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(54) **FLUID PUMP AND FLUID MACHINE**

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(57) **ABSTRACT**

A fluid pump includes a driving part, a movable part that is movable by power transmitted from the driving part via a transmission part, a fixed part disposed on a side of the movable part, opposite to the transmission part, to form an operating chamber having an outlet from which a fluid flowing into the operating chamber is pressure-fed to an outside in a liquid state by the movable part, and an introduction passage for introducing a part of the fluid in the operating chamber to the transmission part. Accordingly, the liquid fluid can be introduced to the transmission part such as a bearing through the introduction passage.

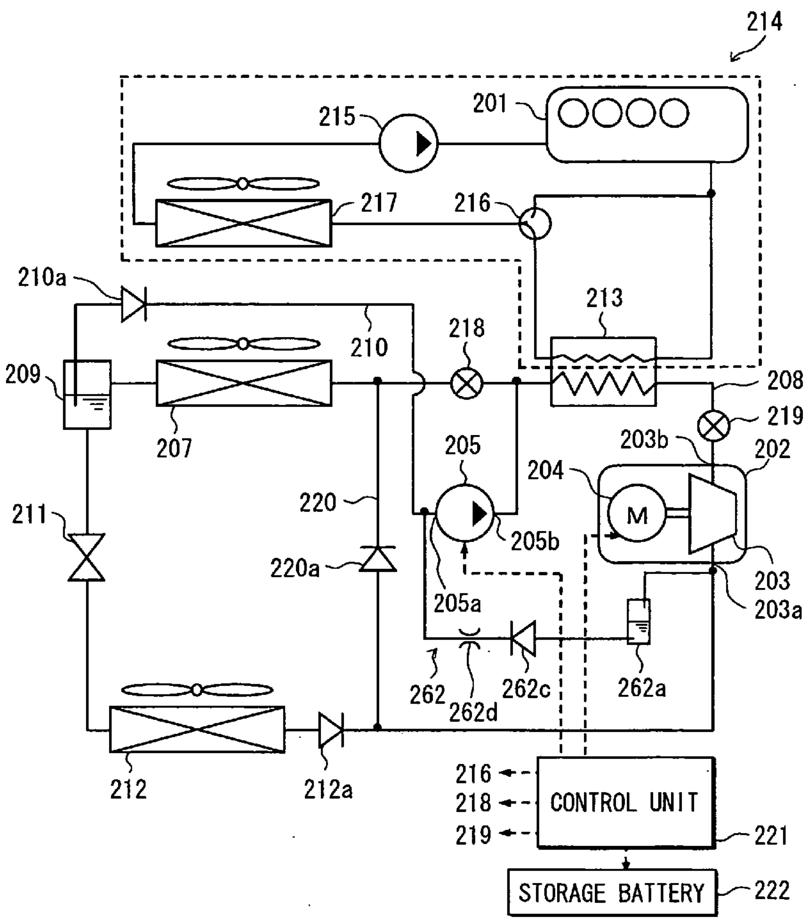
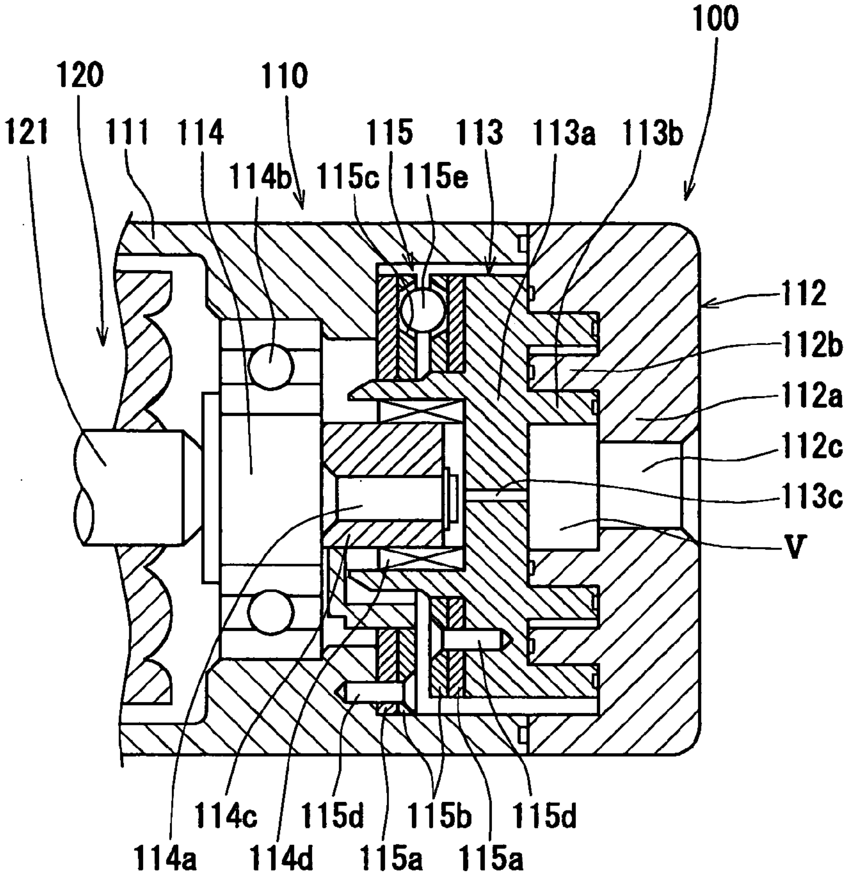


FIG. 1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115c
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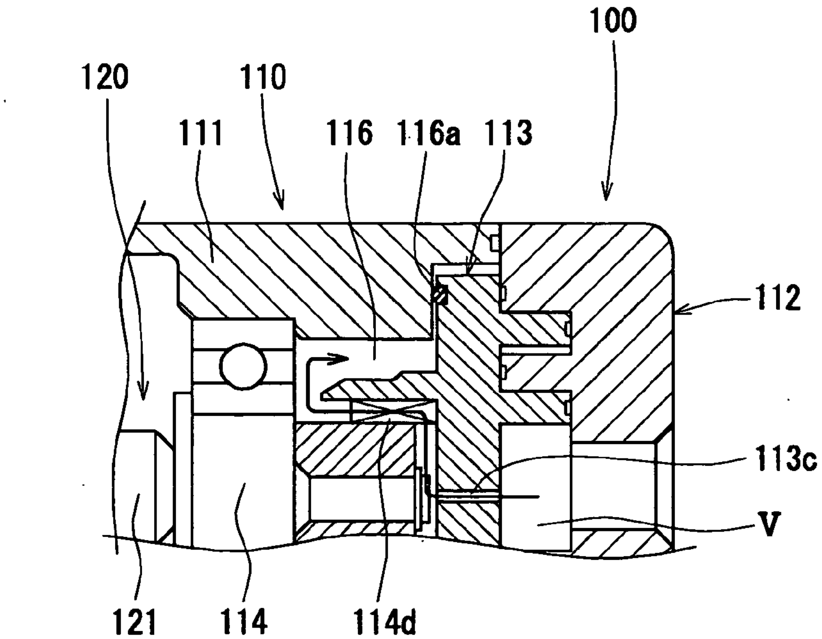
113c
V
114c
115d
115b
115d
114a
114d
115a
115a

FIG. 2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116
116a
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112
113c
V
121
114
114d

FIG. 3

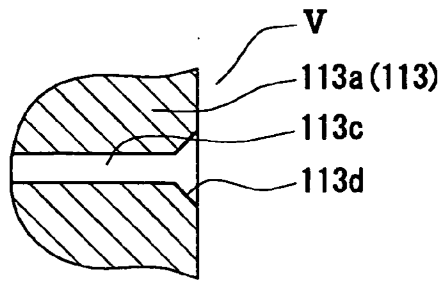


FIG. 4

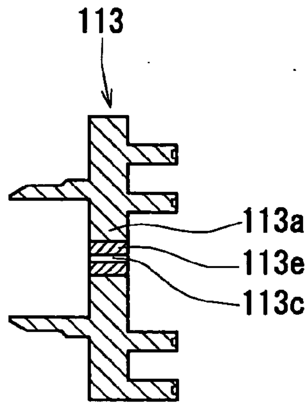


FIG. 5

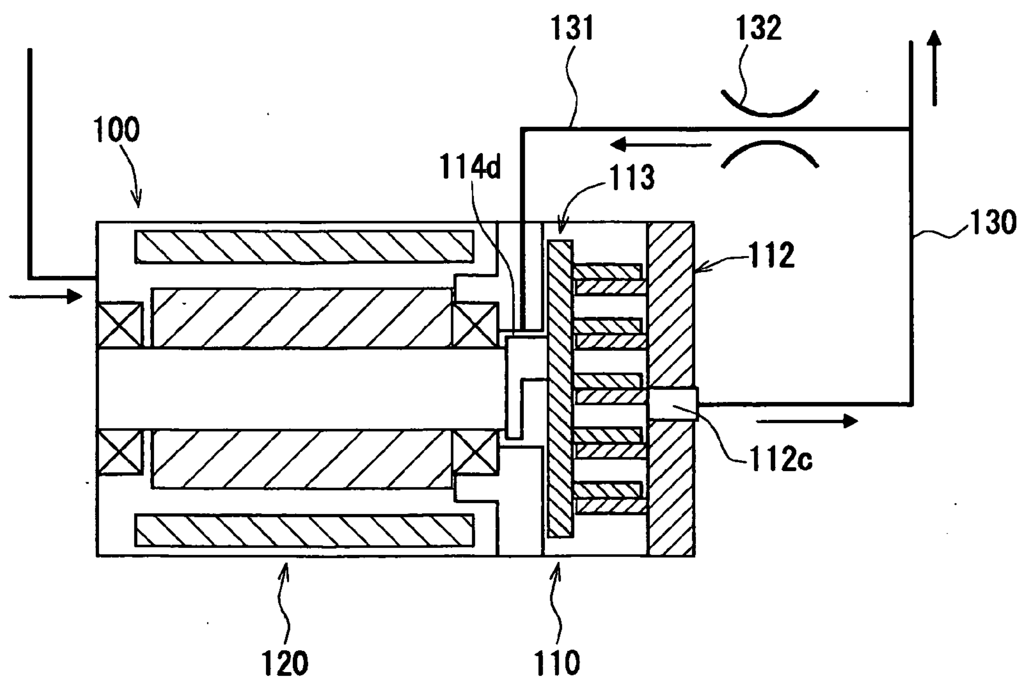


FIG. 6

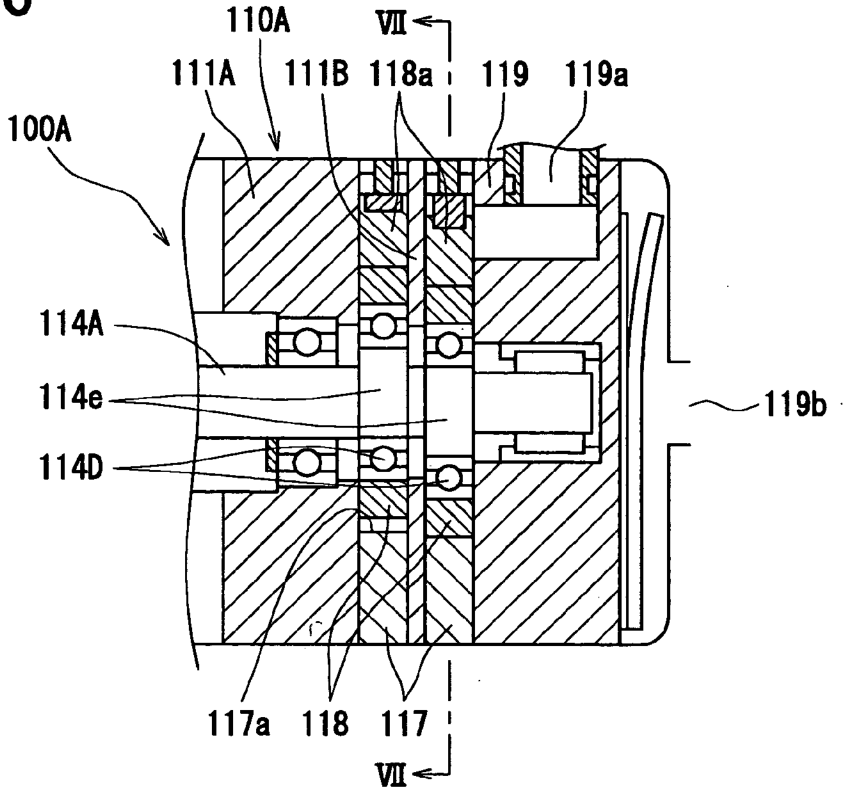

110A
VII
111A
111B
118a
119
119a
100A
114A
114e
119b
114D
117a
118
117
VII

FIG. 7

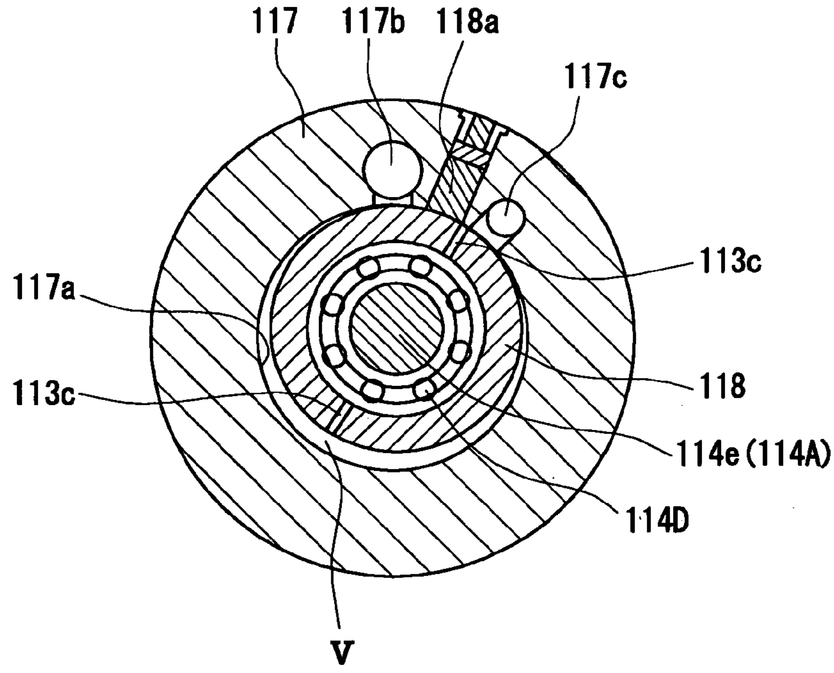

117
117b
118a
117c
113c
117a
118
113c
114e(114A)
114D
V

FIG. 8

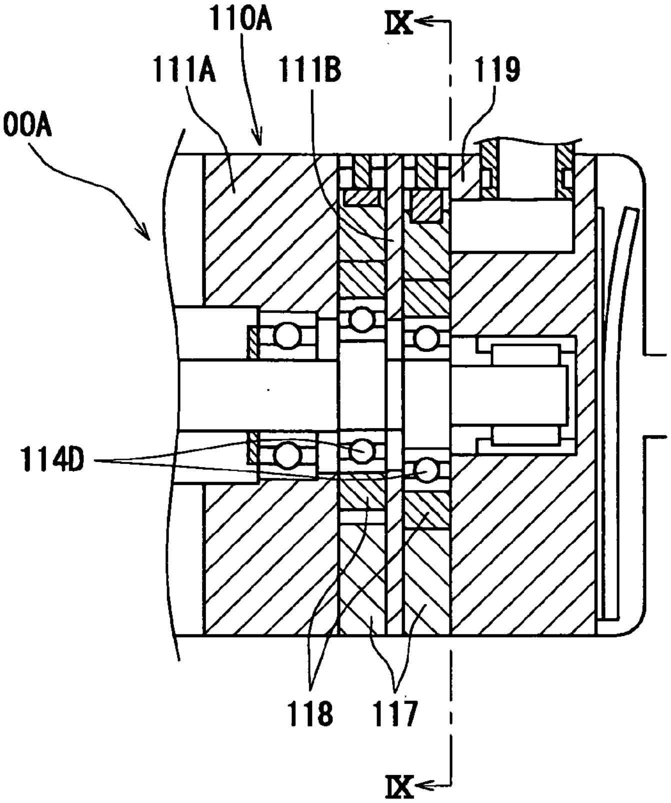


FIG. 9

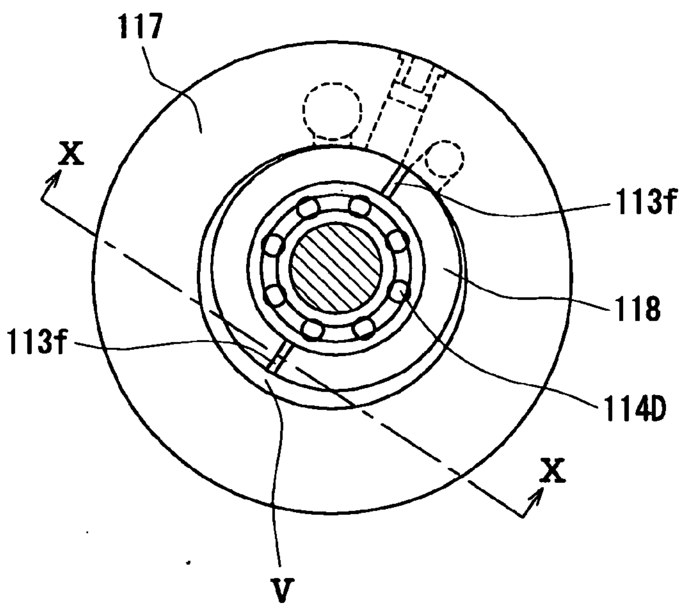


FIG. 10

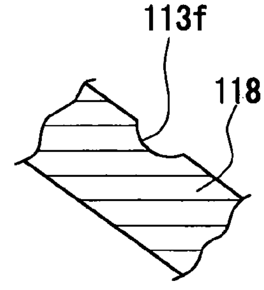
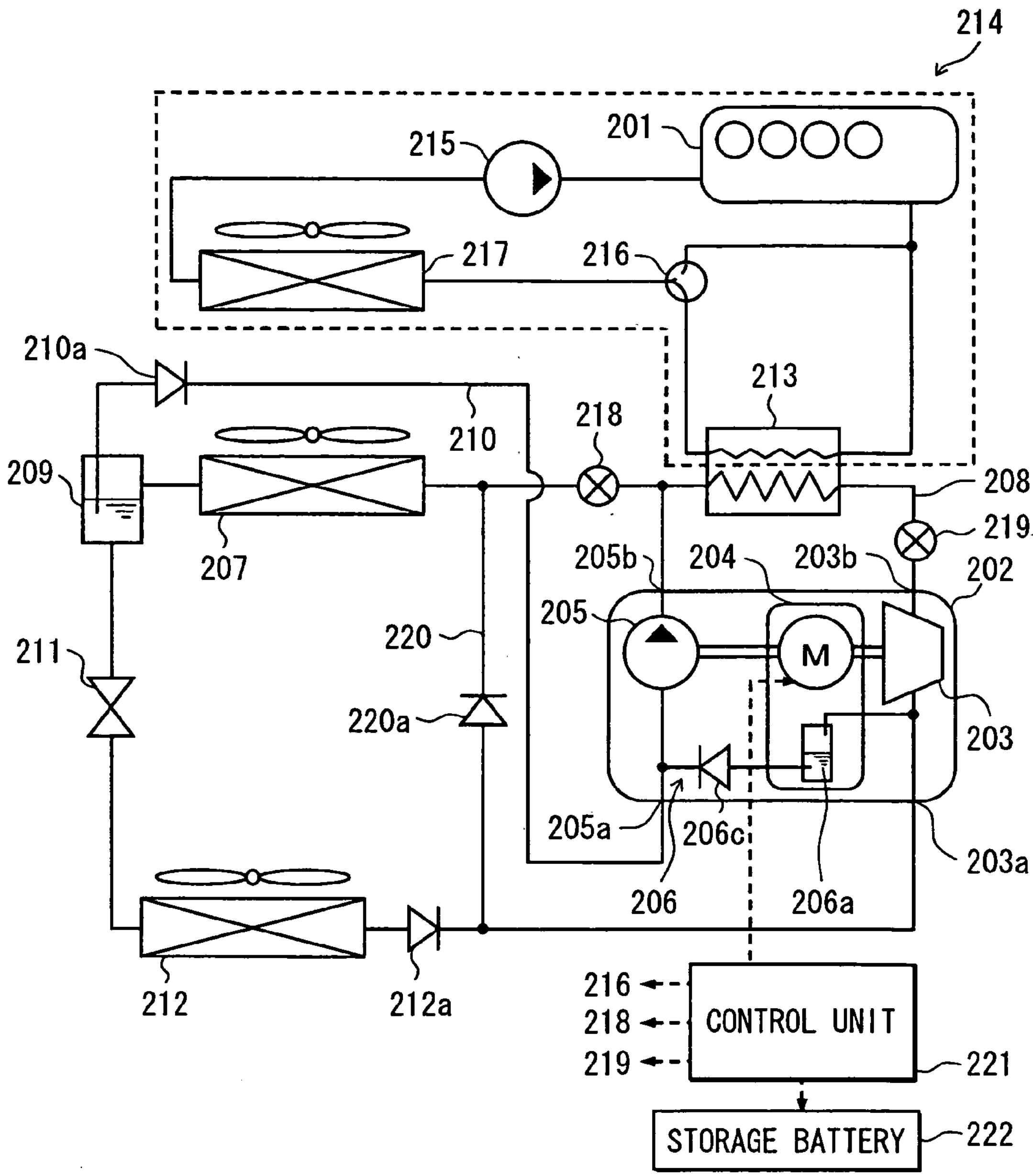


