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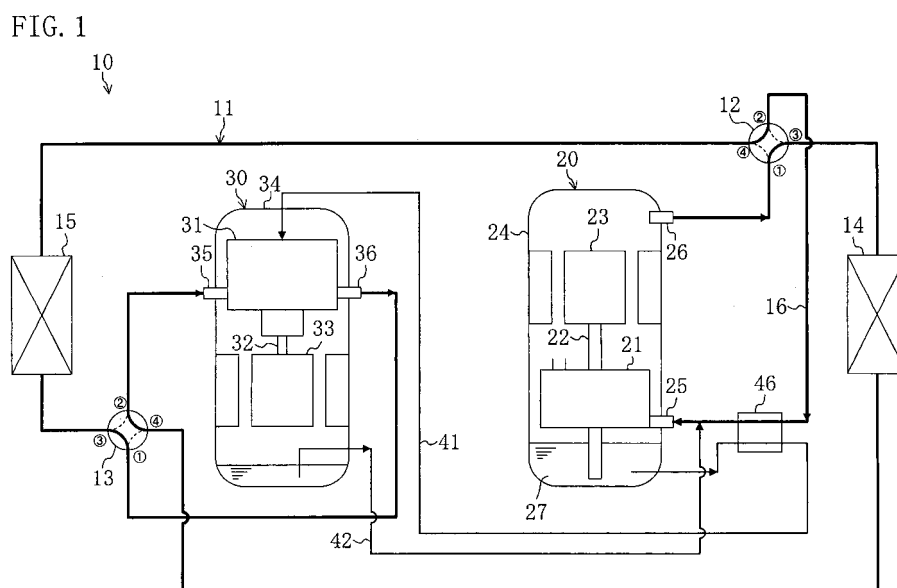
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(54) **REFRIGERATING DEVICE**

(57) A refrigerant circuit (11) in an air conditioner (10) includes a compressor (20) and an expander (30). In the compressor (20), refrigerant compressed by a compression mechanism (21) is discharged into the internal space of a compressor casing (24). In the compressor (20), re-

frigeration oil which has accumulated in the bottom of the compressor casing (24) is supplied to the compression mechanism (21). The refrigeration oil in the bottom of the compressor casing (24) is directly introduced into an expansion mechanism (31) of the expander (30) through an oil supply pipe (41).



Description

TECHNICAL FIELD

[0001] The present invention relates to systems for supplying lubricating oil to expanders in refrigeration systems including compressors and the expanders.

BACKGROUND ART

[0002] Refrigeration systems operating in refrigeration cycles by circulating refrigerant are known, and are widely used in, for example, air conditioners. For example, Patent Document 1 discloses a refrigeration system including a compressor for compressing refrigerant and a power-recovery expander for expanding the refrigerant. Specifically, in a refrigeration system shown in FIG. 1 of Patent Document 1, an expander is coupled to a compressor by a single shaft, and power obtained by the expander is used for driving the compressor. In a refrigeration system shown in FIG. 6 of Patent Document 1, an electric motor is coupled to a compressor, and an electric generator is coupled to an expander. In this refrigeration system, the compressor is driven by the electric motor to compress refrigerant, whereas the electric generator is driven by the expander to generate electricity.

[0003] A fluid machine in which an expander and a compressor are coupled together by a single shaft is disclosed in, for example, Patent Document 2. In the fluid machine disclosed in this patent document, a single casing houses a compression mechanism as a compressor, an expansion mechanism as an expander, and a shaft coupling these mechanisms. In this fluid machine, an oil supply passageway is formed in the shaft, and lubricating oil which has accumulated in the bottom of the casing is drawn up into the compression mechanism and the expansion mechanism through the oil supply passageway.

[0004] Patent Document 3 discloses a so-called sealed compressor. In this sealed compressor, a compression mechanism and an electric motor are housed in a single casing. In addition, in this sealed compressor, an oil supply passageway is formed in a driving shaft for the compression mechanism such that lubricating oil which has accumulated in the bottom of the casing is supplied to the compression mechanism through the oil supply passageway.

Patent Document 1: Japanese Laid-Open Patent Publication No. 2000-241033

Patent Document 2: Japanese Laid-Open Patent Publication No. 2005-299632

Patent Document 3: Japanese Laid-Open Patent Publication No. 2005-002832

DISCLOSURE OF INVENTION

Problems that the Invention is to Solve

[0005] A refrigeration system in which a compressor and an expander formed as separate units are connected to a refrigerant circuit as disclosed in Patent Document 1 can employ a sealed compressor as disclosed in Patent Document 3. In this case, in the compressor, a compression mechanism is lubricated with lubricating oil which has accumulated in a casing.

[0006] Similarly to the compression mechanism of the compressor, an expansion mechanism of the expander is constituted by a fluid machine. Thus, in the same manner as the compression mechanism, the expansion mechanism also needs lubrication with lubricating oil. However, no specific consideration has been given to how to supply lubricating oil to the expansion mechanism of the expander.

[0007] It is therefore an object of the present invention to achieve, in a refrigeration system including a compressor and an expander formed as separated units, high reliability of the refrigeration system by ensuring supply of lubricating oil to each of the compressor and the expander.

