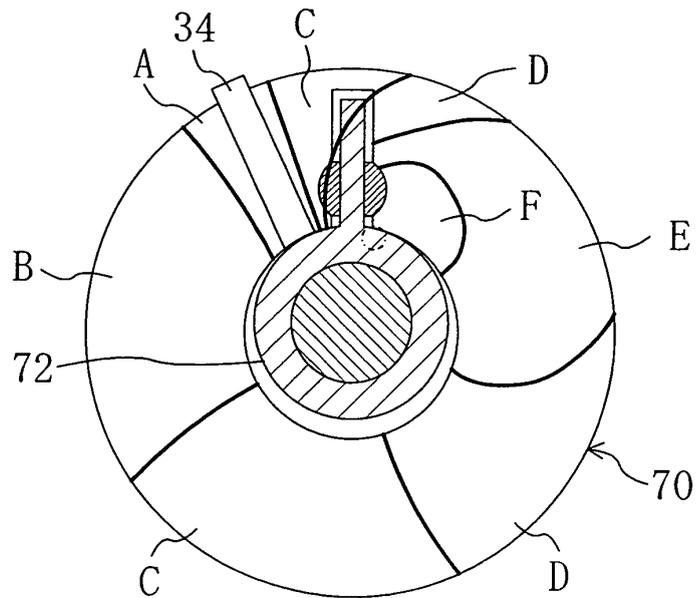


FIG. 11

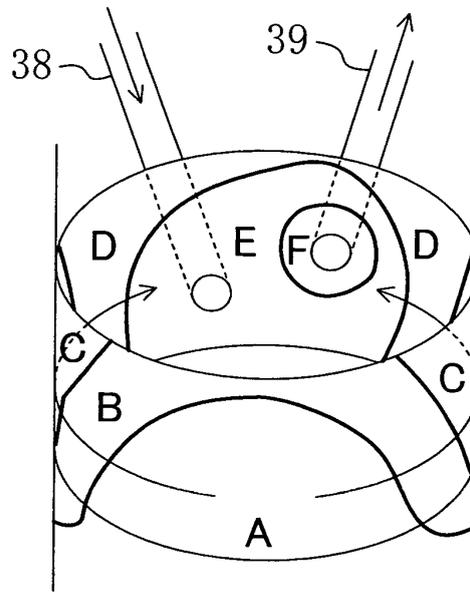


FIG. 12

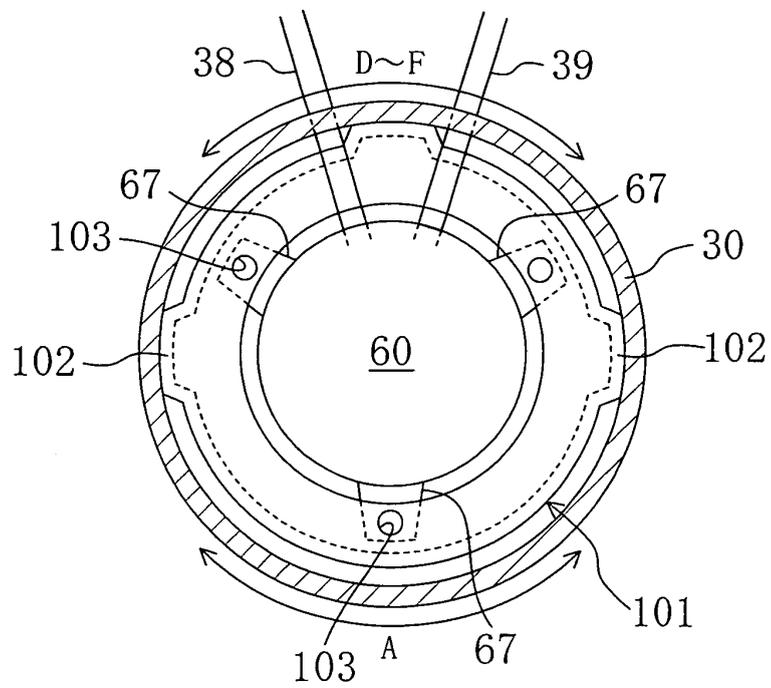
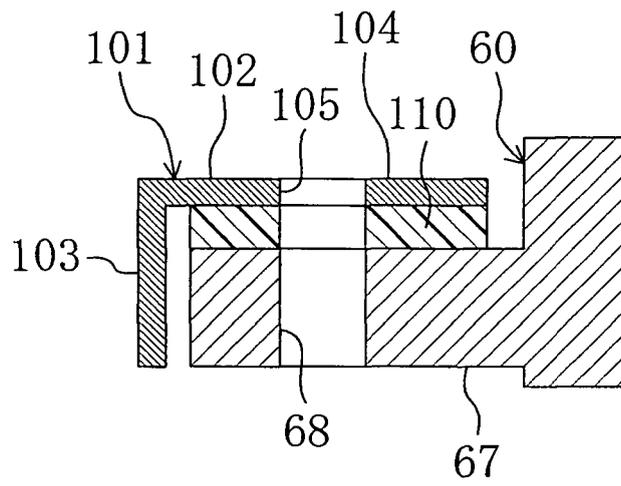


FIG. 13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/072576

A. CLASSIFICATION OF SUBJECT MATTER F04C23/02(2006.01)i, F01C13/04(2006.01)i, F01C21/06(2006.01)i, F04C29/04(2006.01)i, F25B11/02(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) F04C23/02, F01C13/04, F01C21/06, F04C29/04, F25B11/02		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007 Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007		
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 A	JP 2006-257884 A (Daikin Industries, Ltd.), 28 September, 2006 (28.09.06), Par. Nos. [0028] to [0063]; Fig. 2 (Family: none)	1 2-15
X A	JP 2006-132329 A (Daikin Industries, Ltd.), 25 May, 2006 (25.05.06), Par. Nos. [0070] to [0071]; Fig. 2 (Family: none)	1 2-15
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> 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 10 December, 2007 (10.12.07)		Date of mailing of the international search report 25 December, 2007 (25.12.07)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/072576

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 948/1975 (Laid-open No. 85309/1976) (Daikin Industries, Ltd.), 08 July, 1976 (08.07.76), Description, page 5, line 11 to page 6, line 12; Figs. 1 to 2 (Family: none)	2-15
A	JP 60-132094 A (Matsushita Electric Industrial Co., Ltd.), 13 July, 1985 (13.07.85), Page 1, right column, line 2 to page 2, upper left column, line 16; Figs. 1 to 2 (Family: none)	2-15
A	JP 2-123296 A (Toshiba Corp.), 10 May, 1990 (10.05.90), Page 3, upper right column, lines 11 to 19; Fig. 3 (Family: none)	2-15
A	JP 2005-240562 A (Nippon Soken, Inc., Denso Corp.), 08 September, 2005 (08.09.05), Par. No. [0037]; Fig. 2 (Family: none)	10-12,14

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2005106064 A [0004]