FIG. 11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208
219
207
205b
204
203b
202
205
M
220
220a
211
203
205a
206c
203a
206
206a
212
212a
216
218
219
CONTROL UNIT
221
STORAGE BATTERY
222

FIG. 12

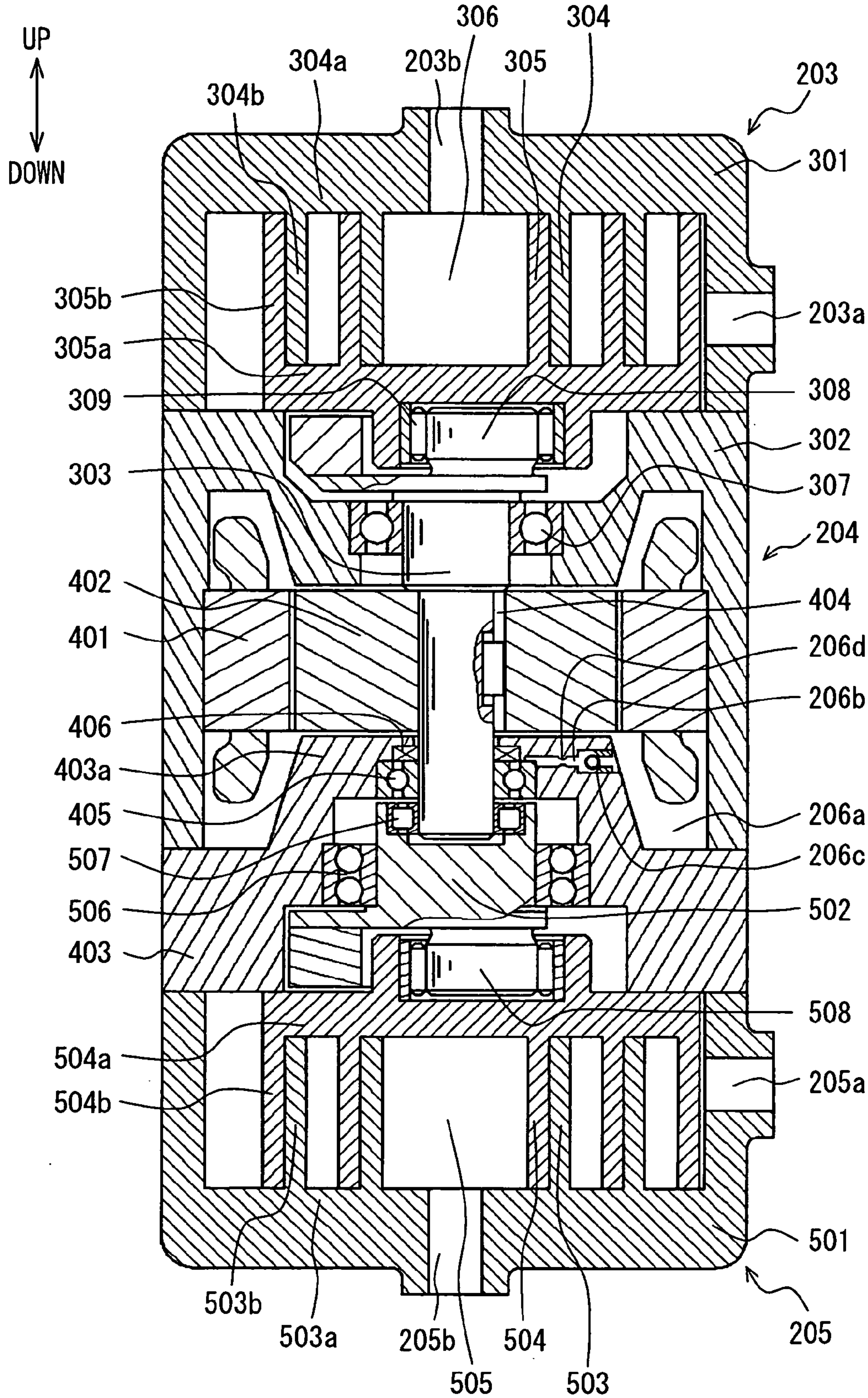
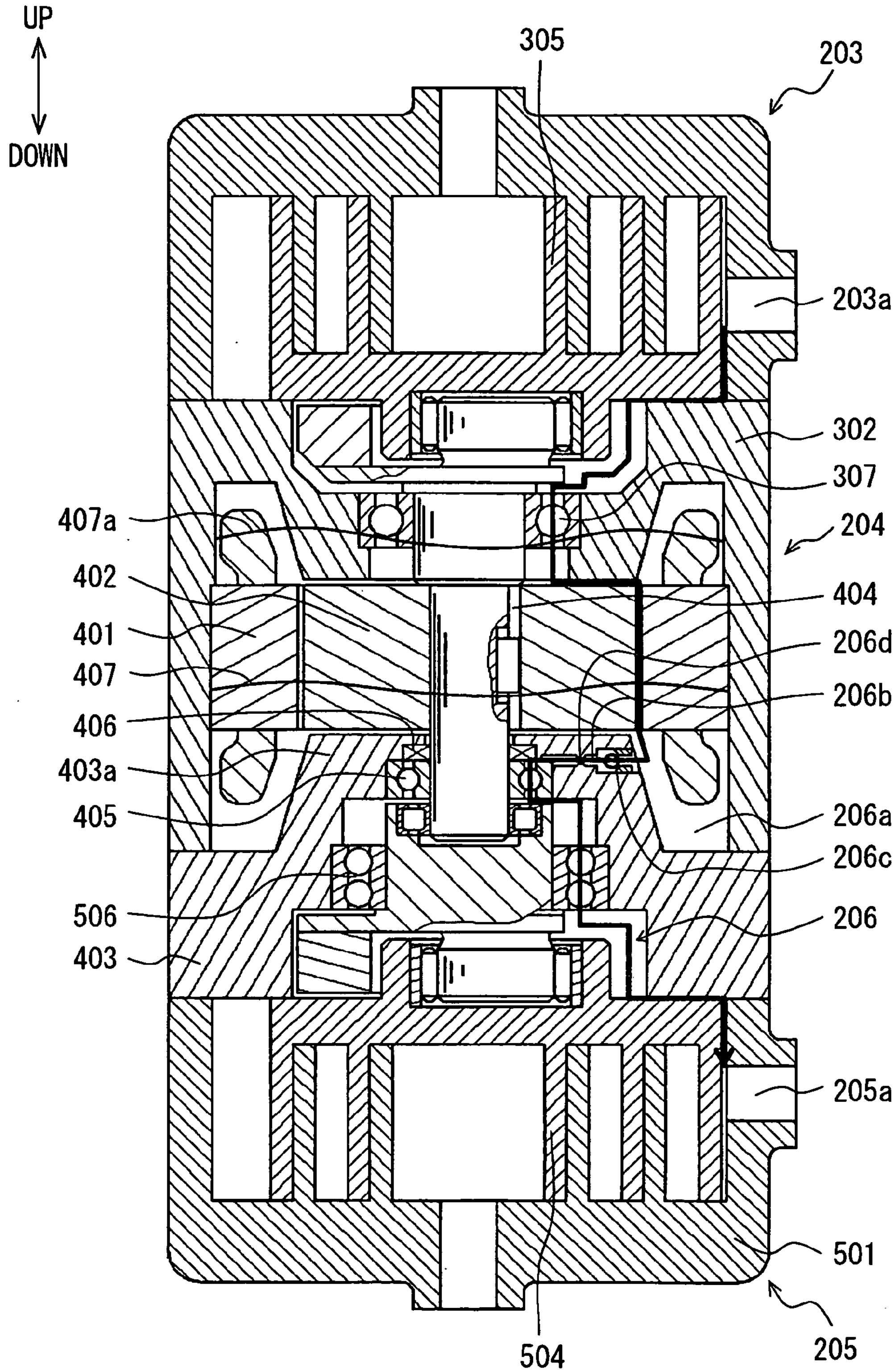

UP
DOWN
306
304
304a
203b
305
203
304b
301
305b
203a
305a
309
308
302
303
307
204
402
404
401
206d
206b
406
403a
405
206a
507
206c
506
502
403
508
504a
504b
205a
501
503b
205
503a
205b
504
505
503

FIG. 13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DOWN
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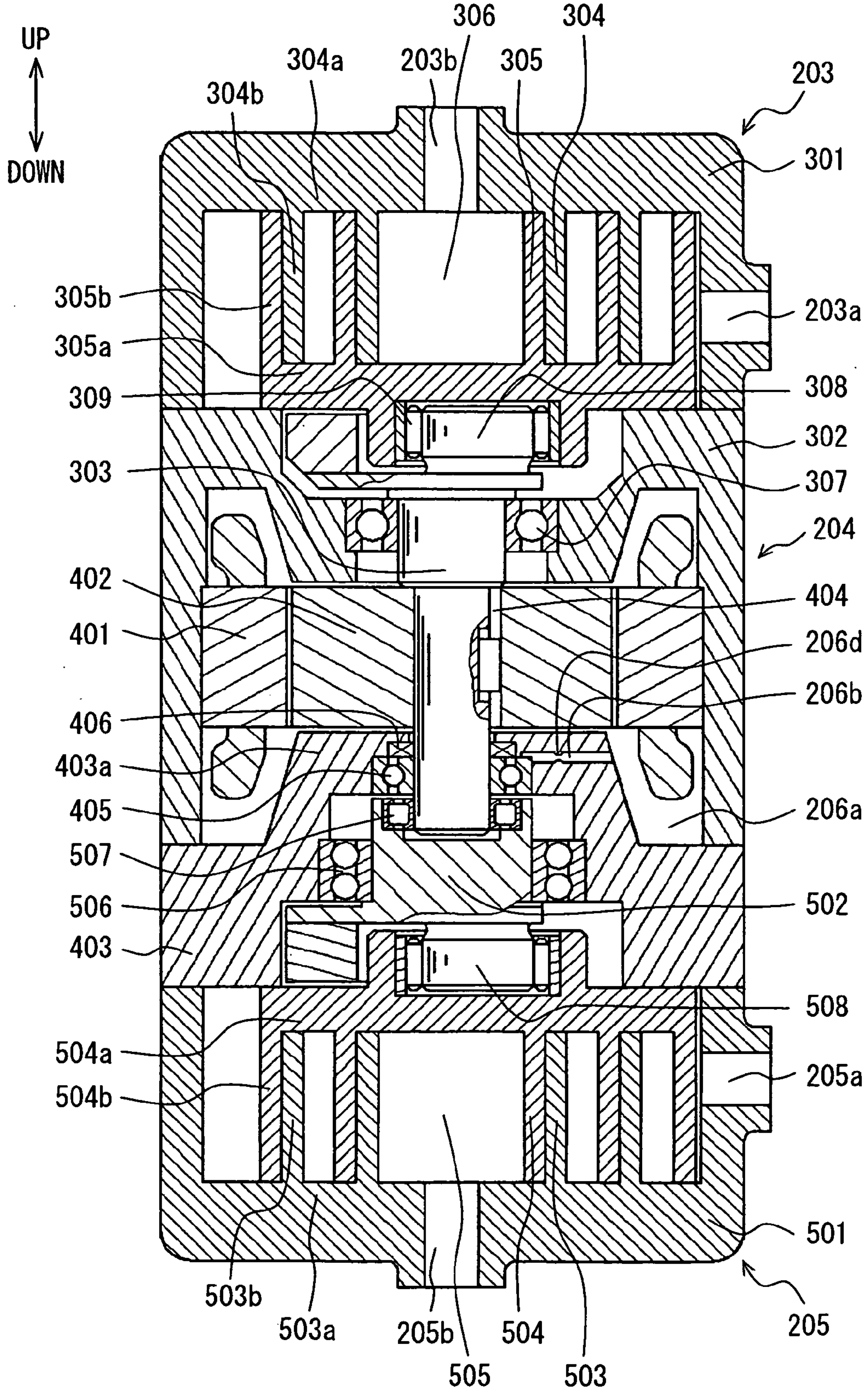
203
203a
302
307
204
407a
402
401
407
406
403a
405
404
206d
206b
206a
206c
506
403
206
205a
501
504
205

FIG. 14



UP
DOWN
306
304
304a
203b
305
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304b
301
305b
203a
305a
309
308
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204
402
404
401
206d
206b
406
403a
405
206a
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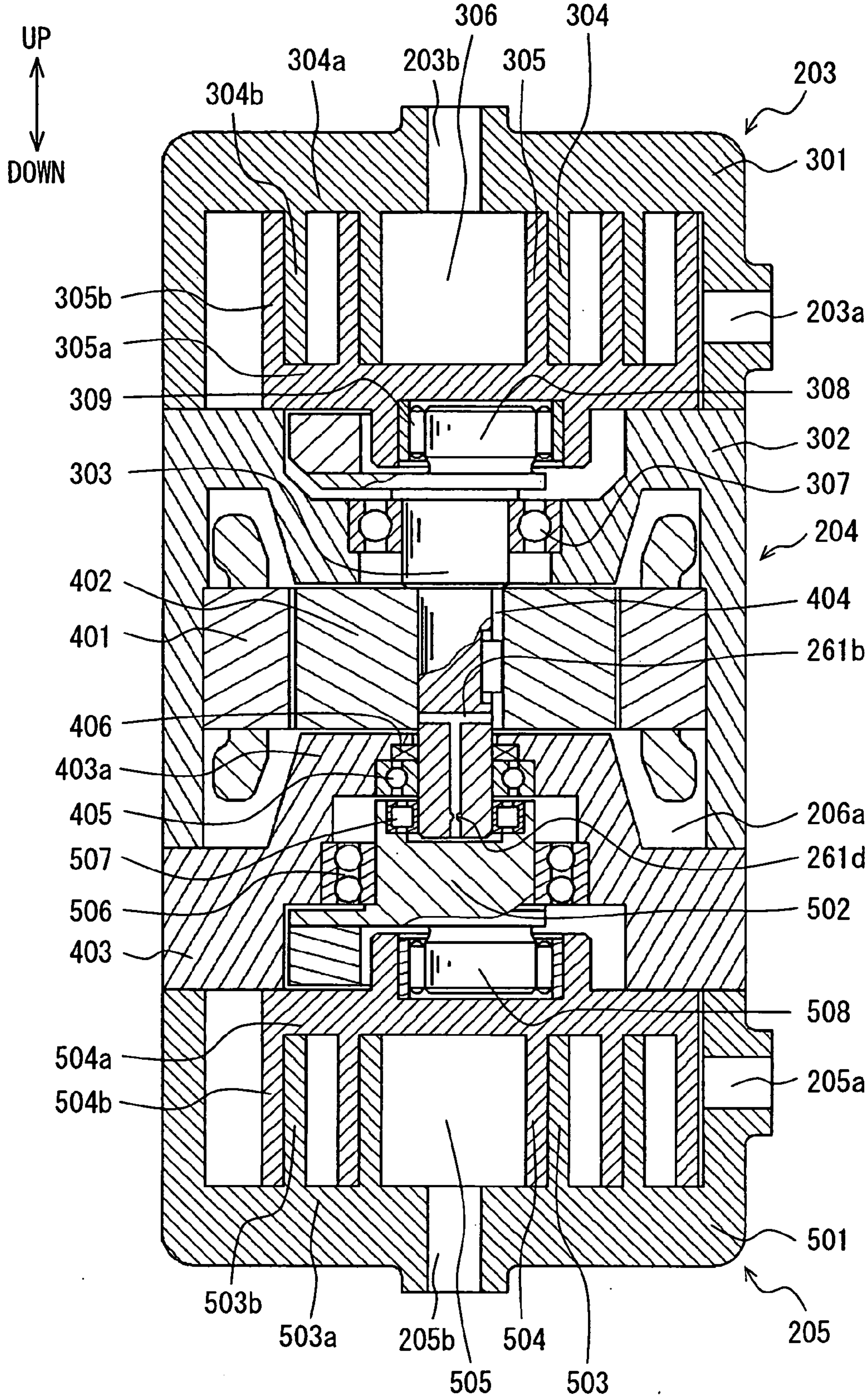
502
403
508
504a
504b
205a
501
503b
503a
205b
504
205
505
503

FIG. 15



UP
DOWN
306
304
304a
203b
305
203
304b
301
305b
203a
305a
309
308
302
303
307
204
402
404
401
261b
406
403a
405
206a
507
261d
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508
504a
205a
504b
501
503b
205
503a
205b
504
505
503