Means of Solving the Problems

[0008] A first aspect of the present invention is directed to a refrigeration system including a refrigerant circuit (11) including a compressor (20) and an expander (30). The refrigeration system performs a refrigeration cycle by circulating refrigerant in the refrigerant circuit (11). The compressor (20) includes a compressor casing (24) in the shape of a sealed vessel and a compression mechanism (21) housed in the compressor casing (24) and configured to compress sucked refrigerant and to discharge the compressed refrigerant into the compressor casing (24), and supplies lubricating oil stored in the compressor casing (24) to the compression mechanism (21). The expander (30) includes an expansion mechanism (31) for generating power by expansion of inflow refrigerant and an expander casing (34) housing the expansion mechanism (31). An oil supply passageway (41) for supplying the lubricating oil stored in the compressor casing (24) to the expansion mechanism (31) is provided such that the expansion mechanism (31) is lubricated with the lubricating oil supplied through the oil supply passageway (41).

[0009] In the first aspect, the refrigeration cycle is performed by circulating refrigerant in the refrigerant circuit (11). In the compressor (20), the compression mechanism (21) compresses sucked refrigerant, and discharges the compressed refrigerant into the internal space of the compressor casing (24). The high-pressure refrigerant derived from the compressor casing (24) dissipates heat to an object such as the air or water, and then flows into the expansion mechanism (31) of the expander (30).

to be expanded. In the expansion mechanism (31), power is recovered from the inflow high-pressure refrigerant. The refrigerant expanded by the expansion mechanism (31) takes heat from an object such as the air or water, and then is sucked into the compression mechanism (21) of the compressor (20).

[0010] The compressor casing (24) of the first aspect has an internal pressure equal to the pressure of refrigerant immediately after being discharged from the compression mechanism (21), and lubricating oil is stored in the internal space of the compressor casing (24). The lubricating oil stored in the compressor casing (24) is supplied to the compression mechanism (21), and is used for lubricating the compression mechanism (21). The lubricating oil stored in the compressor casing (24) is also supplied to the expansion mechanism (31) through the oil supply passageway (41), and is used for lubricating the expansion mechanism (31).

[0011] In a second aspect of the present invention, the refrigeration system according to the first aspect further includes an oil supply pipe (41) having an end connected to a bottom of the compressor casing (24) and another end connected to the expansion mechanism (31), wherein the oil supply pipe (41) forms the oil supply passageway.

[0012] In the second aspect, the oil supply passageway is constituted by the oil supply pipe (41). Lubricating oil in the compressor casing (24) flows into an end of the oil supply pipe (41), and this inflow lubricating oil flows toward the other end of the oil supply pipe (41). Lubricating oil flowing in the oil supply pipe (41) is introduced into the expansion mechanism (31) from the other end of the oil supply pipe (41).

[0013] In a third aspect of the present invention, the refrigeration system according to the first or second aspect further includes an oil return passageway (42) for returning lubricating oil which has accumulated in the expander casing (34) to the compressor (20).

[0014] In the third aspect, the refrigeration system further includes the oil return passageway (42). In the expander (30), part of lubricating oil supplied to the expansion mechanism (31) through the oil supply passageway (41) flows from the expander (30) together with refrigerant which has passed through the expansion mechanism (31), whereas the other part of the lubricating oil leaks from the expansion mechanism (31), and accumulates in the expander casing (34). This lubricating oil which has accumulated in the expander casing (34) is sent back to the compressor (20) through the oil return passageway (42).

[0015] In a fourth aspect of the present invention, in the refrigeration system according to the third aspect, the oil return passageway (42) is configured to introduce lubricating oil to a suction side of the compression mechanism (21).

[0016] In the fourth aspect, lubricating oil which has accumulated in the expander casing (34) flows into the suction side of the compression mechanism (21) through

the oil return passageway (42), and is sucked into the compression mechanism (21) together with low-pressure refrigerant. The lubricating oil sucked into the compression mechanism (21) together with the refrigerant is discharged from the compression mechanism (21) into the internal space of the compressor casing (24) together with the compressed refrigerant.

[0017] In a fifth aspect of the present invention, the refrigeration system according to one of the first through fourth aspects further includes a cooling heat exchanger (46) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with refrigerant sucked into the compression mechanism (21).

[0018] In the fifth aspect, the refrigeration system further includes the cooling heat exchanger (46). The cooling heat exchanger (46) performs heat exchange between lubricating oil flowing in the oil supply passageway (41) and refrigerant sucked into the compression mechanism (21). The refrigerant sucked into the compression mechanism (21) has a temperature lower than that of the lubricating oil flowing in the oil supply passageway (41). Accordingly, in the cooling heat exchanger (46), the lubricating oil flowing in the oil supply passageway (41) is cooled.

[0019] In a sixth embodiment of the present invention, the refrigeration system according to the third or fourth aspect further includes a cooling heat exchanger (47) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with lubricating oil flowing in the oil return passageway (42).

[0020] In the sixth embodiment, the refrigeration system further includes the cooling heat exchanger (47). The cooling heat exchanger (47) performs heat exchange between lubricating oil flowing in the oil supply passageway (41) and lubricating oil flowing in the oil return passageway (42). The lubricating oil flowing in the oil return passageway (42) has a temperature lower than that of the lubricating oil flowing in the oil supply passageway (41). Accordingly, in the cooling heat exchanger (47), the lubricating oil flowing in the oil supply passageway (41) is cooled.

[0021] In a seventh aspect of the present invention, the refrigeration system according to one of the first through fourth aspects includes a cooling heat exchanger (48) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with outdoor air.