FIG. 16

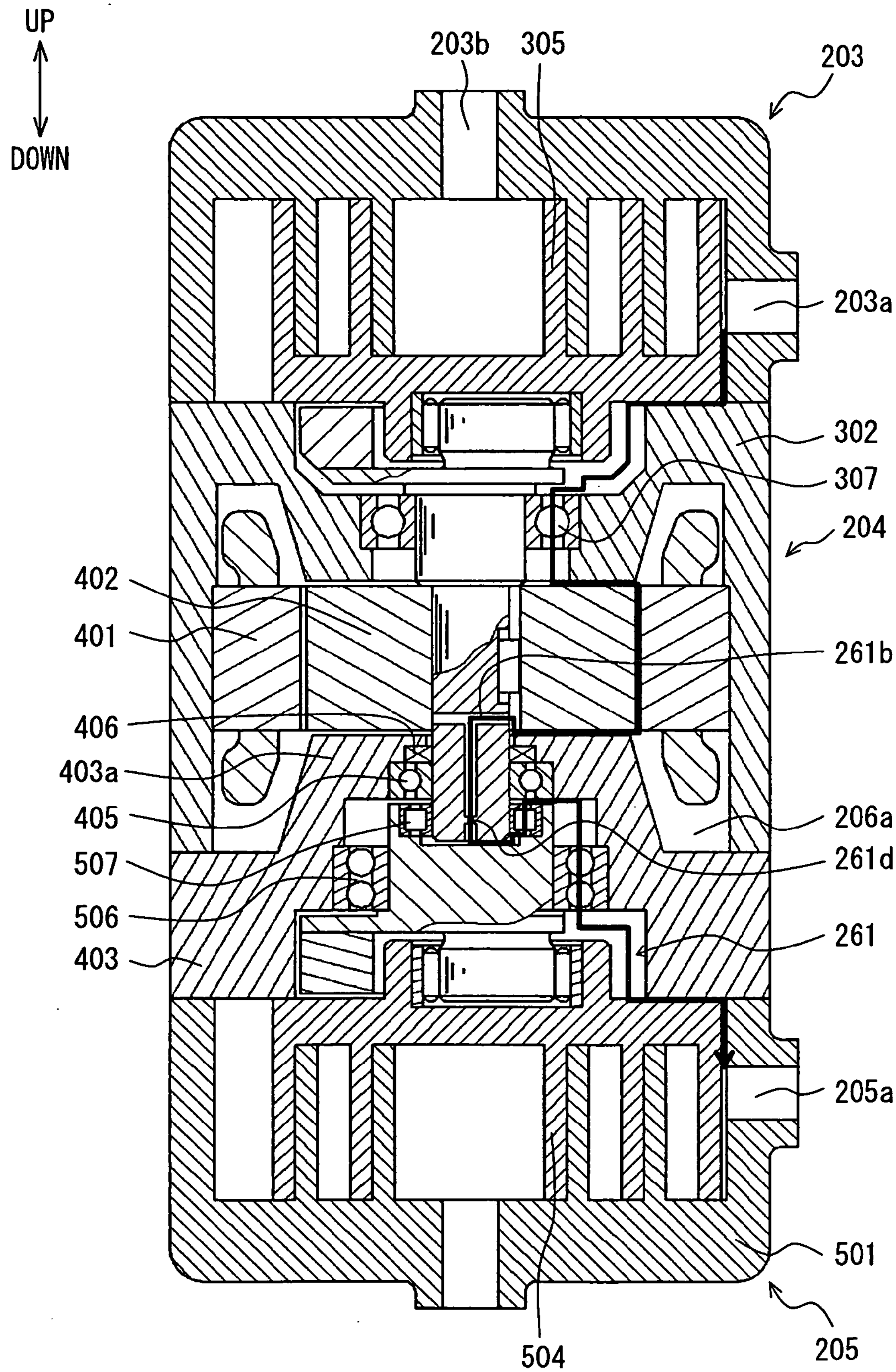
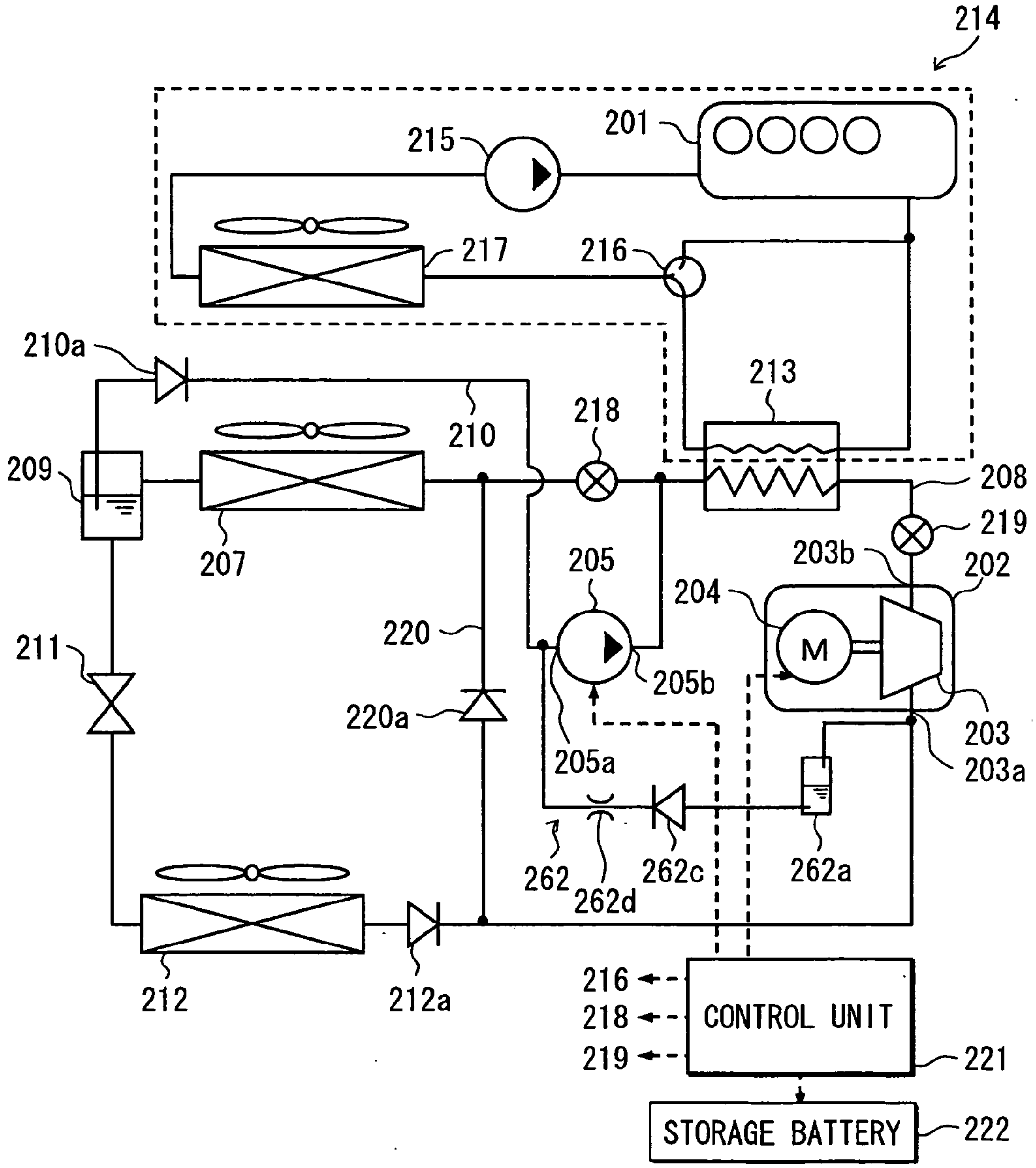

UP
DOWN
203b
305
203
203a
302
307
204
402
401
261b
406
403a
405
206a
507
261d
506
261
403
205a
501
504
205

FIG. 17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M
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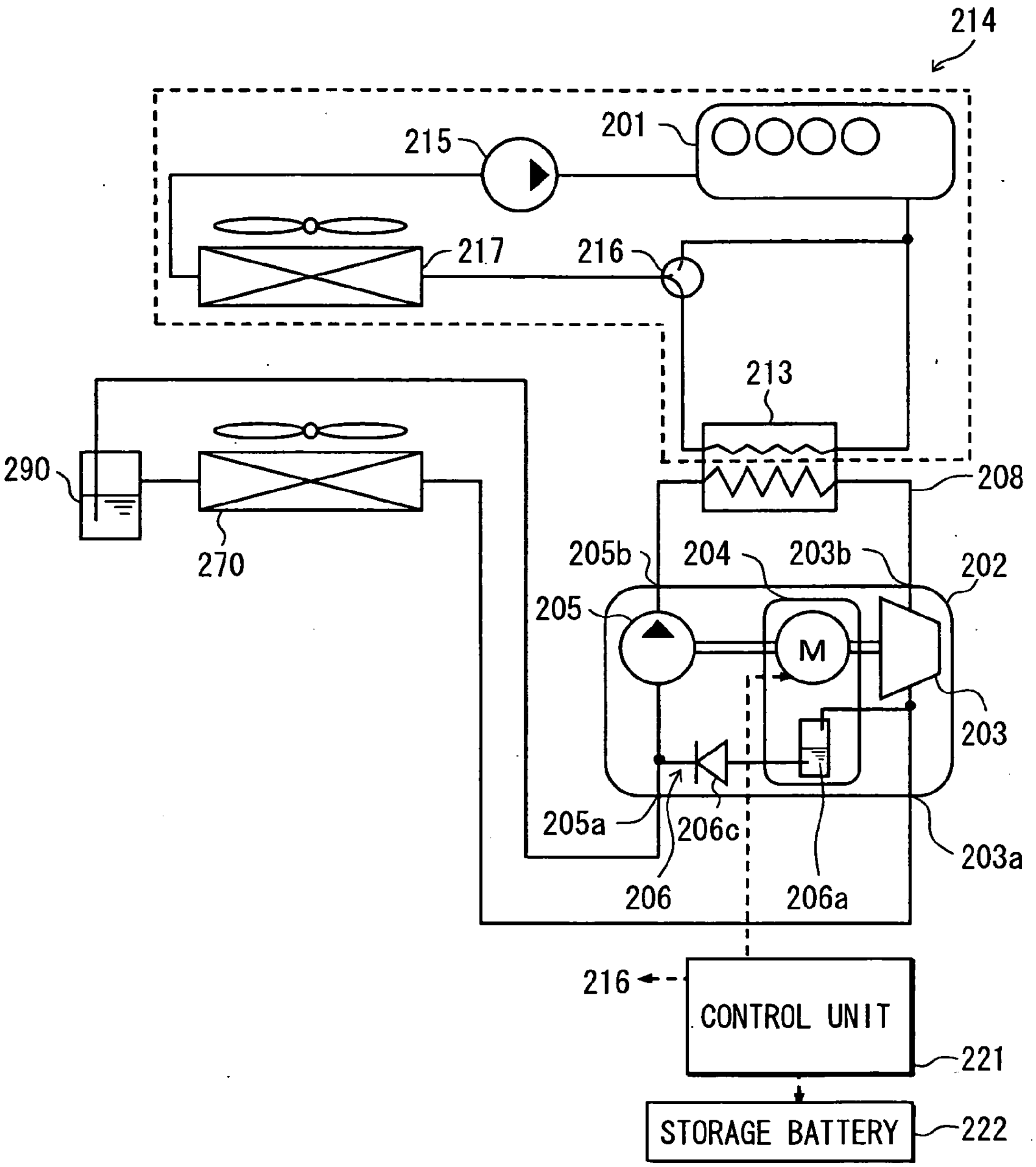
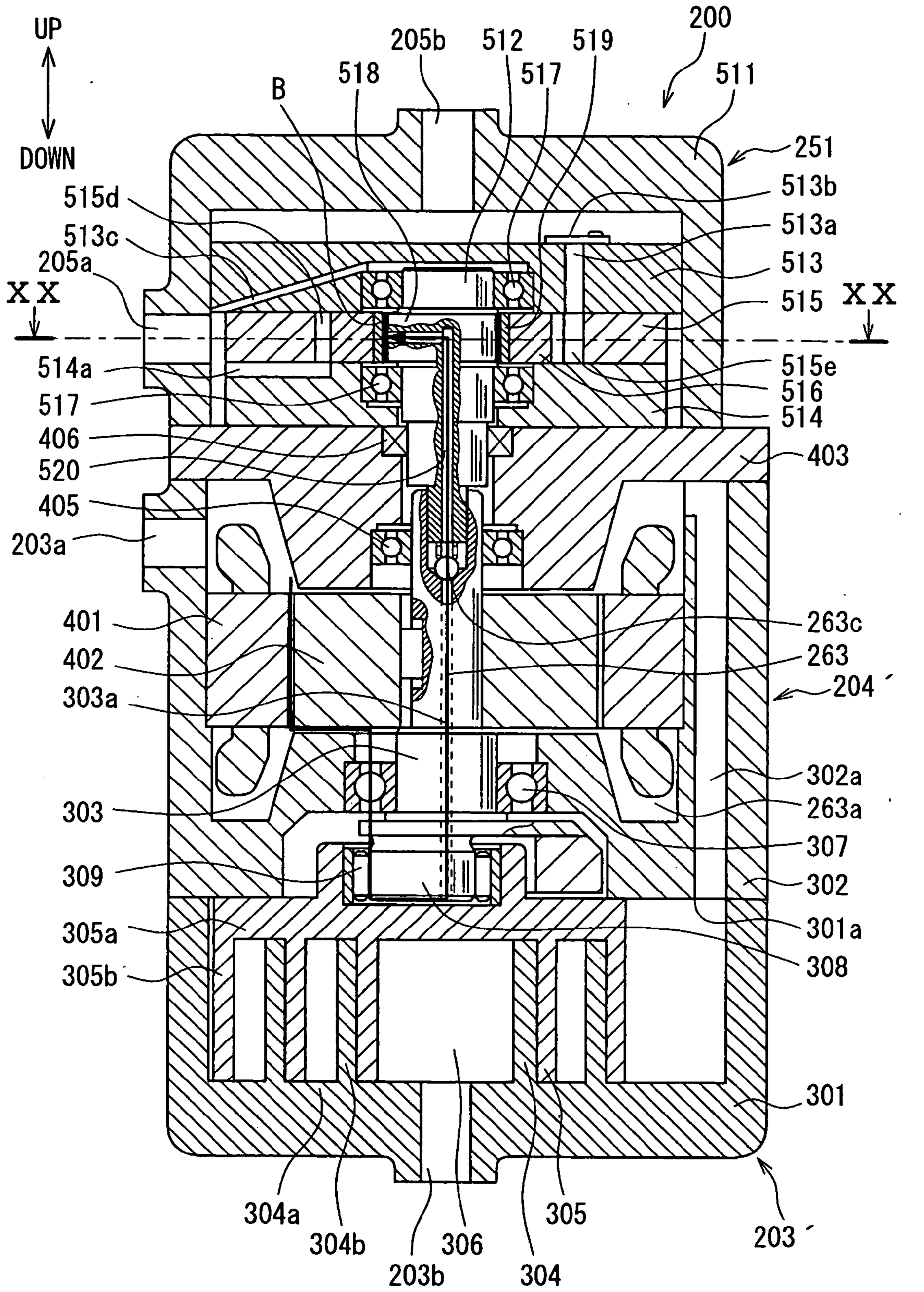
205b
211
220a
203
205a
203a
262
262d
262c
262a
212
212a
216
218
219
CONTROL UNIT
221
STORAGE BATTERY
222

FIG. 18



214
201
215
217
216
213
290
270
208
205b
204
203b
202
205
M
203
205a
206c
203a
206
206a
216
CONTROL UNIT
221
STORAGE BATTERY
222

FIG. 19


UP
DOWN
200
205b
512
519
518
517
511
B
251
515d
513b
513c
513a
205a
513
XX
XX
515
514a
515e
517
516
514
406
403
520
405
203a
401
263c
402
263
303a
204´
302a
303
263a
307
309
302
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305b
301
304a
304b
203b
306
304
305
203´

FIG. 20

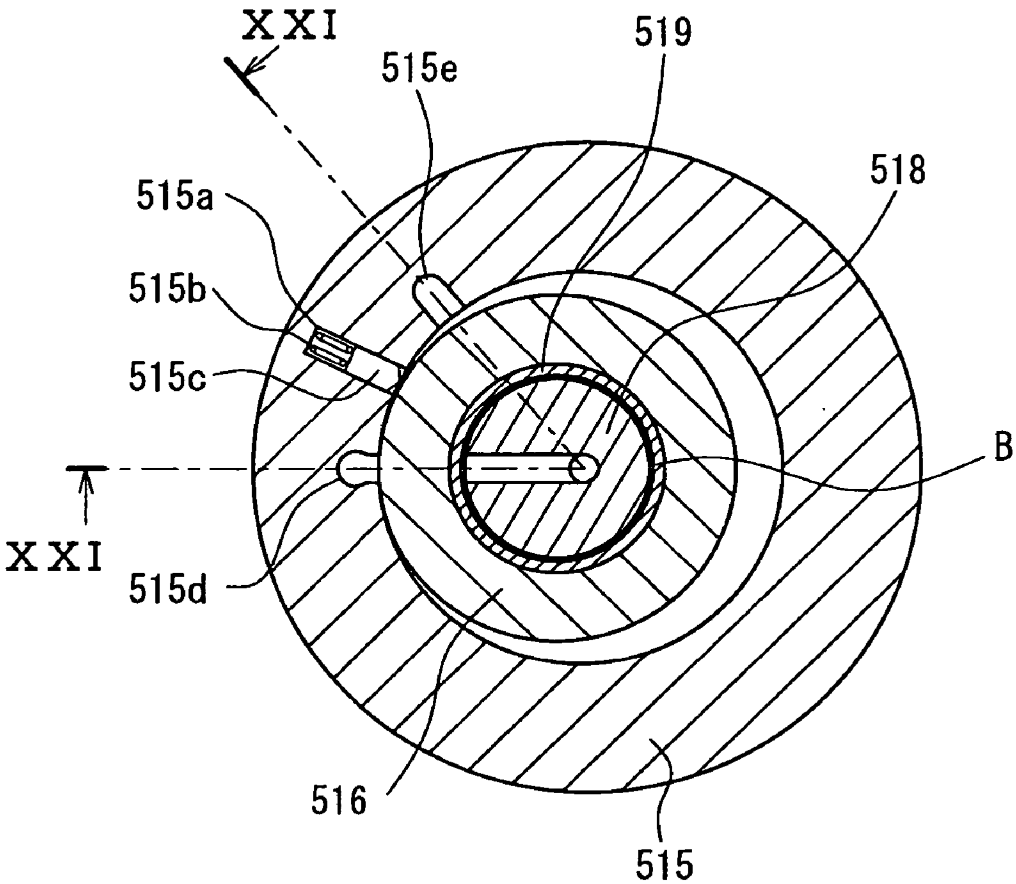


FIG. 21

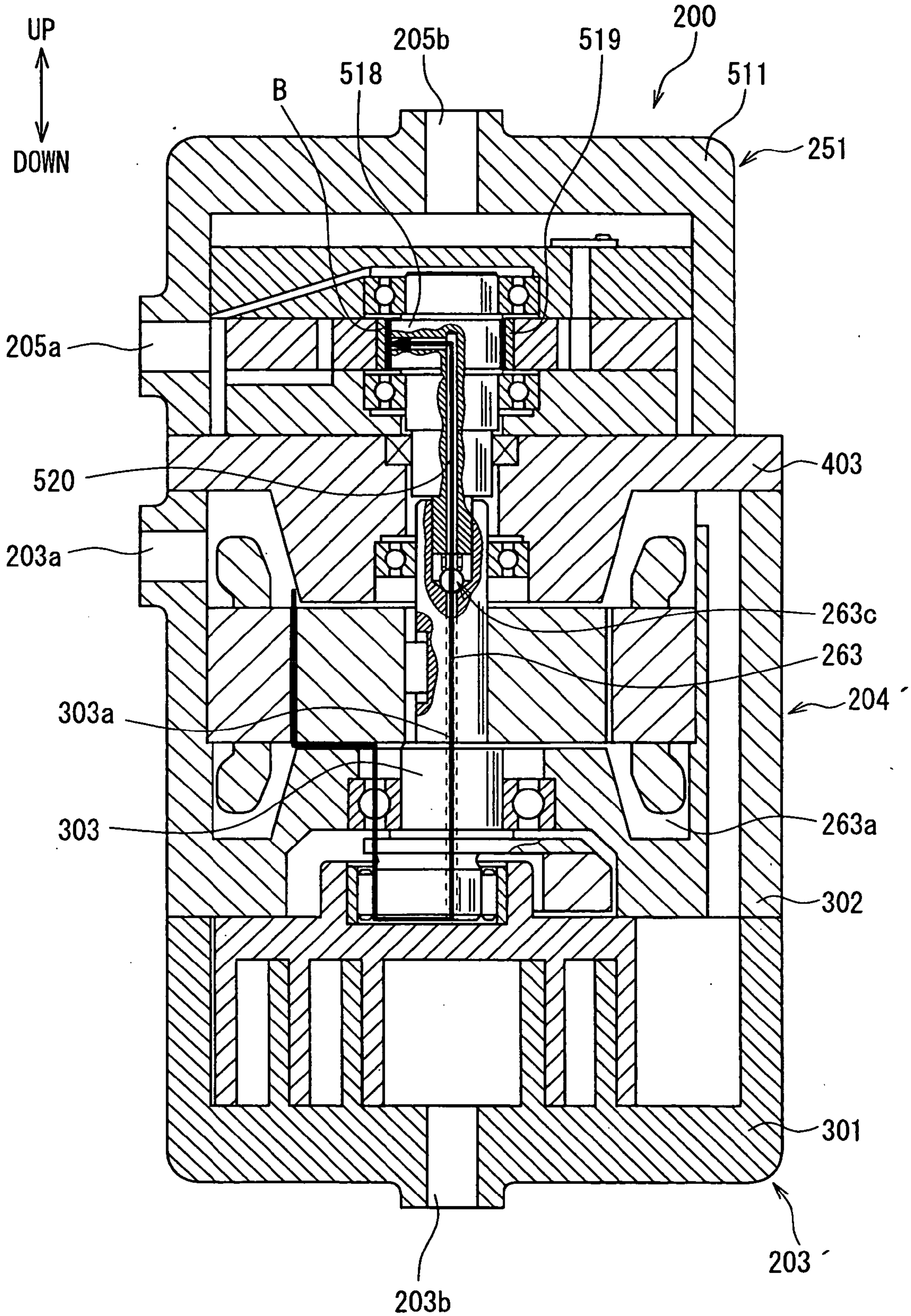

UP
DOWN
205b
519
200
518
B
511
251
205a
520
403
203a
263c
263
303a
204
303
263a
302
301
203
203b

FIG. 22 PRIOR ART

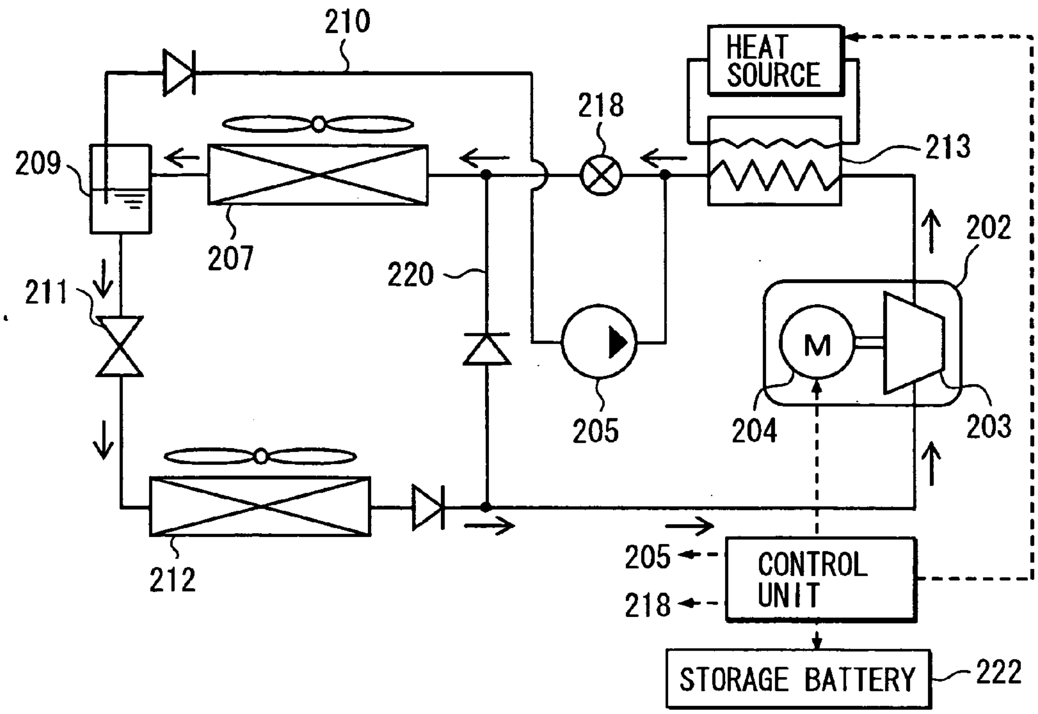
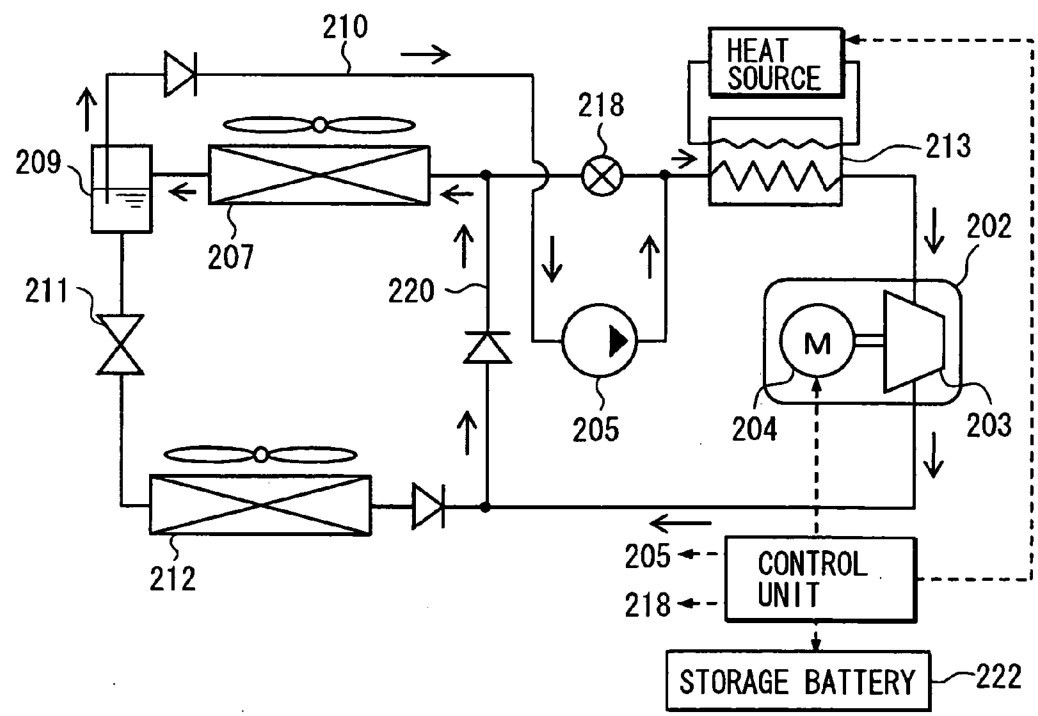


FIG. 23 PRIOR ART



FLUID PUMP AND FLUID MACHINE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on Japanese Patent Applications No. 2005-58048 filed on Mar. 2, 2005, No. 2005-127909 filed on Apr. 26, 2005 and No. 2006-4017 filed on Jan. 11, 2006, the contents of which are incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a fluid pump applicable to a refrigerant pump for pressure-feeding, for example, a liquid refrigerant in a Rankine cycle to a heater. In addition, the present invention relates to a fluid machine used for the Rankine cycle. The fluid pump and the fluid machine can be suitably used for a vapor compression type refrigerator combined with a Rankine cycle.

[0004] 2. Description of the Related Art

[0005] Conventionally, a fluid machine disclosed in, for example, JP-A-7-12068 is known as a fluid machine such as a compressor used for a refrigeration cycle. That is, this fluid machine is a scroll type machine and has a crankshaft for moving a revolving scroll. The shaft part of the crankshaft is rotatably supported by a bearing part and the crank part is connected to a revolving scroll via the bearing part in a back pressure chamber.

[0006] The crankshaft has an oil supply passage penetrating through in its axial direction, and this oil supply passage has an oil supply port and an oil supply groove that are open toward portions close to the bearing parts of the shaft part and the crank part. In a chamber of a casing of the fluid machine, the pressure of refrigerant is set at high pressure on a side opposite to the scroll of the crankshaft and is set at middle pressure in a back pressure chamber. Lubricating oil in the casing passes through the oil supply passage, the oil supply port and the oil supply groove, to respective bearings, by the pressure difference between the high pressure and the middle pressure to thereby lubricate the respective bearings.

[0007] However, in the above-described fluid machine, the oil supply passage, oil supply port, and the oil supply groove to the crankshaft need to be formed. In addition, in the casing, the high-pressure portion and the middle-pressure portion need to be set with respect to the crankshaft. This makes the structure of the fluid machine complex.

[0008] Moreover, the technology of using a compressor for a refrigeration cycle as an expander for a Rankine cycle in a vapor compression type refrigerator combined with a Rankine cycle is disclosed in JP-A-63-964494. Furthermore, US 2004/0,231,331 describes a fluid machine capable of recovering thermal energy with high efficiency in a vapor compression type refrigerator.

[0009] In US 2004/0,231,331, the direction of flow of refrigerant when a fluid machine is made to function as a compressor is reversed relative to that when the fluid machine is made to function as an expander by using a refrigerant pump of refrigerant pressure-feeding means for pressure-feeding refrigerant to the fluid machine, and thermal energy is converted to electric energy with high efficiency by providing a passage for transmitting power from the expander to a generator with a speed change mechanism.

[0010] The direction of flow of refrigerant in US 2004/0,231,331 will be described with reference to **FIG. 22** and **FIG. 23**. When a fluid machine **202** integrated with an expander is operated as a compressor, power is supplied to the compression and expansion part **203** of the fluid machine **202** integrated with an expander, heat source is not supplied to a heater **213**, and an open/close valve **218** is opened and a refrigerant pump **205** is not operated. Hence, as shown by arrows in **FIG. 22**, the refrigerant flows in the direction of: the fluid machine **202** integrated with an expander→the heater **213**→the open/close valve **218**→a radiator **207**→a vapor-liquid separator **209**→an expansion valve **211**→an evaporator **212**→the fluid machine **202** integrated with an expander. This is the same as the publicly known refrigeration cycle and heat absorbed by the refrigerant at the evaporator **212** is radiated at the radiator **207** to produce a refrigeration capacity.

[0011] Next, when the fluid machine **202** integrated with an expander is operated as an expander, a power storing battery **222** (storage battery) is connected to a driving and electric-power generating part **204** of the fluid machine **202** integrated with an expander, heat source is supplied to the heater **213**, the open/close valve **218** is closed and the refrigerant pump **205** is operated. Hence, as shown by arrows in **FIG. 23**, the refrigerant flows in the direction of: the refrigerant pump **205**→the heater **213**→the fluid machine **202** integrated with an expander→a second bypass passage **220**→the radiator **207**→the vapor-liquid separator **209**→a first bypass passage **220**→the refrigerant pump **205**. In this cycle, when the volume of the refrigerant heated by the heater **213** is expanded, the fluid machine **202** integrated with an expander generates mechanical energy and this mechanical energy is converted to electric energy to thereby recover thermal energy.

[0012] Generally, the refrigerant for the vapor compression type refrigerator (for example, HFC-134a) has lower viscosity than lubricating oil or water in the state of a liquid phase and the oil has the property of easily dissolving in liquid-phase refrigerant. For this reason, lubrication is apt to be insufficient in the mechanical sliding parts where only the liquid-phase refrigerant passes.

[0013] JP-A-63-96449 and US 2004/0,231,331 do not disclose anything about lubrication in the mechanical sliding parts of the refrigerant pump. However, in this refrigerant pump, the liquid-phase refrigerant separated by the vapor-liquid separator is sucked and discharged. That is, only the liquid-phase refrigerant passes over the mechanical sliding parts of the refrigerant pump and hence the mechanical sliding parts of the refrigerant pump are apt to be insufficiently lubricated.

[0014] Furthermore, JP-A-63-96449 and US 2004/0,231,331 disclose fluid machines applied to the vapor compression type refrigerator combined with a Rankine cycle, but also in a fluid machine designed specifically for a Rankine cycle, the mechanical sliding parts of the refrigerant pressure-feeding means are apt to be insufficiently lubricated because of the same reason.

SUMMARY OF THE INVENTION

[0015] In view of the foregoing problems, it is a first object of the present invention to provide a fluid pump which effectively introduce lubricating oil to a transmission part, e.g., bearings, with a simple structure.

[0016] It is a second object of the present invention to provide a fluid machine which effectively lubricates mechanical sliding parts in a refrigerant pressure-feeding member.

[0017] It is a third object of the present invention to provide a vapor compression type refrigerator combined with a Rankine cycle, which effectively lubricates mechanical sliding parts in a refrigerant pressure-feeding member.

[0018] According to an aspect of the present invention, a fluid pump includes a driving part, a movable part that is movable by power transmitted from the driving part, a transmission part through which the power from the driving part is transmitted to the movable part, a fixed part disposed on a side of the movable part opposite to the transmission part to form an operating chamber having an outlet from which a fluid flowing into the operating chamber is pressure-fed to an outside in a liquid state by the movable part, and an introduction passage for introducing a part of the fluid in the operating chamber to the transmission part. Therefore, liquid fluid can be easily supplied to the transmission part including bearings, and foreign subject in the bearings can be effectively discharged. Furthermore, when the transmission part including the bearings can be effectively lubricated using the liquid fluid including lubricating oil.

[0019] The introduction passage can be provided in the movable part, and the introduction passage has an opening part opened to the operating chamber to be tapered. Alternatively, the movable part includes a passage part for defining the introduction passage, and the passage part is a member separate from the movable part.

[0020] For example, the movable part is a movable scroll having a base plate portion and a first wall portion protruding from the base plate portion in a spiral shape, the fixed part is a fixed scroll having a spiral second wall portion engaged with the first wall portion. In this case, the introduction passage has a diameter smaller than a predetermined value, and is provided in the base plate portion of the movable scroll to make the operating chamber communicate with the transmission part at a predetermined pressure loss. Furthermore, the transmission part can be housed in a closed space. In this case, the movable scroll receives a back pressure applied thereto on a side of the fixed scroll by the fluid introduced into the closed space. In addition, the movable scroll can be provided with a plurality of holes, each having a diameter smaller than a predetermined value, for adjusting pressure between the operating chamber and the closed space.

[0021] Alternatively, the movable part can be a rotor that is made to revolve by the driving part arranged in a center of the movable part. In this case, the fixed part is a cylinder housing in which a cylinder housing the rotor is disposed, and the introduction passage is a passage having a diameter smaller than a predetermined value, and is provided in the rotor to make the operating chamber communicate with the transmission part at a predetermined pressure loss. The introduction passage may be a groove that is provided on an end surface in an axial direction of the rotor and makes the operating chamber communicate with the transmission part at a predetermined pressure loss.

[0022] According to another aspect of the present invention, a fluid machine includes: an expansion member having a function of outputting mechanical energy by expansion of refrigerant, the expansion member having a low-pressure port from which low-pressure vapor-phase refrigerant after being decompressed flows out and a high-pressure port from which high-pressure refrigerant before being decompressed flows in; an electric power generating member having a function of generating electric power by using the mechanical energy; a refrigerant pressure-feeding member for pressure-feeding refrigerant to the expansion member, the refrigerant pressure-feeding member having a refrigerant suction port from which liquid-phase refrigerant is sucked and a refrigerant discharge port from which liquid-phase refrigerant is discharged; and a communication part for making the low-pressure port of the expansion member communicate with the refrigerant suction port of the refrigerant pressure-feeding member. Furthermore, the communication part separates lubricating oil from vapor-phase refrigerant and supplies the lubricating oil to the refrigerant suction port. In this case, the fluid machine can effectively lubricate mechanical sliding parts in a refrigerant pressure-feeding member.

[0023] A housing can be provided to house all of the expansion member, the electric power generating member and the refrigerant pressure-feeding member. Furthermore, the low-pressure port can be arranged above the refrigerant suction port. For example, the expansion member having the low-pressure port is arranged above the electric power generating member, and the refrigerant pressure-feeding member having the refrigerant suction port is arranged below the electric power generating member. Furthermore, the communication part can separate the oil from the vapor-phase refrigerant by gravity by the use of a difference in specific gravity between the vapor-phase refrigerant and the oil and includes an oil storing part for storing the separated oil, and the oil storing part is provided in the electric power generating member.

[0024] The communication part can be provided with a check valve for preventing the liquid-phase refrigerant from flowing back from the refrigerant suction port to the low-pressure port. In this case, the communication part has a throttle mechanism connected in series to the check valve, and the throttle mechanism has a refrigerant passage area smaller than a refrigerant passage area of the check valve.

[0025] Furthermore, a transmission part for transmitting driving power from the expansion member to the refrigerant pressure-feeding member can be provided. In this case, the refrigerant pressure-feeding member is operated by the driving power from the expansion member. For example, the transmission part is a one-way clutch that transmits the mechanical energy as the driving power from the expansion member only when the expansion member outputs the mechanical energy.

[0026] The expansion member can be a compression and expansion member that has a function of compressing refrigerant by driving power applied thereto, and the electric power generating member can be a driving and electric-power generating member that applies the driving power to the compression and expansion member. In this case, when the compression and expansion member compresses refrigerant, the low-pressure port sucks low-pressure vapor-phase refrigerant after being decompressed and the high-pressure port discharges high-pressure refrigerant before being decompressed.

[0027] According to another aspect of the present invention, a fluid machine includes: an expansion member having a function of outputting mechanical energy by expansion of refrigerant; a refrigerant pressure-feeding member for pressure-feeding refrigerant to the expansion member, the expansion member having a low-pressure port from which low-pressure vapor-phase refrigerant after being decompressed flows out and a high-pressure port from which high-pressure refrigerant after being decompressed flows in, and a communication part that introduces oil contained in refrigerant flowing out from the low-pressure port to a sliding part of the refrigerant pressure-feeding member. Therefore, the fluid machine can effectively lubricate mechanical sliding parts in the refrigerant pressure-feeding member.