[0022] In the seventh aspect, the refrigeration system further includes the cooling heat exchanger (48). The cooling heat exchanger (48) performs heat exchange between lubricating oil flowing in the oil supply passageway (41) and the outdoor air. The outdoor air has a temperature lower than that of the lubricating oil flowing in the oil supply passageway (41). Accordingly, in the cooling heat exchanger (48), the lubricating oil flowing in the oil supply passageway (41) is cooled.

[0023] In an eighth aspect of the present invention, in the refrigeration system according to one of the first

through seventh aspects, the refrigerant circuit (11) includes a first suction-side passageway (17) for establishing communication between an evaporator of the refrigerant circuit (11) and internal space of the expander casing (34), and a second suction-side passageway (18) for establishing communication between the internal space of the expander casing (34) and a suction side of the compression mechanism (21), and the expander casing (34) is configured to separate refrigerant from the first suction-side passageway (17) into gas refrigerant and liquid refrigerant, and to send the gas refrigerant to the second suction-side passageway (18).

[0024] In the eighth aspect, the first suction-side passageway (17) and the second suction-side passageway (18) are provided in the refrigerant circuit (11). In this refrigerant circuit (11), low-pressure refrigerant which has flown from the evaporator flows into the internal space of the expander casing (34) through the first suction-side passageway (17). The refrigerant which has flown into the internal space of the expander casing (34) is sucked into the compression mechanism (21) through the second suction-side passageway (18). That is, in the refrigerant circuit (11) of this aspect, the refrigerant which has flown from the evaporator passes through the internal space of the expander casing (34), and then is sucked into the compression mechanism (21) of the compressor (20).

[0025] In the evaporator of the refrigerant circuit (11), inflow refrigerant does not completely evaporate, and part of the refrigerant flows from the evaporator without change in the state of liquid refrigerant, in some cases. In such cases, if a large amount of liquid refrigerant flows from the evaporator, the liquid refrigerant might be sucked into the compression mechanism (21) to cause damage on the compression mechanism (21).

[0026] On the other hand, in this eighth aspect, even if refrigerant in a gas-liquid two-phase state flows from the first suction-side passageway (17) into the internal space of the expander casing (34), this refrigerant is separated into gas refrigerant and liquid refrigerant, and the gas refrigerant is sent to the compression mechanism (21) through the second suction-side passageway (18). That is, the expander casing (34) of this aspect functions as an accumulator.

[0027] In a ninth aspect of the present invention, in the refrigeration system according to the eighth aspect, the expander (30) includes an electric generator (33) housed in the expander casing (34) and driven by the expansion mechanism (31), and the first suction-side passageway (17) communicates with a portion of the internal space of the expander casing (34) below the electric generator (33), whereas the second suction-side passageway (18) communicates with a portion of the internal space of the expander casing (34) above the electric generator (33).

[0028] In the ninth aspect, the electric generator (33) is housed in the expander casing (34). The electric generator (33) is driven by the expansion mechanism (31), thereby generating electricity. In this aspect of the

present invention, low-pressure refrigerant which has flown into the internal space of the expander casing (34) through the first suction-side passageway (17) passes upward through the electric generator (33), and then flows into the second suction-side passageway (18). If refrigerant flowing from the first suction-side passageway (17) into the expander casing (34) is in a gas-liquid two-phase state, gas refrigerant and flows into the second suction-side passageway (18) through the electric generator (33), whereas liquid refrigerant adheres to the electric generator (33) and then flows down to the bottom of the expander casing (34).

EFFECTS OF THE INVENTION

[0029] According to the present invention, lubricating oil is stored in the compressor casing (24) having an internal pressure equal to the pressure of refrigerant immediately after being discharged from the compression mechanism (21), and this lubricating oil is supplied to both the compression mechanism (21) and the expansion mechanism (31). Specifically, according to the present invention, lubricating oil is stored in a part having the highest pressure in the refrigerant circuit (11), and this lubricating oil is supplied to the compression mechanism (21) and the expansion mechanism (31) both having portions whose pressures are lower than the internal pressure of the compressor casing (24). Accordingly, the source of lubricating oil has a higher pressure than its destination, thus ensuring the supply of lubricating oil to each of the compression mechanism (21) and the expansion mechanism (31). Thus, according to the present invention, a sufficient amount of lubricating oil can be supplied to the compression mechanism (21) and the expansion mechanism (31), thus preventing troubles such as seizing of the compression mechanism (21) and the expansion mechanism (31). As a result, reliability of the refrigeration system can be obtained.

[0030] In the third aspect of the present invention, lubricating oil in the expander casing (34) returns to the compressor (20) through the oil return passageway (42). Since the amount of lubricating oil contained in the refrigerant circuit (11) is constant, an increase in the amount of lubricating oil in the expander casing (34) causes a decrease in the amount of refrigeration oil stored in the compressor casing (24) accordingly. Thus, an insufficient amount of lubricating oil might be supplied to the compression mechanism (21) and the expansion mechanism (31). On the other hand, in this aspect, lubricating oil in the expander casing (34) is sent back to the compression mechanism (21) through the oil return passageway (42). Accordingly, in this aspect, a sufficient amount of lubricating oil is stored in the compressor casing (24), thus further ensuring the supply of refrigeration oil to the compression mechanism (21) and the expansion mechanism (31).

[0031] In the fourth aspect of the present invention, lubricating oil which has accumulated in the expander

casing (34) is sent to the suction side of the compression mechanism (21). The suction side of the compression mechanism (21) has the lowest pressure in the refrigerant circuit (11). More specifically, in this aspect, a pressure difference always occurs between the internal space of the expander casing (34) in which lubricating oil accumulates and the destination to which the refrigeration oil returns. Accordingly, in this aspect, lubricating oil in the expander casing (34) can be sent back to the compressor (20) as intended, resulting in that a sufficient amount of lubricating oil is stored in the compressor casing (24).

[0032] In the internal space of the compressor casing (24), both lubricating oil and refrigerant discharged from the compression mechanism (21) are present. Accordingly, the temperature of the lubricating oil stored in the compressor casing (24) is approximately the same as the temperature of the refrigerant discharged from the compression mechanism (21). On the other hand, the temperature of refrigerant immediately after being discharged from the compression mechanism (21) is highest among portions of refrigerant circulating in the refrigerant circuit (11). Thus, if high-temperature lubricating oil stored in the compressor casing (24) were supplied to the expansion mechanism (31) without any treatment, refrigerant passing through the expansion mechanism (31) would be heated by this lubricating oil, thus increasing the enthalpy of the refrigerant flowing from the expansion mechanism (31). The increase in the enthalpy of the refrigerant flowing from the expansion mechanism (31) might reduce the amount of heat taken from the air or water, for example, to cause performance degradation of the refrigeration system.

[0033] On the other hand, in the fifth, sixth, and seventh aspects of the present invention, lubricating oil discharged from the compressor casing (24) and flowing in the oil supply passageway (41) is cooled in the cooling heat exchanger (46, 47, 48), and then is supplied to the expansion mechanism (31). Accordingly, the amount of heat entering into refrigerant passing through the expansion mechanism (31) from the lubricating oil supplied through the oil supply passageway (41) can be smaller than that in a case where lubricating oil stored in the compressor casing (24) is introduced into the expansion mechanism (31) without any treatment. Thus, in these aspects, the enthalpy of the refrigerant flowing from the expansion mechanism (31) can be reduced, thus suppressing performance degradation of the refrigeration system.

[0034] In particular, in the fifth aspect, heat exchange is performed between refrigerant sucked into the compression mechanism (21) (i.e., lowest-temperature refrigerant among portions of refrigerant circulating in the refrigerant circuit (11)) and lubricating oil flowing in the oil supply passageway (41). Accordingly, in this aspect, it is possible to ensure a reduction in the temperature of lubricating oil introduced into the expansion mechanism (31) through the oil supply passageway (41), thus further ensuring suppression of performance degradation of the

refrigeration system.

[0035] In the eighth aspect of the present invention, the expander casing (34) also functions as an accumulator for separating liquid refrigerant from refrigerant sucked into the compressor (20). Accordingly, no additional accumulators are necessary in the refrigerant circuit (11). As a result, the number of parts constituting the refrigerant circuit (11) can be reduced, and thus the configuration of the refrigeration system can be simplified.

[0036] In the ninth aspect of the present invention, refrigerant which has flown from the first suction-side passageway (17) into the expander casing (34) passes through the electric generator (33), and then flows into the second suction-side passageway (18). Accordingly, in a case where refrigerant which has flown from the first suction-side passageway (17) into the expander casing (34) is in a gas-liquid two-phase state, most part of the refrigerant flowing into the second suction-side passageway (18) is gas refrigerant. Thus, in this aspect, it is possible to ensure prevention of damage on the compression mechanism (21) because of sucking of liquid refrigerant. As a result, high reliability of the compressor (20) can be obtained.

[0037] In this ninth aspect, since refrigerant passes through the electric generator (33), the electric generator (33) is cooled by this refrigerant. Accordingly, in this aspect, a temperature rise in the electric generator (33) can be suppressed, thus enhancing the efficiency of the electric generator (33).

BRIEF DESCRIPTION OF DRAWINGS

[0038]

[FIG. 1] FIG. 1 is a refrigerant circuit diagram illustrating a configuration of an air conditioner according to a first embodiment.

[FIG. 2] FIG. 2 is a longitudinal cross-sectional view schematically showing a main portion of an expander in the first embodiment.

[FIG. 3] FIG. 3 is an enlarged view showing a main portion of an expansion mechanism in the first embodiment.

[FIG. 4] FIG. 4 is a transverse cross-sectional view schematically showing states of rotary mechanism parts for every 90° of the rotational angle of an output shaft in the expansion mechanism in the first embodiment.

[FIG. 5] FIG. 5 is a refrigerant circuit diagram illustrating a configuration of an air conditioner according to a first modified example of the first embodiment.

[FIG. 6] FIG. 6 is a refrigerant circuit diagram illustrating a configuration of an air conditioner according to a second modified example of the first embodiment.

[FIG. 7] FIG. 7 is a refrigerant circuit diagram illustrating a configuration of an air conditioner according to a second embodiment.

[FIG. 8] FIG. 8 is a refrigerant circuit diagram illustrating a configuration of an air conditioner according to a modified example of the second embodiment.

[FIG. 9] FIG. 9 is a longitudinal cross-sectional view schematically showing a main portion of an expander in a third embodiment.

[FIG. 10] FIG. 10 is a transverse cross-sectional view schematically showing the state of a rotary mechanism for every 90° of the rotational angle of an output shaft in the third embodiment.