[0028] According to another aspect of the present invention, a vapor compression type refrigerator combined with a Rankine cycle includes: a compression and expansion member that has a function of compressing and discharging refrigerant by driving power applied thereto and a function of outputting mechanical energy by expansion of refrigerant, the compression and expansion member having a low-pressure port from which low-pressure refrigerant after being decompressed is sucked and flows out and a high-pressure port from which high-pressure refrigerant before being decompressed is discharged and flows in; a driving and electric-power generating member that has a function of applying the driving power to the compression and expansion member and a function of generating electric power by the mechanical energy; a refrigerant pressure-feeding member that pressure-feeds refrigerant to the compression and expansion member, the refrigerant pressure-feeding member having a refrigerant suction port from which liquid-phase refrigerant is sucked and a refrigerant discharge port from which liquid-phase refrigerant is discharged; and a communication part that makes the low-pressure port communicate with the refrigerant suction port. Furthermore, the communication part separates lubricating oil from the vapor-phase refrigerant and supplying the lubricating oil to the refrigerant suction port. Accordingly, mechanical sliding parts in the refrigerant pressure-feeding member can be effectively lubricated.

[0029] According to another aspect of the present invention, a vapor compression type refrigerator combined with a Rankine cycle, includes: a compression and expansion member that has a function of compressing and discharging refrigerant by driving power applied thereto and a function of outputting mechanical energy by expansion of refrigerant; a driving and electric-power generating member that has a function of applying the driving power to the compression and expansion member and a function of generating electric power by the mechanical energy; a refrigerant pressure-feeding member that pressure-feeds refrigerant to the compression and expansion member; a first communicating part through which a refrigerant suction side of the refrigerant pressure-feeding member communicates with a mechanical sliding portion of the refrigerant pressure-feeding member; and a second communication part that makes the low-pressure port communicate with the mechanical sliding portion. In addition, the second communication part separates lubricating oil from the vapor-phase refrigerant and supplying the lubricating oil to the mechanical sliding portion. Accordingly, the mechanical sliding portion of the refrigerant pressure-feeding member can be effectively and sufficiently lubricated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Additional objects and advantages of the present invention will be more readily apparent from the following detailed description of preferred embodiments when taken together with the accompanying drawings.

[0031] **FIG. 1** is a cross-sectional view showing a refrigerant pump in a first embodiment of the present invention.

[0032] **FIG. 2** is a cross-sectional view showing a refrigerant pump in a second embodiment of the present invention.

[0033] **FIG. 3** is a cross-sectional view showing a small-diameter passage in a third embodiment of the present invention.

[0034] **FIG. 4** is a cross-sectional view showing a small-diameter passage in a fourth embodiment of the present invention.

[0035] **FIG. 5** is a cross-sectional view showing a refrigerant pump in a fifth embodiment of the present invention.

[0036] **FIG. 6** is a cross-sectional view showing a refrigerant pump in a sixth embodiment of the present invention.

[0037] **FIG. 7** is a cross-sectional view taken on a line VII-VII in **FIG. 6**.

[0038] **FIG. 8** is a cross-sectional view showing a refrigerant pump in a seventh embodiment of the present invention.

[0039] **FIG. 9** is a cross-sectional view taken on a line IX-IX in **FIG. 8**.

[0040] **FIG. 10** is a cross-sectional view taken on a line X-X in **FIG. 9**.

[0041] **FIG. 11** is a schematic diagram showing an entire cycle construction of the eighth embodiment.

[0042] **FIG. 12** is a cross-sectional view of a fluid machine integrated with an expander of the eighth embodiment.

[0043] **FIG. 13** is a schematic sectional view showing a communication means of the eighth embodiment.

[0044] **FIG. 14** is a cross-sectional view of a fluid machine integrated with an expander of a ninth embodiment.

[0045] **FIG. 15** is a cross-sectional view of a fluid machine integrated with an expander of a tenth embodiment.

[0046] **FIG. 16** is a schematic sectional view showing a communication means of the tenth embodiment.

[0047] **FIG. 17** is a schematic diagram showing an entire cycle construction of an eleventh embodiment.

[0048] **FIG. 18** is a schematic diagram showing an entire cycle construction of a twelfth embodiment.

[0049] **FIG. 19** is a cross-sectional view of a fluid machine of a thirteenth embodiment.

[0050] **FIG. 20** is a cross-sectional view taken on the line XX-XX in **FIG. 19**.

[0051] **FIG. 21** is a cross-sectional view taken on the line XXI-XXI in **FIG. 20**.

[0052] **FIG. 22** is a schematic diagram showing the direction of flow of refrigerant in a refrigerant cycle of a conventional example.

[0053] **FIG. 23** is a schematic diagram showing the direction of another flow of refrigerant in a refrigerant cycle of the conventional example.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

[0054] In this embodiment, a fluid pump in accordance with the present invention is typically used for a refrigerant pump **100** for pressure-feeding liquid refrigerant (corresponding to fluid in the present invention) in a Rankine cycle. Hereinafter, the basic construction of the refrigerant pump **100** will be descried by the use of **FIG. 1**. The Rankine cycle is a cycle that includes a refrigerant pump **100**, a heater, an expander, and a condenser, which are connected to each other in the shape of a cycle. The Rankine cycle feeds liquid refrigerant from the refrigerant pump **100** to the heater and heats the liquid refrigerant by, for example, the waste heat of an internal combustion engine for a vehicle to produce superheated vapor and feeds the superheated vapor into the expander and recycles mechanical energy produced by the expansion of the refrigerant.

[0055] The refrigerant pump **100** in this embodiment is an electrically driven scroll type refrigerant pump that uses scrolls **112**, **113** in a pump part **110** and has the pump part **110** driven by a motor part **120**. The liquid refrigerant pressure-fed by the refrigerant pump **100** contains lubricating oil of order of several % for lubricating transmission parts such as bearing **114***d* to be described later.

[0056] The pump part **110** is constructed of a fixed scroll (corresponding to a fixed part in the present invention) **112** fixed to a pump housing **111**, a movable scroll (corresponding to a movable part in the present invention) **113** that revolves and shifts in position opposite to this fixed scroll **112**, a pump shaft (corresponding to a driving part in the present invention) **114** for driving the movable scroll **113**, and the like.

[0057] The fixed scroll **112** is constructed of a plate-shaped base plate portion **112***a* and a spiral tooth portion (corresponding to a second wall part in the present invention) **112***b* protruding from the base plate portions **112***a* to the movable scroll **113**. Meanwhile, the movable scroll **113** is constructed of a spiral tooth portion (corresponding to a first wall part in the present invention) **113***b*, which is in contact with and is engaged with the tooth portion **112***b*, and a base plate portion **113***a* having this tooth portion **113***b* formed thereon. The movable scroll **113** revolves in a state where both tooth portions **112***b*, **113***b* are in contact with each other to shift the position of an operating chamber V formed by both the scrolls **112**, **113**. The fixed scroll **112** has a discharge port **112***c*, which communicates with the operating chamber V and is connected to the heater (not shown), formed in the center of the base plate portion **112***a*.

[0058] The pump shaft **114** is a crankshaft having an eccentric portion **114***a* formed eccentrically with respect to a rotational central axis at one end in a direction of length and is rotatably supported by the bearing **114***b* fixed to the pump housing **111**. A bushing **114***c* is mounted on this eccentric portion **114***a* in such a way to swing with respect to the eccentric portion **114***a* (driven crank mechanism). This bushing **114***c* is coupled to the movable scroll **113** via the bearing (corresponding to a transmission part in the present invention) **114***d*. A side opposite to the eccentric portion of the pump shaft **114** is connected to the motor shaft **121** of the motor part **120**. The bearing **114***d* is a transmission part for transmitting a driving force to the pump mechanism and is a part including portion to be lubricated such as a sliding portion, a rolling portion or a friction portion.

[0059] A plate-shaped race **115***a* and a plate-shaped retainer **115***b* are fixed in layers to each of a surface on a side opposite to the fixed scroll of the movable scroll **113** and a surface of the pump housing **111**, which is opposite to this surface, by bolts **115***d*. Balls **115***e* are interposed between tapered holes formed in each retainer **115***b*. This construction forms a rotation preventing mechanism **115**. The rotation preventing mechanism **115** prevents the movable scroll **113** from rotating while the pump shaft **114** rotates one rotation and causes the movable scroll **113** to revolve around the rotational center of the pump shaft **114**.

[0060] In this embodiment, a small-diameter passage **113***c* (corresponding to an introduction passage in the present invention) for making the operating chamber V communicate with the bearing **114***d* at a specified pressure loss is formed in the central portion of the movable scroll **113**. Here, as to the size of the small-diameter passage **113***c*, its inside diameter "d" and length "L" (thickness of the movable scroll **113**) are set at 0.1 mm and 6 mm, respectively, so as to prevent a large amount of liquid refrigerant from flowing from the operating chamber V to the bearing **114***d* and to be able to be formed by actual machining (mechanical machining or electric discharge machining).

[0061] The amount of liquid refrigerant G pressure-fed by the refrigerant pump **100** is set at 230 kg/h and the validity of the flow rate AG (kg/h) of the liquid refrigerant flowing through the small-diameter passage **113***c* is checked by the following mathematical equation 1 (Hagen-Poiseuille's Equation).

$$\Delta G=(\pi/8\mu)\times(\Delta P/L)\times(d/2)^4\times\rho\times3600 \quad \text{(Mathematical equation 1)}$$

where μ is viscosity of liquid refrigerant (Pa), ΔP is a pressure difference (MPa) of liquid refrigerant applied to small-diameter passage **113***c*, and ρ is density of liquid refrigerant (kg/m^3)

[0062] Specifically, when it is assumed that d=0.1, L=6, $\mu=2\times10^{-4}$, $\Delta P=2\times10^6$, and $\rho=1100$, the flow rate ΔG of liquid refrigerant becomes 16 kg/h and is a level of 7% with respect to the amount of pressure-fed liquid refrigerant G (230 kg/h).

[0063] An open end on a side opposite to the operating chamber V of the small-diameter passage **113***c* is open to the end surface of the eccentric portion **114***a*. The cylindrical bushing **114***c* is supported by the outside surface in the radial direction of the eccentric portion **114***a*. The end surface of the eccentric portion **114***a* and the end surface of the bushing

114*c* are opposite to the base plate portion **113***a* of the movable scroll **113** and a disk-shaped space is partitioned between them. The end portion of the movable scroll **113** side of the bearing **114***d* is so positioned as to directly face the outside in the radial direction of this disk-shaped space. The movable scroll **113** has a cylindrical holding portion that is formed in a protruding manner and holds the bearing **114***d* inside. The disk-shaped space communicates with a space partitioned outside in the radial direction of the holding portion through a space in the bearing **114***d* or a space between the eccentric portion **114***a* and the bushing **114***b*. The rotation preventing mechanism **115** is arranged outside in the radial direction of this holding portion. In this construction, the small-diameter passage **113***c* communicates with the disk-shaped space and this space reaches directly to the bearing **114***d*. As a result, a passage is formed which passes through the small-diameter passage **113***c* and reaches the bearing **114***d* arranged on the back of the movable scroll **113**.

[0064] Next, operation based on the above-described construction and operation effect will be described. When the pump shaft **114** is rotated by the operation of the motor part **120**, the movable scroll **113** is made to revolve, the operating chamber V is displaced in such a way as to move from the outside diameter side of the movable scroll **113** to the center side. The liquid refrigerant, which is discharged from the condenser and flows into from a suction port (not shown), passes through the operating chamber V and is discharged from a discharge port **112***c* and is pressure-fed to the heater.

[0065] In this embodiment, the movable scroll **113** has the small-diameter passage **113***c* formed therein and hence a portion (corresponding to approximately 7% described above) of pressure-fed liquid refrigerant is positively introduced from the operating chamber V to the side of the bearing **114***d* according to a pressure difference. Hence, by a simple structure that only the small-diameter passage **113***c* is formed in the movable scroll **113**, the bearing **114***d* can be cooled and lubricated by lubricating oil contained in the liquid refrigerant to improve the reliability of the refrigerant pump **100**. Conversely, when the reliability of the refrigerant pump **100** is maintained at the same level, the refrigerant pump **100** can be produced at lower cost. For example, it is possible to eliminate the need of selecting an expensive material for the bearing **114***d*, or performing surface treatment or heat treatment to the bearing **114***d*. Here, because fluid to be used is liquid (liquid refrigerant), unlike the case of gas, the small-diameter passage **113***c* can be formed in a size (in particular, inside diameter d relating to the cross-sectional area of passage) that can be actually machined without being significantly affected by the amount of pressure-feed of liquid refrigerant and can produce the above-described effect.

Second Embodiment

[0066] The second embodiment in accordance with the present invention is shown in **FIG. 2**. The second embodiment is provided with a closed backpressure chamber **116** as compared with the above-described first embodiment.

[0067] Here, a sealing member **116***a* is interposed between the movable scroll **113** and the pump housing **111** and another sealing member (not shown) is interposed between the pump shaft **114** (or a motor shaft **121**) and the pump housing **111** to form the closed back-pressure chamber **116** on a side opposite to the fixed scroll of the movable scroll **113**.

[0068] With this, the bearing **114***d* can be lubricated by the liquid refrigerant introduced from the operating chamber V through the small-diameter passage **113***c* and a back pressure (pressure applied to the fixed scroll **112**) can be applied to the movable scroll **113**. Hence, the thrust clearance between the movable scroll **113** and the fixed scroll **112** can be adjusted, which results in making it possible to eliminate the need for providing a specifically designed adjustment function. Since a pressure difference applied to the front and the back of the movable scroll **113** can be reduced, the set strength (for example, set thickness) of the movable scroll **113** can be decreased and hence the movable scroll **113** can be reduced in weight and cost. In the second embodiment, the other parts can be made similarly to the above-described first embodiment.

Third Embodiment

[0069] The third embodiment in accordance with the present invention is shown in **FIG. 3**. In the third embodiment, the shape of the small-diameter passage **113***c* is changed as compared with the above-described first embodiment. That is, an opening of the small-diameter passage **113***c* on the side of the operating chamber V has a tapered portion **113***d*. The tapered portion **113***d* provides the small-diameter passage **113***c* with an opening. In the small-diameter passage **113***c*, its most part is formed as a circular main portion having a specified small diameter and an opening is formed as the tapered portion in a tapered shape. In the tapered portion **113***d*, the inside diameter of the small-diameter passage **113***c* is gradually enlarged toward the operating chamber V. The tapered portion **113***d* provides a circular opening having a diameter larger than the inside diameter of the small-diameter passage **113***c* at the wall surface on the operating chamber V side of the base plate portion **113***a* of the movable scroll **113**. The tapered portion **113***d* provides a wall surface shaped like a funnel that uniformly converges from the wall surface on the operating chamber V side of the base plate portion **113***a* of the movable scroll **113** to the main portion of the small-diameter passage **113***c*.

[0070] These shapes enable the liquid refrigerant to flow smoothly and to smooth the flow of the liquid refrigerant introduced into the bearing **114***d*. In the third embodiment, the other parts can be made similarly to the above-described first embodiment or the second embodiment.

Fourth Embodiment

[0071] The fourth embodiment in accordance with the present invention is shown in **FIG. 4**. In the fourth embodiment, a portion where the small-diameter passage **113***c* is formed is formed of a member separate from the movable scroll **113** as compared with the above-described first embodiment. That is, this separate member is previously formed as an orifice member **113***e* having the small-diameter passage **113***c* and this orifice member **113***e* is fixed in the central portion of the base plate portion **113***a* of the movable scroll **113** by press-in or the like.

[0072] Accordingly, it possible to form the small-diameter passage **113***c* in the state of orifice member **113***e* separated from the movable scroll **113** and hence to form the small-diameter passage **113**c with ease. In the fourth embodiment, the other parts can be made similarly to the above-described first embodiment.

Fifth Embodiment

[0073] The fifth embodiment in accordance with the present invention is shown in **FIG. 5**. In the fifth embodiment, an introduction passage is formed outside the refrigerant pump **100** as compared with the above-described first embodiment. That is, a return passage **131** communicating with the bearing **114**d is formed in a discharge side passage **130** connected from the discharge port **112**c to the heater and a throttle portion **132** corresponding to the small-diameter passage **113**c is formed in the middle of this return passage **131**.

[0074] Accordingly, it possible to introduce a part of liquid refrigerant discharged from the discharge port **112**c into the bearing **114**d through the throttle portion **132** and to produce the same effect as the first embodiment.

Sixth Embodiment

[0075] The sixth embodiment in accordance with the present invention is shown in **FIG. 6** and **FIG. 7**. In the sixth embodiment, the present invention is applied to a rotary vane type refrigerant pump **100**A.

[0076] A pump part **110**A of the rotary vane type refrigerant pump **100**A includes a pump housing **111**A, a cylinder housing **117**, a pump housing **111**B, a cylinder housing **117**, a cylinder **117**a and a rotor **118** formed in an end housing **119**, which are connected to each other in sequence. Here, the pump part **110**A is a two-cylinder pump provided with two cylinders **117**a and two rotors **118**. The end housing **119** has a suction port **119**a from which the liquid refrigerant is sucked, and a discharge port **119**b from which the liquid refrigerant flows out from the operating chamber V.

[0077] The cylinder **117**a is formed in a circular cross section in the central portion of the cylinder housing **117**. The cylinder housing **117** corresponds to a fixed part in the present invention. The pump shaft **114**A has a circular cam part **114**e, which is eccentric with respect to the pump shaft **114**A, formed thereon, and a flat cylindrical rotor **118** is fitted on the outer peripheral side of this cam part **114**e via a bearing **114**D (corresponding to a transmission part in the present invention). The rotor **118** corresponds to a movable part in the present invention. The rotor **118** has an outside diameter set smaller than the inside diameter of the cylinder **117**a and is inserted into the cylinder **117**a such that the rotor **118** revolves in the cylinder **117**a by the cam part **114**e. A vane **118**a, which can slide in the radial direction of the rotor **118** and is pressed toward the center to thereby abut against the rotor **118**, is put in the outer peripheral portion of the rotor **118**. A space surrounded by the rotor **118** and the vane **118**a is formed as the operating chamber V in the cylinder **117**a.

[0078] In the cylinder housing **117**, a refrigerant inlet **117**b and a refrigerant outlet **117**c that communicate with the inside of the cylinder **117**a are formed close to the vane **118**a in such a way as to sandwich this vane **118**a. The refrigerant inlet **117**b is connected to the suction port **119**a by a passage (not shown) and the refrigerant outlet **117**c is connected to the discharge port **119**b by a passage (not shown).

[0079] In this embodiment, the small-diameter passages **113**c (e.g., two) each passing through the rotor **118** are formed at a first position between the refrigerant outlet **117**c of the rotor **118** and the vane **118**a and a second position opposite to the first position. For example, the two small-diameter passages **113**c are formed at positions opposite to each other across the center of the rotor **118**, respectively. An outside opening end in the radial direction of the small-diameter passage **113**c is open to the outer peripheral surface of the rotor **118** and an inside opening end in the radial direction of the small-diameter passage **113**c is open to the inner peripheral surface of the rotor **118**. The bearing **114**D is located in a space between the rotor **118** and the cam part **114**e in the rotor **118**. The small-diameter passage **113**c communicates with the space between the rotor **118** and the cam part **114**e.

[0080] In this refrigerant pump **100**A, the liquid refrigerant flows from the suction port **119**a and the refrigerant inlet **117**b into the operating chamber V and flows out from the refrigerant outlet **117**c and the discharge port **119**b by the revolving operation of the rotor **118**. A part of liquid refrigerant in the operating chamber V is introduced from the small-diameter passage **113**c into the bearing **114**D. Hence, just as with the first embodiment, it is possible to have a lubricating effect on the bearing **114**D and to improve the reliability of the refrigerant pump **100**A.