[FIG. 11] FIG. 11 is a longitudinal cross-sectional view schematically showing a main portion of an expander in a modified example of the third embodiment.

Description of Characters

[0039]

- 10 air conditioner (refrigeration system)
- 11 refrigerant circuit
- 17 first pipe (first suction-side passageway)
- 18 second pipe (second suction-side passageway)
- 20 compressor
- 21 compression mechanism
- 24 compressor casing
- 30 expander
- 31 expansion mechanism
- 33 electric generator
- 34 expander casing
- 41 oil supply pipe (oil supply passageway)
- 42 oil return pipe (oil return passageway)
- 46 cooling heat exchanger
- 47 cooling heat exchanger
- 48 cooling heat exchanger

BEST MODE FOR CARRYING OUT THE INVENTION

[0040] Hereinafter, embodiments of the present invention will be specifically described with reference to the drawings.

«EMBODIMENT 1»

[0041] A first embodiment of the present invention is now described. This embodiment is directed to an air conditioner (10) configured by a refrigeration system according to the present invention.

<Overall Configuration of Air Conditioner>

[0042] As illustrated in FIG. 1, the air conditioner (10) of this embodiment includes a refrigerant circuit (11). A compressor (20), an expander (30), an outdoor heat exchanger (14), an indoor heat exchanger (15), a first four-way selector valve (12), and a second four-way selector valve (13) are connected to the refrigerant circuit (11). The refrigerant circuit (11) is filled with carbon dioxide

(CO₂) as refrigerant. The refrigerant circuit (11) includes an oil supply pipe (41), an oil return pipe (42), and a cooling heat exchanger (46).

[0043] The configuration of the refrigerant circuit (11) is now described. A discharge pipe (26) of the compressor (20) is connected to a first port of the first four-way selector valve (12), and a suction pipe (25) of the compressor (20) is connected to a second port of the first four-way selector valve (12). An outflow pipe (36) of the expander (30) is connected to a first port of the second four-way selector valve (13), and an inflow pipe (35) of the expander (30) is connected to a second port of the second four-way selector valve (13). An end of the outdoor heat exchanger (14) is connected to a third port of the first four-way selector valve (12), and the other end of the outdoor heat exchanger (14) is connected to a fourth port of the second four-way selector valve (13). An end of the indoor heat exchanger (15) is connected to a third port of the second four-way selector valve (13), and the other end of the indoor heat exchanger (15) is connected to a fourth port of the first four-way selector valve (12). In this refrigerant circuit (11), a pipe connecting the suction pipe (25) of the compressor (20) and the second port of the first four-way selector valve (12) constitutes a suction-side pipe (16).

[0044] The outdoor heat exchanger (14) is an air-heat exchanger for performing heat exchange between refrigerant and the outdoor air. The indoor heat exchanger (15) is an air-heat exchanger for performing heat exchange between refrigerant and the indoor air. Each of the first four-way selector valve (12) and the second four-way selector valve (13) is configured to switch between a first position (i.e., the position indicated by the solid lines in FIG. 1) in which the first and third ports communicate with each other and the second and fourth ports communicate with each other, and a second position (i.e., the position indicated by the broken lines in FIG. 1) in which the first and fourth ports communicate with each other and the second and third ports communicate with each other.

[0045] The compressor (20) is a so-called high-pressure domed hermetic compressor. This compressor (20) includes a compressor casing (24) in an elongated cylindrical shape. The compressor casing (24) houses a compression mechanism (21), an electric motor (23), and a driving shaft (22). The compression mechanism (21) constitutes a so-called rotary positive-displacement fluid machine. In the compressor casing (24), the electric motor (23) is placed above the compression mechanism (21). The driving shaft (22) extends vertically, and couples the compression mechanism (21) and the electric motor (23) together.

[0046] The compressor casing (24) includes the suction pipe (25) and the discharge pipe (26). The suction pipe (25) penetrates the side surface of the compressor casing (24) at a location near the bottom of the compressor casing (24). An end of the suction pipe (25) is directly connected to the compression mechanism (21). The dis-

charge pipe (26) penetrates a top portion of the compressor casing (24). A starting end of the discharge pipe (26) is open to the space above the electric motor (23) in the compressor casing (24). The compression mechanism (21) compresses refrigerant sucked from the suction pipe (25), and releases the refrigerant into the compressor casing (24).

[0047] Refrigeration oil serving as lubricating oil is stored in the bottom of the compressor casing (24). In this embodiment, polyalkylene glycol (PAG) is used as refrigeration oil. Although not shown, an oil supply passageway is formed in the driving shaft (22) along the axis of the driving shaft (22). This oil supply passageway is open at the bottom of the driving shaft (22). The bottom of the driving shaft (22) is immersed in an oil sump (27). The refrigeration oil in the compressor casing (24) is supplied to the compression mechanism (21) through the oil supply passageway of the driving shaft (22).

[0048] The expander (30) includes an expander casing (34) having an elongated cylindrical shape. The expander casing (34) houses an expansion mechanism (31), an electric generator (33), and an output shaft (32). The expansion mechanism (31) constitutes a so-called rotary positive-displacement fluid machine. The expansion mechanism (31) will be described in detail later. In the expander casing (34), the electric generator (33) is placed below the expansion mechanism (31). The output shaft (32) vertically extends, and couples the expansion mechanism (31) and the electric generator (33) together.

[0049] The expander casing (34) includes an inflow pipe (35) and an outflow pipe (36). Each of the inflow pipe (35) and the outflow pipe (36) penetrates the side surface of the expander casing (34) at locations near the top of the expander casing (34). The terminal end of the inflow pipe (35) is directly connected to the expansion mechanism (31). The starting end of the outflow pipe (36) is directly connected to the expansion mechanism (31). The expansion mechanism (31) expands refrigerant from the inflow pipe (35), and sends the expanded refrigerant to the outflow pipe (36). That is, refrigerant passing through the expander (30) does not flow into the internal space of the expander casing (34), but passes only through the expansion mechanism (31).

[0050] The starting end of the oil supply pipe (41) is connected to the compressor (20), and the terminal end of the oil supply pipe (41) is connected to the expander (30). Specifically, the starting end of the oil supply pipe (41) penetrates a bottom portion of the compressor casing (24), and is open to the internal space of the compressor casing (24). This starting end of the oil supply pipe (41) is immersed in refrigeration oil which has accumulated in the bottom of the compressor casing (24), and is open at approximately the same level as the bottom of the driving shaft (22). On the other hand, the terminal end of the oil supply pipe (41) is directly connected to the expansion mechanism (31) in the expander casing (34). The location at which the oil supply pipe (41) is connected to the expansion mechanism (31) will be de-

scribed later. This oil supply pipe (41) constitutes an oil supply passageway. Refrigeration oil which has accumulated in the bottom of the compressor casing (24) is supplied to the expansion mechanism (31) through the oil supply pipe (41).

[0051] The cooling heat exchanger (46) is connected to the oil supply pipe (41) and the suction-side pipe (16). This cooling heat exchanger (46) performs heat exchange between refrigeration oil flowing in the oil supply pipe (41) and refrigerant flowing in the suction-side pipe (16).

[0052] The starting end of the oil return pipe (42) is connected to the expander (30), and the terminal end of the oil return pipe (42) is connected to the suction-side pipe (16). Specifically, the starting end of the oil return pipe (42) penetrates a bottom portion of the expander casing (34), and is open to the internal space of the expander casing (34). The starting end of this oil return pipe (42) is open near the bottom of the expander casing (34). On the other hand, the terminal end of the oil return pipe (42) is connected to a portion of the suction-side pipe (16) downstream from the cooling heat exchanger (46). In the expander (30), refrigeration oil which has leaked from the expansion mechanism (31) accumulates in the expander casing (34). The refrigeration oil that has accumulated in the expander casing (34) is introduced into the suction-side pipe (16) through the oil return pipe (42), and is sucked into the compression mechanism (21) together with refrigerant which has flown through the suction-side pipe (16).

<Configuration of Expander>

[0053] A configuration of the expander (30) is described in detail with reference to FIGS. 2 through 4.

[0054] As illustrated in FIG. 2, two eccentric portions (79, 89) are formed at the top of the output shaft (32). The two eccentric portions (79, 89) have larger diameters than that of a main shaft portion (38). One of the eccentric portions (79, 89) located at the lower level is the first eccentric portion (79), and the other located at the upper level is the second eccentric portion (89). The first eccentric portion (79) and the second eccentric portion (89) are eccentric to the same direction. The outer diameter of the second eccentric portion (89) is larger than that of the first eccentric portion (79). The eccentricity of the main shaft portion (38) with respect to the axis thereof is higher in the second eccentric portion (89) than in the first eccentric portion (79).

[0055] The output shaft (32) has an oil supply passageway (90). The oil supply passageway (90) extends along the axis of the output shaft (32). An end of the oil supply passageway (90) is open at the top surface of the output shaft (32). Near the other end of the oil supply passageway (90), the oil supply passageway (90) is bent at a right angle, then runs along the diameter of the output shaft (32), and is open at the outer periphery of the output shaft (32) at a location slightly below the first eccentric portion

(79). The oil supply passageway (90) includes two branch passageways (91, 92) extending along the diameter of the output shaft (32). The first branch passageway (91) is open at the outer periphery of the first eccentric portion (79). The second branch passageway (92) is open at the outer periphery of the second eccentric portion (89).

[0056] The expansion mechanism (31) is a so-called rotary fluid machine of a swinging piston type. This expansion mechanism (31) includes two pairs of cylinders (71, 81) and pistons (75, 85). The expansion mechanism (31) also includes a front head (61), an intermediate plate (63), and a rear head (62).

[0057] In the expansion mechanism (31), the front head (61), the first cylinder (71), the intermediate plate (63), the second cylinder (81), the rear head (62), and an upper plate (65) are stacked in this order. In this state, the lower surface of the first cylinder (71) is closed with the front head (61), and the upper surface of the first cylinder (71) is closed with the intermediate plate (63). On the other hand, the lower surface of the second cylinder (81) is closed with the intermediate plate (63), and the upper surface of the second cylinder (81) is closed with the rear head (62). The inner diameter of the second cylinder (81) is larger than that of the first cylinder (71).

[0058] The output shaft (32) penetrates the stack of the front head (61), the first cylinder (71), the intermediate plate (63), and the second cylinder (81). The first eccentric portion (79) of the output shaft (32) is located in the first cylinder (71), and the second eccentric portion (89) of the first eccentric portion (79) is located in the second cylinder (81).