[0081] In this embodiment, the liquid refrigerant is introduced so as to lubricate the bearing **114**D. When the refrigerant is dispersedly mixed with lubricating oil, a higher lubricating operation can be expected. An open type bearing in which parts to be lubricated such as ball, roller, rolling surface, sliding surface are not enclosed can be used as the bearing **114**D. For example, when an open type sliding bearing is used, the liquid refrigerant according to a pressure difference can be supplied to parts to be lubricated such as sliding part, rolling part, and friction part of the bearing **114**D through the small-diameter passages **113**c formed in the rotor **118**. In order to surely lubricate parts such as balls received between the inner ring and the outer ring of the bearing **114**D, a through hole or a groove as a passage may be formed in bearing parts such as inner ring, outer ring, and cover. For example, a passage communicating with a hole made in the rotor **118** can be formed in the outer ring.

Seventh Embodiment

[0082] The seventh embodiment in accordance with the present invention is shown in **FIG. 8** to **FIG. 10**. In the seventh embodiment, the small-diameter passages **113**c are changed to grooves **113**f as compared with the sixth embodiment.

[0083] The groove **113**f is a groove (see **FIG. 10**) that is formed in the end surface in the axial direction of the rotor **118** (for example, end surface on the right side of each rotor **118**) and is circular in cross section. The groove **113**f is formed in such a way as to be straight in a longitudinal direction from the outer peripheral surface of the rotor **118** to the inner peripheral surface (see **FIG. 9**). Here, two grooves **113**f are formed at positions opposite to each other across the center of the rotor **118**, respectively, in such a way as to oppose each other in the end surface in the axial direction of the rotor **118**.

[0084] The above-described grooves **113**f forms introduction passages each having a lunate cross section between the rotor **118** and the pump housing **119** on the right side in **FIG. 8** and between the rotor **118** and the pump housing **111**B on the left side in **FIG. 8** and causes the operating chamber V to communicate with the bearing **114**D.

[**0085**] This introduction passage (groove **113***f*) having a lunate cross section (arc section), just as with the above-described sixth embodiment, can introduce a part of liquid refrigerant from the operating chamber V to the bearing **114**D and hence can produce an lubricating effect to the bearing **114**D. Here, the introduction passage can be formed by forming the groove **113***f* in the rotor **118** and hence can be easily formed as compared with the case of forming the small-diameter passage **113***c* as described in the sixth embodiment.

[**0086**] As to the cross-sectional shape of the groove **113***f*, the groove **113***f* is preferably formed in the shape described in **FIG. 9** and **FIG. 10**, but the groove **113***f* is not necessarily formed in a circular shape but may be formed in a polygonal shape. Moreover, as to the longitudinal shape, the groove **113***f* may be formed in a curved shape or in a circular shape. Furthermore, as to the number of grooves **113***f*, one groove **113***f* may be formed in the end surface in the axial direction of the rotor **118** and three or more grooves **13***f* may be formed. In addition, the groove **113***f* is formed not only in one surface of end surfaces in the axial direction of the rotor **118** (surface on the right side in **FIG. 8**) but also in both surfaces. As a result, the lubricating effect can be further enhanced.

Eight Embodiment

[**0087**] **FIG. 11** is a diagram showing an entire cycle construction of a vapor compression type refrigerator for a vehicle in accordance with the eighth embodiment of the present invention. The vapor compression type refrigerator for a vehicle of this embodiment is a refrigerator combined with a Rankin cycle that produces cold and heat to air-condition a vehicle compartment and recovers thermal energy from waste heat produced in an engine **201**.

[**0088**] First, a fluid machine **202** integrated with an expander is a fluid machine that is mounted in a vehicle engine room and is constructed of a compression and expansion part **203**, a driving and electric-power generating part **204**, a refrigerant pump **205**, and an oil supply passage **206**. The compression and expansion part **203**, the driving and electric-power generating part **204**, and the refrigerant pump **205** are combined into an integral structure and the fluid machine **202** integrated with an expander is formed in the shape of a cylinder in its entirety.

[**0089**] The compression and expansion part **203** is a compression and expansion means having: both of the function of a compressor for compressing and discharging refrigerant by a driving power applied thereto at the time of air-conditioning a vehicle compartment (hereinafter referred to as a compressor mode); and the function of outputting mechanical energy by the expansion of the refrigerant at the time of recovering thermal energy (hereinafter referred to as an expander mode). The compression and expansion part **203** has a low-pressure port **203***a* from which low-pressure vapor-phase refrigerant is sucked and a high-pressure port **203***b* from which high-pressure refrigerant is discharged and flows in.

[**0090**] The driving and electric-power generating part **204** is driving and electric-power generating means having both of the function of providing the compression and expansion part **203** with a driving force at the time of air-conditioning the vehicle compartment and the function of generating electric power by the mechanical energy outputted by the compression and expansion part **203** at the time of recovering thermal energy.

[**0091**] The refrigerant pump **205** is refrigerant pressure-feeding means for pressure-feeding liquid-phase refrigerant to the compression and expansion part **203** at the time of recovering thermal energy. The refrigerant pump **205** has a refrigerant suction port **205***a* from which liquid-phase refrigerant is sucked and a refrigerant discharge port **205***b* from which the liquid-phase refrigerant is discharged.

[**0092**] The oil supply passage **206** is communication means for causing the low-pressure port **203***a* to communicate with the refrigerant suction port **205***a*. The oil supply passage **206** is provided with an oil storing chamber **206***a* for separating lubricating oil from the vapor-phase refrigerant and for storing the lubricating oil, and a check valve **206***c* for allowing the oil flow from the low-pressure port **203***a* only to the refrigerant suction port **205***a*. The detailed descriptions of the other parts of the fluid machine **202** integrated with an expander will be provided.

[**0093**] Next, a radiator **207** radiates the heat of the refrigerant to cool the refrigerant, and the refrigerant inlet of the radiator **207** is connected to the high-pressure port **203***b* of the fluid machine **202** integrated with an expander by a refrigerant piping **208**.

[**0094**] A vapor-liquid separator **209** is a receiver that is connected to the refrigerant outlet of the radiator **207** and separates the refrigerant flowing out from the radiator **207** into vapor-phase refrigerant and liquid-phase refrigerant. Moreover, the vapor-liquid separator **209** is connected also to the refrigerant suction port **205***a* by a first bypass passage **210**.

[**0095**] The first bypass passage **210** is refrigerant piping for supplying the liquid-phase refrigerant separated by the vapor-liquid separator **209** to the refrigerant pump **205**. The first bypass passage **210** is provided with a check valve **210***a* for allowing the refrigerant to flow from the vapor-liquid separator **209** only to the refrigerant pump **205**. Moreover, the refrigerant supplied to the refrigerant pump **205** is discharged from the refrigerant discharge port **205***b*, and the refrigerant discharge port **205***b* is connected to the refrigerant piping **208**.

[**0096**] An expansion valve **211** is connected to the liquid-phase refrigerant outlet of the vapor-liquid separator **209** and reduces the pressure of the separated liquid-phase refrigerant to expand the refrigerant. This embodiment employs a temperature type expansion valve that reduces the pressure of the refrigerant isoenthalpically and controls a throttle opening in such a way that the degree of superheat of the refrigerant sucked into the low-pressure port **203***a* of the fluid machine **202** integrated with an expander in the compressor mode approaches a specified value.

[**0097**] An evaporator **212** is a heat absorber that is connected to the expansion valve **211** and evaporates the refrigerant having its pressure reduced by the expansion valve **211** to effect a heat absorption action. The refrigerant outlet of the evaporator **212** is connected to the low-pressure port **203***a* of the fluid machine **202** integrated with an expander. Refrigerant piping for connecting the evaporator **212** and the fluid machine **202** integrated with an expander is provided with a check valve **212***a*, and the check valve **212***a* allows the refrigerant to flow from the refrigerant outlet of the evaporator **212** only to the low-pressure port **203***a*.

[**0098**] A heater **213** is a heat exchanger that is interposed between the high-pressure port **203***b* of the refrigerant piping **208** and the connection portion of the refrigerant discharge port **205***b* and exchanges heat between the refrigerant flowing through the refrigerant piping **208** and engine cooling water (hot water) to thereby heat the refrigerant.

[**0099**] Here, the engine cooling water is circulated through a hot water circuit **214** shown by a broken line in **FIG. 11** so as to cool the engine **201**. A water pump **215** of the hot water circuit **214** is an electrically driven pump for circulating the engine cooling water. A three-way valve **216** is an electromagnetic valve for switching between a circuit for introducing the engine cooling water flowing out from the engine **201** into the heater **213** and a circuit for not introducing the engine cooling water into the heater **213** but causing the engine cooling water to bypass the heater **213**. Moreover, a radiator **217** is a heat exchanger that exchanges heat between the engine cooling water and the outside air to thereby cool the engine cooling water.

[**0100**] An open/close valve **218** is provided between the connection portion of the refrigerant discharge port **205***b* to the refrigerant piping **208** and the radiator **207**, and is an electromagnetic valve that opens/closes the refrigerant piping **208**. A control valve **219** is interposed between the high-pressure port **203***b* of the refrigerant piping **208** and the heater **213**, and is an electromagnetic valve that functions as a discharge valve, that is, a check valve for allowing the refrigerant to flow from the high-pressure port **203***b* only to the heater **213** in the compressor mode and is brought into a valve opening state in the expander mode.

[**0101**] A second bypass passage **220** is refrigerant piping for connecting the low-pressure port **203***a* of the fluid machine **202** integrated with an expander and the refrigerant inlet of the radiator **207**. The second bypass passage **220** is provided with a check valve **220***a* for allowing the refrigerant to flow from the low-pressure port **203***a* only to the radiator **207**.

[**0102**] A control unit **221** performs, according to the operating mode of the fluid machine **202** integrated with an expander, the control of: supplying electric power to a driving and electric-power generating part **204**; connecting the driving and electric-power generating part **204** to an electric power storage battery **222**; switching the three-way valve **216**; the open/close valve **218**; and the control valve **219**.

[**0103**] Next, the detail of the fluid machine **202** integrated with an expander will be described with reference to the cross-sectional view in **FIG. 12**. Arrows shown in the drawing indicate an up and down direction (vertical direction) when the fluid machine **202** integrated with an expander is mounted in a vehicle engine room.

[**0104**] First, the compression and expansion part **203** will be now described. The compression and expansion part **203** is arranged on the uppermost portion of the fluid machine **202** integrated with an expander and is provided with a mechanism for compressing and expanding the refrigerant. This compression and expansion mechanism can be made to a structure similarly to the publicly known scroll type compression mechanism.

[**0105**] Specifically, the compression and expansion part **203** includes: an upper housing **301**; a middle housing **302**; a shaft **303**; a fixed scroll (shell) **304** of a fixed part that is formed integrally with the upper housing **301**; a revolving scroll **305** of a movable part that revolves and shifts in position in a space between the middle housing **302** and the fixed scroll **304**; an operating chamber **306** of a space which is formed between the fixed scroll **304** and the revolving scroll **305** and in which the refrigerant is compressed and expanded; a low-pressure port **203***a* which communicates with the operating chamber **306** and from which the refrigerant is sucked and flows out; a high-pressure port **203***b* which communicates with the operating chamber **306** and from which the refrigerant is discharged and flows in; and the like.

[**0106**] The upper housing **301** and the middle housing **302** act as protecting members for protecting the compression and expansion part **203**. The upper housing **301** is integrally constructed of the fixed scroll **304**, and have the high-pressure port **203***b* and the low-pressure port **203***a*. The upper housing **301** and the middle housing **302** are coupled to each other by screws via a sealing member such as gasket and O-ring (not shown) and are adapted to prevent the refrigerant from leaking from a joined portion.

[**0107**] The shaft **303** is a crankshaft supported by the middle housing **302** via a ball bearing **307** and provided with an eccentric part **308** that is eccentric with respect to the rotational central axis to an upper end side in the axial direction. The eccentric part **308** has the revolving scroll **305** rotatably coupled thereto via a needle bearing **309**.

[**0108**] The fixed scroll **304** is constructed of a plate-shaped base plate portion **304** and a spiral tooth portion **304***b* protruding from the base plate portion **304***a* toward the middle housing **302** (in the down direction). Meanwhile, the revolving scroll **305** (movable scroll) is constructed of a spiral tooth portion **305***b*, which is in contact with and is engaged with the tooth portion **304***b* of the fixed scroll **304**, and a base plate portion **305***a* having the tooth portion **305***b* formed thereon.

[**0109**] Further, a rotation preventing mechanism (not shown) is interposed between the revolving scroll **305** and the middle housing **302**. The rotation preventing mechanism causes the revolving scroll **305** to revolve around the eccentric portion **308** one revolution while the shaft **303** rotates one rotation. When the shaft **303** rotates, the revolving scroll **305** does not rotate but revolves around the rotational central axis of the shaft **303**. In this embodiment, a pin-ring (pin-hole) type mechanism is employed as the rotation preventing mechanism.

[**0110**] The low-pressure port **203***a* is an inlet/outlet of the low-pressure refrigerant formed in the outer peripheral portion of the upper housing **301** and communicates with the outermost diameter portion of the operating chamber **306**. The high-pressure port **203***b* is an inlet/outlet of the high-pressure refrigerant formed in the upper portion of the upper housing **301** and is formed at a position communicating with the operating chamber **306** in the state of the smallest volume.

[**0111**] Next, the driving and electric-power generating part **204** will be described. The driving and electric-power generating part **204** is arranged below the compression and expansion part **203** in the middle housing **302** and is provided with a mechanism for driving the compression and expansion part **203** and for generating electric power. This driving and electric power generating mechanism has the same structure as a publicly known direct current motor.

[**0112**] Specifically, the driving and electric-power generating part **204** is constructed of the middle housing **302**, the shaft **303**, a stator **401**, a rotor **402** rotating in the stator **401**, a coupling part housing **403** for supporting the shaft **303**, and the like.

[**0113**] The middle housing **302** and the coupling part housing **403** act as the protecting members of the driving and electric-power generating part **204**. The middle housing **302** and the coupling part housing **403** are coupled to each other by screws via sealing members such as gasket and O-ring and are adapted to prevent the refrigerant from leaking from a coupled portion between the middle housing **302** and the coupling part housing **403**. Moreover, the middle housing **302** and the shaft **303** are common to the constituent parts of the compression and expansion part **203** so as to reduce the size of the fluid machine.

[**0114**] The stator **401** is a stator coil having a winding wound thereon and is fixed to the inner wall surface of the middle housing **302**. The rotor **402** is a magnet rotor having a permanent magnet berried therein and has a key groove **404** formed on the inner peripheral side and is fixed to the shaft **303** by a key.

[**0115**] The coupling part housing **403** has a protrusion **403***a* protruding to the middle housing (in the upper direction) in the shape of a steeple head. An end portion opposite to (at the lower end in the axial direction of) the eccentric part **308** of the shaft **303** is supported by this protrusion **403***a* via a ball bearing **405**. A lip seal **406** for preventing the leakage of the refrigerant and oil between the driving and electric-power generating part **204** and the refrigerant pump **205** is interposed between the ball bearing **405** and the coupling part housing **403**.

[**0116**] A space, formed by the inner wall surface of the middle housing **302** and the wall surface on the protrusion **403***a* side of the coupling part housing **403**, forms a space in which the shaft **303**, the stator **401** and the rotor **402** are arranged and at the same time, forms an oil storing chamber **206***a* in a remaining space where these parts are not arranged. The oil storing chamber **206***a* is oil storing means for separating oil from the vapor-phase refrigerant and for storing the separated oil.

[**0117**] Furthermore, in the protrusion **403***a*, there is provided with a communication hole **206***b* for causing the oil storing chamber **206***a* to communicate with the refrigerant suction port **205***a* of the refrigerant pump **205**. In the communication hole **206***b*, a check valve **206***c* is provided to allow the oil to flow from the oil storing chamber **206***a* only to the refrigerant pump **205**. Moreover, an orifice **206***d* is formed on the downstream side of the check valve **206***c* in the direction of flow of the oil in the communication hole **206***b*. The orifice **206***d* is a throttle mechanism for adjusting the amount of oil supplied from the oil storing chamber **206***a* to the refrigerant pump **205** to an appropriate amount.

[**0118**] In this embodiment, the orifice **206***d* is formed on the downstream side of the check valve **206***c* in the direction of flow of oil but may be formed on the upstream side of the check valve **206***c*. In this embodiment, an orifice having a minimum opening diameter of 0.5 mm is used to realize the proper amount of oil supplied to the refrigerant pump **205**.

[**0119**] Next, the refrigerant pump **205** will be described. The refrigerant pump **205** is arranged on the most downstream portion of the fluid machine **202** integrated with an expander and is refrigerant pressure-feeding means provided with a mechanism for pressure-feeding the refrigerant. In this embodiment, the refrigerant pressure-feeding mechanism of the refrigerant pump **205** can have the same structure as the publicly known scroll type compression mechanism.

[**0120**] Specifically, the refrigerant pump **205** includes: a lower housing **501**, the coupling part housing **403**; the pump shaft **502**; a fixed scroll (shell) **503** that is a fixed part integral with the lower housing **501**; a revolving scroll **504** (movable scroll) that is a moving member revolving and shifting in position in a space between the coupling part housing **403** and the fixed scroll **503**; an operating chamber **505** that feeds the refrigerant in a space between the fixed scroll **503** and the revolving scroll **504**; a refrigerant suction port **205***a* which communicates with the operating chamber **505** and from which the refrigerant is sucked; a refrigerant discharge port **205***b* which communicates with the operating chamber **505** and from which the refrigerant is discharged; and the like.

[**0121**] The lower housing **501** and the coupling part housing **403** act as protecting members for protecting the refrigerant pump **205**. The lower housing **501** is integrally constructed of the fixed scroll **503**, and has the refrigerant discharge port **205***b* and the refrigerant suction port **205***a*. Moreover, the lower housing **501** and the coupling part housing **403** are coupled to each other by screws via sealing members such as gasket and O-ring to prevent the refrigerant from leaking from the coupled portion. In addition, the coupling part housing **403** is common to the constituent parts of the driving and electric-power generating part **204** so as to reduce the size of the fluid machine.

[**0122**] The pump shaft **502** is supported by the coupling part housing **403** via a ball bearing **506**. The pump shaft **502** is coupled to the shaft **303** by a one-way clutch **507**. The one-way clutch is power transmitting means that has the function of transmitting the rotational driving force of the shaft **303** to the pump shaft **502** only in the expander mode.

[**0123**] Moreover, the pump shaft **502** is a crankshaft having an eccentric part **508** that is eccentric with respect to the rotational central axis on the lower end side in the axial direction. The revolving scroll **504** is rotatably coupled to the eccentric part **508** via a needle bearing.

[**0124**] The fixed scroll **503** is constructed of a plate-shaped base plate part **503***a* and a spiral tooth part **503***b* that protrudes from the base plate part **503***a* toward the coupled part housing **403** (in the up direction). Meanwhile, the revolving scroll **504** is constructed of a spiral tooth part **504***b* that is contact with and is engaged with the tooth part **503***b* of the fixed scroll **503** and the base plate part **504***a* having the tooth part **504***b* formed thereon.

[0125] Moreover, a rotation preventing mechanism (not shown) is interposed between the revolving scroll **504** and the coupling part housing **403**. The rotation preventing mechanism causes the revolving scroll **504** to revolve around the eccentric part **508** one revolution while the pump shaft **502** rotates one rotation. When the pump shaft **502** rotates, the revolving scroll **504** does not rotate but revolves around the rotational central axis of the pump shaft **502**. The rotation preventing mechanism in this embodiment employs the same pin-ring (pin-hole) type mechanism as the compression and expansion part **203**.