[0059] As also illustrated in FIGS. 3 and 4, the first piston (75) is provided in the first cylinder (71), and the second piston (85) is provided in the second cylinder (81). Each of the first and second pistons (75, 85) is in the shape of a ring or a cylinder. The outer diameter of the first piston (75) is equal to the outer diameter of the second piston (85). The inner diameter of the first piston (75) is approximately equal to the outer diameter of the first eccentric portion (79), and the inner diameter of the second piston (85) is approximately equal to the outer diameter of the second eccentric portion (89). The first eccentric portion (79) penetrates the first piston (75), and the second eccentric portion (89) penetrates the second piston (85).

[0060] The outer periphery of the first piston (75) is in slidable contact with the inner periphery of the first cylinder (71). An end surface of the first piston (75) is in slidable contact with the front head (61), and the other end surface of the first piston (75) is in slidable contact with the intermediate plate (63). In the first cylinder (71), a first fluid chamber (72) is formed between the inner periphery of the first cylinder (71) and the outer periphery of the first piston (75). On the other hand, the outer periphery of the second piston (85) is in slidable contact with the inner periphery of the second cylinder (81). An end surface of the second piston (85) is in slidable contact with the rear head (62), and the other end surface of the

second piston (85) is in slidable contact with the intermediate plate (63). In the second cylinder (81), a second fluid chamber (82) is formed between the inner periphery of the second cylinder (81) and the outer periphery of the second piston (85).

[0061] The first and second pistons (75, 85) are respectively provided with, and continuous to, blades (76, 86). The blades (76, 86) are in the shape of plates extending in the radius direction of the pistons (75, 85), and project outward from the outer peripheries of the pistons (75, 85). The blade (76) of the first piston (75) is inserted in a bushing hole (78) of the first cylinder (71), and the blade (86) of the second piston (85) is inserted in a bushing hole (88) of the second cylinder (81). The bushing holes (78, 88) of the cylinders (71, 81) are respectively formed through the cylinders (71, 81) in the direction along the thickness of the cylinders (71, 81), and are respectively open at the inner peripheries of the cylinders (71, 81).

[0062] Each of the cylinders (71, 81) includes a pair of bushings (77, 87). Each of the bushings (77, 87) is a small piece whose inner surface is flat and outer surface forms an arc. In each of the cylinders (71, 81), the pair of bushings (77, 87) is inserted in the bushing hole (78, 88) to sandwich the blade (76, 86). The inner surfaces of the bushings (77, 87) are in slidable contact with the blade (76, 86), and the outer peripheries of the bushings (77, 87) are slidable along the cylinder (71, 81). The blade (76, 86) continuous to the piston (75, 85) is supported by the cylinder (71, 81) with the bushings (77, 87) interposed therebetween, and is rotatable about, and movable forward and away from, the cylinder (71, 81).

[0063] The first fluid chamber (72) in the first cylinder (71) is partitioned by the first blade (76) continuous to the first piston (75). In FIGS. 3 and 4, the portion at the left of the first blade (76) is a first high-pressure chamber (73) with a higher pressure, and the portion at the right of the first blade (76) is a first low-pressure chamber (74) with a lower pressure. The second fluid chamber (82) in the second cylinder (81) is partitioned by the second blade (86) continuous to the second piston (85). In FIGS. 3 and 4, the portion at the left of the second blade (86) is a second high-pressure chamber (83) with a higher pressure, and the portion at the right of the second blade (86) is a second low-pressure chamber (84) with a lower pressure.

[0064] The first cylinder (71) and the second cylinder (81) are positioned such that the locations of the bushings (77, 87) coincide with each other in the peripheral direction. In other words, the second cylinder (81) is placed at an angle of 0° with respect to the first cylinder (71). As described above, the first eccentric portion (79) and the second eccentric portion (89) are eccentric to the same direction with respect to the axis of the main shaft portion (38). Accordingly, the first blade (76) is at the most backward position closest to the outside of the first cylinder (71), and the second blade (86) is at the most backward position closest to the outside of the second cylinder (81).

[0065] The first cylinder (71) includes an inflow port (67). The inflow port (67) is open at a portion of the inner periphery of the first cylinder (71) slightly at the left of the bushings (77) in FIGS. 3 and 4. The inflow port (67) can communicate with the first high-pressure chamber (73). Although not shown, the inflow pipe (35) is connected to the inflow port (67).

[0066] The second cylinder (81) includes an outflow port (68). The outflow port (68) is open at a portion of the inner periphery of the second cylinder (81) slightly at the right of the bushings (87) in FIGS. 3 and 4. The outflow port (68) can communicate with the second low-pressure chamber (84). Although not shown, the outflow pipe (36) is connected to the outflow port (68).

[0067] The intermediate plate (63) includes a communication path (64). This communication path (64) penetrates the intermediate plate (63) in the direction along the thickness of the intermediate plate (63). An end of the communication path (64) is open at the surface of the intermediate plate (63) facing the first cylinder (71) at the right of the first blade (76). The other end of the communication path (64) is open at the surface of the intermediate plate (63) facing the second cylinder (81) at the left of the second blade (86). As illustrated in FIG. 3, the communication path (64) extends obliquely with respect to the thickness direction of the intermediate plate (63), and establishes communication between the first low-pressure chamber (74) and the second high-pressure chamber (83).

[0068] As described above, the first low-pressure chamber (74) of the first rotary mechanism part (70) and the second high-pressure chamber (83) of the second rotary mechanism part (80) communicate with each other through the communication path (64). The first low-pressure chamber (74), the communication path (64), and the second high-pressure chamber (83) form a single closed space. This closed space constitutes an expansion chamber (66).