[0126] The refrigerant suction port **205***a* is a suction port of the liquid-phase refrigerant made in the outer peripheral portion of the lower housing **501** and communicates with the outermost diameter portion of the operating chamber **505**. The refrigerant discharge port **205***b* is the discharge port of the refrigerant made in the lower portion of the lower housing **501** and is made at a position communicating with the operating chamber **505**.

[0127] Next, an oil supply passage **206** will be described. The oil supply passage **206**, as shown by the arrow in **FIG. 13**, is so constructed as to communicate in the order of: the low-pressure port **203***a*→the space between the middle housing **302** and the revolving scroll **305**→the space in the ball bearing **307**→the oil storing chamber **206***a*→the communication hole **206***b*→the space in the ball bearing **405**→ the space in the ball bearing **506**→the space between the coupling part housing **403** and the revolving scroll **504**→the refrigerant suction port **205***a*.

[0128] Next, the operation of the vapor compression type refrigerator in this embodiment will be described. First, in the compressor mode, the control unit **21** supplies the driving and electric-power generating part **204** with electric power and opens the open/close valve **218** and causes the control valve **219** to function as a check valve and switches the three-way valve **216** to the bypass passage of the heater **213**.

[0129] When the driving and electric-power generating part **204** is supplied with electric power, the shaft **303** coupled to the rotor **402** rotates to apply a rotational driving force to the compression and expansion part **203**. Here, in the compression and expansion part **203**, when the revolving scroll **305** revolves in one direction with respect to the fixed scroll **304**, the volume of the operating chamber **306** is decreased; and when the revolving scroll **305** revolves in a reverse direction, the volume of the operating chamber **306** is increased. Hence, the rotational direction of this rotational driving force becomes a direction to decrease the volume of the operating chamber **306** (hereinafter referred to as "compression direction"). Therefore, in the compressor mode, the refrigerant sucked from the low-pressure port **203***a* flows into the operating chamber **306** and is compressed in the operating chamber **306** and is discharged from the high-pressure port **203***b*.

[0130] Here, a part of vapor-phase refrigerant sucked from the low-pressure port **203***a* flows into the oil storing chamber **206***a* communicating with the low-pressure port **203***a*. Since the refrigerant is mixed with oil for lubricating the mechanical sliding parts, the oil also flows into the oil storing chamber **206***a* along with the vapor-phase refrigerant. Since this oil has a larger specific gravity than the vapor-phase refrigerant, the oil is separated from the vapor-phase refrigerant by the gravity and is moved below and is stored in the lowermost portion of the oil storing chamber **206***a*. A wavy line **407** in **FIG. 13** shows the level of oil stored at the time of a normal operation.

[0131] When the oil storing chamber **206***a* is filled with the oil and the oil level goes up as shown by a wavy line **407***a* in **FIG. 13**, the vapor-phase refrigerant is hard to flow into the oil storing chamber **206***a* and hence the oil is hard to separate, which results in being able to prevent the oil from being separated from the refrigerant more than necessary. Furthermore, the oil stored in the oil storing chamber **206***a* exists in the same space as the stator **401** and the rotor **402** and hence also produces the effect of cooling the driving and electric-power generating part **204**.

[0132] The refrigerant discharged from the high-pressure port **203***b* is pressure-fed to the radiator **207** through the control valve **219**, the heater **213**, and the open/close valve **218**. Here, in the compressor mode, the open/close valve **218** is opened and the three-way valve **216** is switched to the bypass passage of the heater **213** and hence the engine cooling water in the hot water circuit **214** bypasses the heater **213** and circulates in the order of: the water pump **215**→the engine **201**→the three-way valve **216**→the radiator **217**→ the water pump **215**. Hence, the refrigerant is not heated, and the heater **213** and the open/close valve **218** function only as refrigerant passages.

[0133] The refrigerant having heat radiated by the radiator **207** is separated into the vapor-phase refrigerant and the liquid-phase refrigerant by the vapor-liquid separator **209**. Here, in the compressor mode, the refrigerant pump **205** is not operated and hence the liquid-phase refrigerant in the vapor-liquid separator **209** is not sucked into the refrigerant pump **205**.

[0134] The liquid-phase refrigerant separated by the vapor-liquid separator **209** has pressure reduced by the expansion valve **211** and absorbs heat in the evaporator **212** and is sucked from the low-pressure port **203***a* of the fluid machine **202** integrated with an expander.

[0135] With this, in the compressor mode, the refrigerant can be circulated in the order of: the fluid machine **202** integrated with an expander→the radiator **207**→the vapor-liquid separator **209**→the expansion valve **211**→the evaporator **212**→the fluid machine **202** integrated with an expander. Hence, a vapor compression type refrigerator can be constructed, which moves heat absorbed by the evaporator **212** to the radiator **207** to thereby radiate the heat.

[0136] Here, the back pressure on the oil storing chamber **206***a* side is the same as the pressure at the low-pressure port **203***a* but the back pressure on the refrigerant suction port **205***a* side is higher than the pressure at the low-pressure port **203***a* because the refrigerant suction port **205***a* communicates with the vapor-liquid separator **209**. When this pressure difference makes the refrigerant in the vapor-liquid separator **209** flow reversely to the oil storing chamber **206***a* via the oil supply passage **206**, the high-pressure refrigerant is again sucked into the low-pressure port **203***a* to cause a reduction in the refrigeration capacity of the vapor compression type refrigerator. Hence, in this embodiment, the check valve **206***c* prevents the backflow of the refrigerant.

[0137] Next, in the expander mode, the control unit **221** connects the driving and electric-power generating part **204** to the power storage battery **222**, closes the open/close valve **218**, opens the control valve **219**, and switches the three-way valve **216** to the heater **213**.

[0138] When the three-way valve **216** is switched to the heater **213**, the engine cooling water in the hot water circuit **214** is circulated in the order of: the water pump **215**→the engine **201**→the heater **213**→the three-way valve **216**→the radiator **217**→the water pump **215**. Hence, the refrigerant in the heater **213** is heated by the waste heat of the engine **201**. The heated refrigerant flows out from the heater **213** to the high-pressure port **203***b* through the control valve **219** and flows from the high-pressure port **203***b* into the operating chamber **306** of the compression and expansion part **203**.

[0139] The refrigerant flowing into the operating chamber **306** is evaporated and expanded to expand the volume of the operating chamber **306** to thereby rotate the revolving scroll **305** and the shaft **303** in the direction for expanding the volume of the operating chamber **306** (hereinafter referred to as "expansion direction"). The expanded refrigerant flows out from the low-pressure port **203***a*.

[0140] This rotation rotates also the rotor **402** coupled to the shaft **303** to change the amount of magnetic flux passing through the coil of the stator **401** to thereby operate the driving and electric-power generating part **204** as a generator. The generated electric power is stored in the electric power storage battery **222** connected to the driving and electric-power generating part **204** via the control unit **221**. That is, the waste heat of the engine **201** expands the refrigerant. The expanded refrigerant causes the fluid machine **202** integrated with an expander to output mechanical energy. The mechanical energy is converted to electric energy by the driving and electric-power generating part **204**. In this manner, thermal energy is recovered.

[0141] Furthermore, a part of this mechanical energy is transmitted as the driving force of the refrigerant pump **205** to the pump shaft **502** via the one-way clutch **507**. Here, in the refrigerant pump **205**, when the pump shaft **502** rotates in the expansion direction, the revolving scroll **504** revolves with respect to the fixed scroll **503** and hence the operating chamber **505** moves from a position communicating with the refrigerant suction port **205***a* to the refrigerant discharge port **205***b*. Hence, in the expander mode, the liquid-phase refrigerant sucked from the refrigerant suction port **205***a* is pressure-fed from the refrigerant discharge port **205***b* to the heater **213** and the pressure-fed refrigerant is heated and expanded so that the compression and expansion part **203** can output more mechanical energy.

[0142] The compression rate of scroll type compression mechanism of the refrigerant pump **205** is one. Accordingly, even when the liquid-phase refrigerant is sucked into the operating chamber **505**, the liquid-phase refrigerant is not compressed so that the refrigerant pump **205** does not produce any operation trouble resulting from liquid compression. In the compressor mode, the driving force is not transmitted to the refrigerant pump **205** by the one-way clutch **507** and hence the refrigerant pump **205** is not operated.

[0143] Meanwhile, the refrigerant flowing out from the low-pressure port **203***a* passes through the second bypass passage **220** by the function of the check valve **212***a* and radiates heat by the radiator **207** and moves to the vapor-liquid separator **209**. Here, a part of refrigerant flowing out from the low-pressure port **203***a* flows into the oil storing chamber **206***a*. Accordingly, just as with the compressor mode, oil is separated and stored in the oil storing chamber **206***a*.

[0144] With this, in the expander mode, the refrigerant can be circulated in the order of: the refrigerant pump **205**→the heater **213**→the fluid machine **202** integrated with an expander→the second bypass passage **220**→the radiator **207**→the vapor-liquid separator **209**→the first bypass passage **210**→the refrigerant pump **205**. In this manner, when the refrigerant is expanded by heat absorbed in the heater **213**, mechanical energy can be produced by the fluid machine **202** integrated with an expander to thereby construct the Ranking cycle.

[0145] Here, the back pressure on the oil storing chamber **206***a* side is the same as the pressure at the low-pressure port **203***a*. The back pressure on the refrigerant suction port **205***a* side is made lower than the pressure at the low-pressure port **203***a* by a pressure loss caused when the refrigerant passes through the radiator **207** and the refrigerant piping and the negative pressure caused by suction of the refrigerant pump **205**.

[0146] By this pressure difference, the oil stored in the oil storing chamber **206***a* is supplied to the refrigerant suction port **205***a* of the refrigerant pump **205** via the oil supply passage **206**. This oil has a property easily dissolving in the liquid-phase refrigerant. However, because the distance from the refrigerant suction port **205***a* to the mechanical sliding parts is short and a sufficient amount of oil can be supplied to the mechanical sliding parts, the oil can reach to the mechanical sliding parts before the oil fully dissolves in the liquid-phase refrigerant. Therefore, the oil can sufficiently lubricate the mechanical sliding parts.

Ninth Embodiment

[0147] In the above-described eighth embodiment, the fluid machine **202** integrated with an expander has been described in which the check valve **206***c* and the orifice **206***d* are set in the communication hole **206***b* of the lubricating oil. In this embodiment, however, as shown by cross-sectional view in **FIG. 14**, only the orifice **206***d* is formed in the communication hole **206***b* but the check valve **206***c* is not set. The other construction is the same as in the eighth embodiment.

[0148] When the fluid machine **202** integrated with an expander is operated in the compressor mode, the refrigerant flows back to the oil storing chamber **206***a* via the communication hole **206***b* by the pressure difference between the back pressure on the oil storing chamber **206***a* side and the back pressure on the suction port **205***a* side. However, a reduction in the refrigeration capacity of the vapor compression type refrigerator caused by this backflow can be allowed when the reduction is as small as a degree not to degrade the air-conditioning function for the vehicle.

[0149] Hence, the passage resistance of the oil supply passage **206** is adjusted by the orifice **206***d*, spaces in the ball bearings **405** and **506**, and the space between the coupling part housing **403** and the revolving scroll **504**, which construct the oil supply passage **206**, to make the determination of the amount of supply of the oil be compatible with the limitation of amount of backflow of the refrigerant. This can produce the same effect as the eighth embodiment even when the check valve **206***c* is not set.

Tenth Embodiment

[**0150**] In the eighth and ninth embodiments, the communication hole **206***b* is made in the coupling part housing **403** to construct the oil supply passage **206**. In this embodiment, however, in place of the oil supply passage **206**, as shown by the cross-sectional view in **FIG. 15**, a communication hole **261***b* having an orifice **261***d* is formed in the lower end side of the shaft **303** to construct the oil supply passage **261**. The other construction is the same as that in the ninth embodiment.

[**0151**] Even when the communication hole **261** b is formed in the lower end side of the shaft **303**, there is produced the same effect as the ninth embodiment. Furthermore, the oil supply passage **261**, as shown by arrow in **FIG. 16**, is so constructed as to communicate in the order of: the low-pressure port **203***a*→the space between the middle housing **302** and the revolving scroll **305**→the space in the ball bearing **307**→the oil storing chamber **206***a*→the communication hole **261***b*→the space in the one-way-clutch **507**→the space in the ball bearing **506**→the space between the coupling part housing **403** and the revolving scroll **504**→the refrigerant suction port **205***a*. Hence, the refrigerant can lubricate the mechanical sliding parts of the one-way-clutch **507**.

Eleventh Embodiment

[**0152**] In the eighth, ninth, and tenth embodiments, there has been provided the description of the vapor compression type refrigerator using the fluid machine **202** integrated with an expander that is integrally constructed of the compression and expansion part **203**, the driving and electric-power generating part **204**, the refrigerant pump **205**, and the oil supply passage **206**. In this embodiment, however, as shown by a general construction diagram in **FIG. 17**, the refrigerant pump **205** and oil supply piping **262** are constructed as separate parts and the fluid machine **202** integrated with an expander is not integrally constructed of the refrigerant pump **205** and the oil supply passage **206**.

[**0153**] The refrigerant pump **205** is an electrically driven pump mounted in the vehicle engine room and is supplied with electric power from the control unit **221** only in the expander mode, thereby being operated. Hence, this embodiment is not provided with the power transmitting means for transmitting the driving power from the compression and expansion part **203**. However, when this refrigerant pump **205** is operated only in the expander mode, a pump may be used which receives driving power from the engine **201** or the compression and expansion part **203** via the power transmitting means, thereby being operated.

[**0154**] The oil supply passage **262** is piping for connecting the low-pressure port **203***a* to the refrigerant suction port **205***a* and is communication means in this embodiment. The oil supply passage **262** is provided with a check valve **262***c* for allowing the oil to flow from an oil tank **262***a* and the low-pressure port **203***a* only to the refrigerant suction port **205***a*, and an orifice **262***d* of a throttle mechanism for adjusting the amount of oil on the downstream side of the check valve **262***c* in the direction of oil.

[**0155**] The oil tank **262***a* is a tank having the function of a receiver that has a space and separates the lubricating oil from the refrigerant by the gravity and stores the lubricating oil. The oil tank **262***a* is oil storing means in this embodiment. The other construction is the same as in the eighth embodiment.

[**0156**] In the above-described construction, in the compressor mode, the control unit **221** does not supply the refrigerant pump **205** with electric power and hence the same vapor compression type refrigerator as in the first embodiment is constructed. In the expander mode, the control unit **221** supplies the refrigerant pump **205** with electric power and hence the same Rankine cycle as in the first embodiment is constructed.

[**0157**] Hence, even when the refrigerant pump **205** and the oil supply piping **262** are constructed separately from the fluid machine **202** integrated with an expander, the oil stored in the oil tank **262***a* is supplied to the refrigerant suction port **205***a* by the pressure difference between the low-pressure port **203***a* and the refrigerant suction port **205***a* and hence can sufficiently lubricate the mechanical sliding parts of the refrigerant pump **205**.

Twelfth Embodiment

[**0158**] In the above-described eighth to eleventh embodiments, the vapor compression type refrigerator combined with the Rankine cycle has been described. In this embodiment, however, a refrigerator designed specifically for the Rankin cycle will be described.

[**0159**] **FIG. 18** is a schematic diagram showing an entire cycle construction of a refrigerator designed specifically for the Rankin cycle of recovering the waste heat of the vehicle engine **201**. First, the fluid machine **202** functioning as an expander has the same construction as in the eighth embodiment. However, the compression and expansion part **203** in the eighth embodiment functions only as expansion means for outputting mechanical energy by the expansion of the refrigerant, and the driving and electric-power generating part **204** functions only as power generating means for generating electric power by the mechanical energy.

[**0160**] In the refrigerator designed specifically for the Rankin cycle, the fluid machine **202** does not operate as a compressor and hence the shaft **303** rotates only in the expansion direction described above. Hence, the shaft **303** may be coupled to the pump shaft **502** so as to rotate integrally with each other without using the one-way clutch **507**.

[**0161**] Next, a radiator **270** radiates heat of the refrigerant to cool the refrigerant. The refrigerant inlet of the radiator **270** is connected to the low-pressure port **203***a* of the fluid machine **202** by refrigerant piping. A vapor-liquid separator **290** is a receiver for separating the refrigerant flowing out from the radiator **270** into the vapor-phase refrigerant and the liquid-phase refrigerant.

[**0162**] The liquid-phase refrigerant side of the vapor-liquid separator **290** and the refrigerant suction port **205***a* of the refrigerant pump **205** are coupled to each other by refrigerant piping so as to supply the separated liquid-phase refrigerant to the refrigerant suction port **205***a*. The refrigerant discharge port **205***b* of the refrigerant pump **205** is coupled to the heater **213**.

[**0163**] The heater **213** is a heat exchanger that exchanges the refrigerant pressure-fed from the refrigerant pump **205** for the engine cooling water to thereby heat the refrigerant. The engine cooling water is circulated through the same hot water circuit **214** as in the eighth embodiment. The refrigerant outlet of the heater **213** is coupled to the high-pressure port **203***b* of the fluid machine **202** by the refrigerant piping.

[**0164**] The control unit **221** connects the electric power generating means to the electric power storage battery **222** and performs the control of switching the three-way valve **216**.

[**0165**] In the above-described construction, the control unit **221** connects the electric power generating means to the electric power storage battery **222** and switches the three-way valve **216** to the heater **213** to construct a Rankin cycle of circulating the refrigerant in the order of: the heater **213**→the fluid machine **202** integrated with an expander→ the radiator **270**→the vapor-liquid separator **290**→the refrigerant pump **205**→the heater **213**. In the manner, just as with the eighth embodiment, electric energy can be stored in the electric power storage battery **222**.

[**0166**] Furthermore, just as with the eighth embodiment, the oil stored in the oil storing chamber **206***a* can be supplied to the refrigerant suction port **205***a* of the refrigerant pump **205** via the oil supply passage and hence can sufficiently lubricate the mechanical sliding parts of the refrigerant pump **205**.

Thirteenth Embodiment

[**0167**] The thirteenth embodiment uses a fluid machine **200** shown in **FIG. 19** in place of the vapor compression type fluid machine **202** integrated with an expander in the twelfth embodiment. The thirteenth embodiment is the same in the other construction as the twelfth embodiment. **FIG. 19** is a cross-sectional view of the fluid machine **200**. In **FIG. 19**, parts having the same or equivalent functions as those in the above-described eighth embodiment are denoted by the same reference symbols.

[**0168**] The fluid machine **200** is constructed of an expansion part **203'**, an electric power generating part **204'**, a refrigerant pump **251**, an oil passage **263**, and the like. In the fluid machine **200**, parts are arranged in order of the refrigerant pump **251**, the electric power generating part **204'**, the expansion part **203'** from the upstream side, which is reverse to the order of arrangement of parts in the fluid machine **202** integrated with an expander in the eighth embodiment.

[**0169**] The basic construction of the expansion part **203'** is the same as that in the eighth embodiment but is different in the arrangement of the low-pressure port **203***a*. In this embodiment, the low-pressure port **203***a* is formed in the outer peripheral portion of the middle housing **302**.

[**0170**] In the middle housing **302**, a low-pressure refrigerant communication passage **302***a* that communicates with a low-pressure refrigerant outflow port **301***a* of the housing **301** of the expansion part **203'** and introduces refrigerant after expansion into the middle housing **302** is formed in the outer peripheral portion of the middle housing **302** in such a way as to extend in the up and down direction.

[**0171**] The low-pressure port **203***a* is formed at a position that is nearly symmetric to the upper end of the low-pressure refrigerant passage **302***a* with respect to the central axis of the shaft **303**.

[**0172**] The basic construction of the electric power generating part **204'** is the same as the electric power generating part **204** in the eighth embodiment but is different in that the low-pressure refrigerant flowing through the low-pressure refrigerant passage **302***a* passes through an internal space in the middle housing **302**, in which the stator **401** and the rotor **402** are arranged, and reaches the low-pressure port **203***a*.

[**0173**] The refrigerant pump **251** is refrigerant pressure-feeding means that pressure-feeds a liquid-phase refrigerant to the expansion part **203'** at the time of recovering thermal energy and employs a publicly-known rolling piston type pressure-feeding mechanism as a pressure-feeding mechanism in this embodiment.

[**0174**] **FIG. 20** is a cross-sectional view taken on the line XX-XX in **FIG. 19**. **FIG. 21** is a cross-sectional view taken on the line XXI-XXI in **FIG. 20**. The refrigerant pump **251** includes a pump housing **511**, the coupling part housing **403**, a pump shaft **512**, a front plate **513**, a rear plate **514**, a cylinder **515**, a pump rotor **516**, and the like. The pump housing **511** has a refrigerant discharge port **205***b* and a refrigerant suction port **205***a*.

[**0175**] The pump shaft **512** is rotatably supported by the front plate **513** and the rear plate **514** via a ball bearing **517** and is a crankshaft having an eccentric portion **518**. The pump rotor **516** is rotatably coupled to the eccentric portion **518**.

[**0176**] The cylinder **515** is sandwiched from above and below by the front plate **513** and the rear plate **514** and has an operating space, in which the pump rotor **516** operates, formed on the inner peripheral side.

[**0177**] The rear plate **514** has a refrigerant suction passage **514***a* for introducing refrigerant flowing from the suction port **205***a* into the hosing **511** to the operating space.

[**0178**] The front plate **513** has a refrigerant discharge passage **513***a* for introducing refrigerant in the operating space to the refrigerant discharge port **205***b*. At the exit of the refrigerant discharge passage **513***a*, a reed valve is provided as a check valve **513***b* that allows the refrigerant to flow only to the refrigerant discharge port **205***b*.

[**0179**] Moreover, the front plate **513** has a suction-side communication passage **513***c* that makes the refrigerant suction port **205***a* communicate with a mechanical sliding part B (specifically, space where the eccentric part **518** is arranged). This suction-side communication passage **513***c* applies pressure on the suction side of the refrigerant pump **251** to the mechanical sliding part B to make the back pressure of the mechanical sliding part B equal to the pressure of the refrigerant suction port **205***a*.

[**0180**] The pump rotor **516** has a sliding bearing **519** on the inner peripheral portion to become a portion coupled to the eccentric part **518**. The amount of clearance between the outside diameter of the eccentric part **518** and the inside diameter of the sliding bearing **519** is approximately from 20 μm to 40 μm.

[0181] A vane 515*c* that is always pressed onto the outer peripheral surface of the pump rotor 516 by a spring 515*b* is arranged in a cut portion 515*a* on the inner peripheral side of the cylinder 515.

[0182] Moreover, the cylinder 515 has a refrigerant suction port 515*d* communicating with the refrigerant suction passage 514*a* and a refrigerant discharge port 515*e* communicating with the refrigerant discharge passage 513*a*.

[0183] The section of the refrigerant pump 251 shown in FIG. 19 shows a cross-sectional view taken on the line XXI-XXI in FIG. 20 for the sake of convenience in showing the refrigerant suction portion 515*d* and the refrigerant discharge port 515*e*.

[0184] The pump shaft 512 protrudes to the coupling part housing 403 (lower side in FIG. 19) and is coupled to the shaft 303. Here, the shaft 303 may be coupled to the pump shaft 512 by the use of transmission means (for example, one-way clutch) capable of transmitting a driving force from the shaft 303 to the pump shaft 512 only when the expansion part 203' outputs mechanical energy. Moreover, a lip seal 406 is interposed between the pump shaft 512 and the coupling part housing 403 to seal therebetween. Here, a seal member having other structure can be used for the sealing, instead of the lip seal 406. Furthermore, the pump shaft 512 has an oil communication hole 520 that makes the end of the coupling part housing 403 communicate with the mechanical sliding part B.

[0185] Next, an oil supply passage 263 will be described. The oil supply passage 263 is communication means for making the low-pressure port 203*a* communicate with the mechanical sliding part B. In this embodiment, the oil supply passage 263 is constructed in such a way that oil separated from the vapor-phase refrigerant, which collides with the stator 401 and the rotor 402 of the power generating part 204' arranged in the middle housing 302 when the vapor-phase refrigerant flowing out of the low-pressure refrigerant outflow port 301*a* moves to the low-pressure port 203*a*, is stored in an oil storing chamber 263*a* and, as shown by arrow in FIG. 19, flows from the oil storing chamber 263*a* in order of the oil communication passage 303*a* of the shaft 303→the check valve 263*c*→the communication hole 520 of the pump shaft 512→the mechanical sliding part B. Here, a pressure in the oil storing chamber 263*a* is equal to a pressure at the low-pressure port 203*a*, and a back pressure on the mechanical sliding part B is equal to the pressure of refrigerant on the refrigerant suction port 205*a* side because the suction side communication passage 513*c* is formed. Further, the pressure of refrigerant on the refrigerant suction port 205*a* side is made lower than the pressure at the low-pressure port 203*a* by a pressure loss caused when the refrigerant passes through the heat radiator 270 and refrigerant piping and negative pressure caused by the suction of the refrigerant pump 205. For this reason, the oil stored in the oil storing chamber 263*a* is supplied to the mechanical sliding part B of the refrigerant pump 251 via the oil supply passage 263 by this pressure difference.

[0186] By the way, in this embodiment, in order to rotate the pump rotor 516, clearances of from 5 μm to 20 μm are formed between the front plate 513 and the pump rotor 516 and between the rear plate 514 and the pump rotor 516, respectively. For this reason, the liquid-phase refrigerant may flow from the refrigerant pressure-feeding space to the mechanical sliding part B through the clearances between the front plate 513 and the pump rotor 516 and between the rear plate 514 and the pump rotor 516 (this liquid-phase refrigerant flowing to the mechanical sliding part B is hereinafter referred to as “leakage refrigerant”). When the leakage refrigerant flows into the mechanical sliding part B, it is also thought that the oil supplied from the oil supply passage 263 to the mechanical sliding part B dissolves in the leakage refrigerant and hence cannot sufficiently lubricate the mechanical sliding part B.

[0187] Hence, the present inventors studied the appropriate amount of supply of oil with respect to the flow rate of leakage refrigerant flowing into the mechanical sliding part B. As a result, the inventors found that when the flow rate of supply of oil was not less than 30% of the flow rate of liquid-phase refrigerant with respect to the flow rate (flow rate of mass) of leakage refrigerant flowing into the mechanical sliding part B, the oil can sufficiently lubricate the mechanical sliding part B. Therefore, in this embodiment, the amount of clearance between the outside diameter of the eccentric part 518 and the inside diameter of the sliding bearing 519 is set at a value of approximately from 20 μm to 40 μm to thereby make the amount of supply of oil supply not less than 30% of the flow rate of liquid-phase refrigerant with reliability.

[0188] Because the clearance between the front plate 523 and the pump rotor 516 is extremely small (for example, from 5 μm to 20 μm) in the thirteenth embodiment, when the leakage refrigerant and the oil pass through this clearance, a pressure loss develops. Hence, it is also recommendable to form a suction side communication passage, which makes the suction side of the refrigerant pump 251 communicate with the clearance between the front plate 523 and the pump rotor 516, in the front plate 523 or the rear plate 514. With this, the leakage refrigerant passes from the refrigerant pressure-feeding space to the suction side communication passage through the clearance between the front plate 513 and the pump rotor 516 and is hard to flow into the mechanical sliding part B.

[0189] Moreover, a single or a plurality of through holes may be formed in both surfaces (upper and lower surfaces) of the pump rotor 516.

[0190] In the thirteenth embodiment has been shown an example in which the fluid machine 200 is applied to an apparatus designed specifically for a Rankin cycle. However, the fluid machine 200 may be applied to a vapor compression type refrigerator combined with a Rankin cycle by the use of a transmission mechanism (for example, one-way clutch) capable of transmitting a driving force from the shaft 303 to the pump shaft 512 only when the expansion part 203' outputs mechanical energy.

[0191] Moreover, the apparatus designed specifically for a Rankin cycle in which the fluid machine 200 integrally constructed of the expansion part 203', the driving and power generating part 204', the refrigerant pump 251, and the oil supply passage 263 has been described in the thirteenth embodiment. However, similarly to the eleventh embodiment, the refrigerant pump and the oil supply piping may be constructed separately. In this case, when the oil flows from the oil supply piping to the communication hole 520 of the pump shaft 512, just as with the thirteenth embodiment, the oil can sufficiently lubricate the mechanical sliding part B.

[0192] Furthermore, in the thirteenth embodiment, specifically, the mechanical sliding part B is constructed of the eccentric part **518** and the sliding part of the sliding bearing **519**, but the mechanical sliding part B is not limited to this.

Other Embodiments

[0193] Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art.

[0194] For example, in the above-described second embodiment having the back pressure chamber **116**, the movable scroll **113** may have multiple small-diameter holes for adjusting the pressure between the operating chamber V and the back pressure chamber **116** in addition to the small-diameter passage **113***c*. The small-diameter holes make the back pressure chamber **116** communicate with the suction side (low-pressure side) of the operating chamber V. With this, when the pressure in the back pressure chamber **116** is excessively increased, the small-diameter holes cause the pressure to leak from the back pressure chamber **116** to the operating chamber V, so as to prevent an excessive increase in the back pressure. Moreover, the small-diameter hole may be provided with a mechanism for feeding the liquid refrigerant to the low pressure side before the back pressure excessively increases. For example, the small-diameter hole may be provided with a safety valve acting as this mechanism. For example, a ball type valve, a valve to be backed up by a spring, a ball spring type valve can be used as the safety valve.

[0195] Furthermore, the present invention can be applied to a liquid pump for pressure-feeding fluid such as a positive-displacement pump including a scroll type pump and a rotary vane type pump. In addition, the above-described first to seventh embodiments can be suitably combined.

[0196] In the above-described eighth to eleventh embodiments, the compression and expansion part **203** is supplied with the rotational driving power from the driving and electric-power generating part **204**, thereby being driven. However, the compression and expansion part **203** may be supplied with the rotational driving power from the engine **201** by the use of a power transmitting mechanism constructed of an electromagnetic clutch, a pulley, and a belt.

[0197] Moreover, in the above-described eighth to twelfth embodiments, the scroll type pump mechanism is employed for the compression and expansion part (expansion means) **203** and the refrigerant pump **205**. However, other type compression and expansion mechanism such as rotary type, piston type, and vane type may be employed.

[0198] Further, in the above-described eighth to twelfth embodiments, energy recovered by the fluid machine **202** integrated with an expander is stored as electric energy in the electric power storage battery **222**. However, the energy may be stored as kinetic energy by the use of a flywheel or mechanical energy such as elastic energy by the use of a spring. In addition, the above-described recovered energy may be used in order to assist the rotational driving power of the engine **201**.

[0199] Still further, in the above-described embodiments, the oil is separated from the refrigerant only by the use of the gravity. It is also recommendable to form the refrigerant passage in a circular shape and to separate the oil from the refrigerant by the use of centrifugal force.

[0200] Such changes and modifications are to be understood as being within the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A fluid pump comprising:

a driving part;

a movable part that is movable by power transmitted from the driving part;

a transmission part through which the power from the driving part is transmitted to the movable part;

a fixed part disposed on a side of the movable part, opposite to the transmission part, to form an operating chamber having an outlet from which a fluid flowing into the operating chamber is pressure-fed to an outside in a liquid state by the movable part; and

an introduction passage for introducing a part of the fluid in the operating chamber to the transmission part.

2. The fluid pump according to claim 1, wherein:

the introduction passage is provided in the movable part; and

the introduction passage has an opening part opened to the operating chamber to be tapered.

3. The fluid pump according to claim 1, wherein:

the movable part includes a passage part for defining the introduction passage; and

the passage part is a member separate from the movable part.

4. The fluid pump according to claim 1, wherein:

the movable part is a movable scroll having a base plate portion and a first wall portion protruding from the base plate portion in a spiral shape;

the fixed part is a fixed scroll having a spiral second wall portion engaged with the first wall portion; and

the introduction passage has a diameter smaller than a predetermined value, and is provided in the base plate portion of the movable scroll to make the operating chamber communicate with the transmission part at a predetermined pressure loss.

5. The fluid pump according to claim 4, wherein:

the transmission part is housed in a closed space; and

the movable scroll receives a back pressure applied thereto on a side of the fixed scroll by the fluid introduced into the closed space.

6. The fluid pump according to claim 5, wherein:

the movable scroll has a plurality of holes, each having a diameter smaller than a predetermined value, for adjusting pressure between the operating chamber and the closed space.

7. The fluid pump according to claim 1, wherein:

the movable part is a rotor that is made to revolve by the driving part arranged in a center of the movable part;

the fixed part is a cylinder housing in which a cylinder housing the rotor is disposed; and

the introduction passage is a passage having a diameter smaller than a predetermined value, and is provided in the rotor to make the operating chamber communicate with the transmission part at a predetermined pressure loss.

8. The fluid pump according to claim 1, wherein:

the movable part is a rotor that is revolve by the driving part arranged in a center of the movable part;

the fixed part is a cylinder housing in which a cylinder housing the rotor is disposed; and

the introduction passage is a groove that is provided on an end surface in an axial direction of the rotor and makes the operating chamber communicate with the transmission part at a predetermined pressure loss.

9. A fluid machine comprising:

an expansion member having a function of outputting mechanical energy by expansion of refrigerant, the expansion member having a low-pressure port from which low-pressure vapor-phase refrigerant after being decompressed flows out and a high-pressure port from which high-pressure refrigerant before being decompressed flows in;

an electric power generating member having a function of generating electric power by using the mechanical energy;

a refrigerant pressure-feeding member for pressure-feeding refrigerant to the expansion member, the refrigerant pressure-feeding member having a refrigerant suction port from which liquid-phase refrigerant is sucked and a refrigerant discharge port from which liquid-phase refrigerant is discharged; and

a communication part for making the low-pressure port of the expansion member communicate with the refrigerant suction port of the refrigerant pressure-feeding member, wherein the communication part separates lubricating oil from vapor-phase refrigerant and supplies the lubricating oil to the refrigerant suction port.

10. The fluid machine according to claim 9, further comprising

a housing which houses all of the expansion member, the electric power generating member and the refrigerant pressure-feeding member.

11. The fluid machine according to claim 9, wherein the low-pressure port is arranged above the refrigerant suction port.

12. The fluid machine according to claim 9, wherein:

the expansion member having the low-pressure port that is arranged above the electric power generating member; and

the refrigerant pressure-feeding member having the refrigerant suction port is arranged below the electric power generating member.

13. The fluid machine according to claim 9, wherein:

the communication part separates the oil from the vapor-phase refrigerant by gravity by the use of a difference in specific gravity between the vapor-phase refrigerant and the oil and includes an oil storing part for storing the separated oil.

14. The fluid machine according to claim 13, wherein the oil storing part is provided in the electric power generating member.

15. The fluid machine according to claim 9, wherein the communication part has a check valve for preventing the liquid-phase refrigerant from flowing back from the refrigerant suction port to the low-pressure port.

16. The fluid machine according to claim 15, wherein:

the communication part has a throttle mechanism connected in series to the check valve; and

the throttle mechanism has a refrigerant passage area smaller than a refrigerant passage area of the check valve.

17. The fluid machine according to claim 9, further comprising

a transmission part for transmitting driving power from the expansion member to the refrigerant pressure-feeding member, wherein the refrigerant pressure-feeding member is operated by the driving power from the expansion member.

18. The fluid machine according to claim 17, wherein the transmission part is a one-way clutch that transmits the mechanical energy as the driving power from the expansion member only when the expansion member outputs the mechanical energy.

19. The fluid machine according to claim 9, wherein:

the expansion member is a compression and expansion member that has a function of compressing refrigerant by driving power applied thereto;

the electric power generating member is a driving and electric-power generating member that applies the driving power to the compression and expansion member; and

when the compression and expansion member compresses refrigerant, the low-pressure port sucks low-pressure vapor-phase refrigerant after being decompressed and the high-pressure port discharges high-pressure refrigerant before being decompressed.

20. A fluid machine comprising:

an expansion member having a function of outputting mechanical energy by expansion of refrigerant;

a refrigerant pressure-feeding member for pressure-feeding refrigerant to the expansion member, the expansion member having a low-pressure port from which low-pressure vapor-phase refrigerant after being decompressed flows out and a high-pressure port from which high-pressure refrigerant after being decompressed flows in; and

a communication part that introduces oil contained in refrigerant flowing out from the low-pressure port to a sliding part of the refrigerant pressure-feeding member.

21. A vapor compression type refrigerator combined with a Rankine cycle, comprising:

a compression and expansion member that has a function of compressing and discharging refrigerant by driving power applied thereto and a function of outputting mechanical energy by expansion of refrigerant, the compression and expansion member having a low-pressure port from which low-pressure refrigerant after being decompressed is sucked and flows out and a high-pressure port from which high-pressure refrigerant before being decompressed is discharged and flows in;

a driving and electric-power generating member that has a function of applying the driving power to the compression and expansion member and a function of generating electric power by the mechanical energy;

a refrigerant pressure-feeding member that pressure-feeds refrigerant to the compression and expansion member, the refrigerant pressure-feeding member having a refrigerant suction port from which liquid-phase refrigerant is sucked and a refrigerant discharge port from which liquid-phase refrigerant is discharged; and

a communication part that makes the low-pressure port communicate with the refrigerant suction port, wherein the communication part separates lubricating oil from the vapor-phase refrigerant and supplying the lubricating oil to the refrigerant suction port.

22. A vapor compression type refrigerator combined with a Rankine cycle, comprising:

a compression and expansion member that has a function of compressing and discharging refrigerant by driving power applied thereto and a function of outputting mechanical energy by expansion of refrigerant, the compression and expansion member having a low-pressure port from which low-pressure refrigerant after being decompressed is sucked and flows out and a high-pressure port from which high-pressure refrigerant before being decompressed is discharged and flows in;

a driving and electric-power generating member that has a function of applying the driving power to the compression and expansion member and a function of generating electric power by the mechanical energy;

a refrigerant pressure-feeding member that pressure-feeds refrigerant to the compression and expansion member, the refrigerant pressure-feeding member having a refrigerant suction side and a mechanical sliding portion;

a first communicating part through which the refrigerant suction side of the refrigerant pressure-feeding member communicates with the mechanical sliding portion of the refrigerant pressure-feeding member; and

a second communication part that makes the low-pressure port communicate with the mechanical sliding portion, wherein the second communication part separates lubricating oil from the vapor-phase refrigerant and supplying the lubricating oil to the mechanical sliding portion.

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