[0069] The front head (61) is shaped such that a center portion of the front head (61) projects downward. A through hole is formed in the center portion of the front head (61), and the output shaft (32) is inserted in this through hole. The front head (61) constitutes a sliding bearing which supports the bottom of the first eccentric portion (79) of the output shaft (32). The front head (61) has a circumferential trench in a lower portion of the through hole in which the main shaft portion (38) of the output shaft (32) is inserted. This circumferential trench faces an end of the oil supply passageway (90) which is open at the outer periphery of the output shaft (32), and constitutes a lower oil reservoir (102).

[0070] A through hole is formed in a center portion of the rear head (62). The main shaft portion (38) of the output shaft (32) is inserted in this through hole. The rear head (62) constitutes a sliding bearing which supports the top of the second eccentric portion (89) of the output shaft (32).

[0071] The upper plate (65) is in the shape of a rela-

tively thick disk, and is placed on the rear head (62). The upper plate (65) has a circular recess at a center portion of the bottom. The upper plate (65) is positioned such that the circular recess thereof faces the top surface of the output shaft (32). The terminal end of the oil supply pipe (41) is connected to the upper plate (65). The terminal end of the oil supply pipe (41) penetrates the upper plate (65) downward, and is open at the circular recess. The circular recess of the upper plate (65) constitutes an upper oil reservoir (101) for storing refrigeration oil supplied from the oil supply pipe (41). The upper plate (65) has a recessed trench (103) at its lower surface. The recessed trench (103) extends from the rim of the upper oil reservoir (101) toward the outer periphery of the upper plate (65).

[0072] In the expansion mechanism (31), the rear head (62) has a first oil passageway (111), the intermediate plate (63) has a second oil passageway (112), and the front head (61) has a third oil passageway (113). The first oil passageway (111) penetrates the rear head (62) in the thickness direction, and allows the terminal end of the recessed trench (103) to communicate with the bushing hole (88) of the second cylinder (81). The second oil passageway (112) penetrates the intermediate plate (63) in the thickness direction, and allows the bushing hole (88) of the second cylinder (81) to communicate with the bushing hole (78) of the first cylinder (71). In the front head (61), an end of the third oil passageway (113) is open at a portion of the upper surface of the front head (61) facing the bushing hole (78) of the first cylinder (71). In the front head (61), the other end of the third oil passageway (113) is open at the inner periphery of the through hole in which the output shaft (32) is inserted.

[0073] In the expansion mechanism (31) of this embodiment configured as described above, the first cylinder (71), the bushings (77) provided in the first cylinder (71), the first piston (75), and the first blade (76) constitute the first rotary mechanism part (70). In addition, the second cylinder (81), the bushings (87) provided in the second cylinder (81), the second piston (85), and the second blade (86) constitute the second rotary mechanism part (80).

-Operation-

[0074] It is now described how the air conditioner (10) operates.

<Cooling Operation>

[0075] During cooling operation, the first four-way selector valve (12) and the second four-way selector valve (13) are set at the first position (i.e., the position indicated by the solid lines in FIG. 1), and refrigerant circulates in the refrigerant circuit (11), thereby performing a vapor compression refrigeration cycle. In the refrigeration cycle performed by the refrigerant circuit (11), the high pressure of this cycle is set at a level higher than the critical

pressure of carbon dioxide which is refrigerant.

[0076] In the compressor (20), the compression mechanism (21) is rotated by the electric motor (23). The compression mechanism (21) compresses refrigerant sucked from the suction pipe (25), and discharges the refrigerant into the compressor casing (24). The high-pressure refrigerant in the compressor casing (24) is discharged from the compressor (20) through the discharge pipe (26). The refrigerant discharged from the compressor (20) is sent to the outdoor heat exchanger (14), and dissipates heat into the outdoor air. The high-pressure refrigerant which has dissipated heat in the outdoor heat exchanger (14) flows into the expander (30).

[0077] In the expander (30), the high-pressure refrigerant which has flown into the expansion mechanism (31) through the inflow pipe (35) is expanded, thereby rotating the electric generator (33). Electric power generated by the electric generator (33) is supplied to the electric motor (23) of the compressor (20). The refrigerant expanded by the expansion mechanism (31) passes through the outflow pipe (36), and is sent from the expander (30). The refrigerant from the expander (30) is sent to the indoor heat exchanger (15). In the indoor heat exchanger (15), the inflow refrigerant takes heat from the indoor air, and evaporates, thereby cooling the indoor air. The low-pressure refrigerant from the indoor heat exchanger (15) flows into the suction pipe (25) of the compressor (20).

<Heating Operation>

[0078] During heating operation, the first four-way selector valve (12) and the second four-way selector valve (13) are set at the second position (i.e., the position indicated by the broken lines in FIG. 1), and refrigerant circulates in the refrigerant circuit (11), thereby performing a vapor compression refrigeration cycle. In the same manner as in the cooling operation, in the refrigeration cycle performed by the refrigerant circuit (11), the high pressure of this cycle is set at a level higher than the critical pressure of carbon dioxide which is refrigerant.

[0079] In the compressor (20), the compression mechanism (21) is rotated by the electric motor (23). The compression mechanism (21) compresses refrigerant sucked from the suction pipe (25), and discharges the refrigerant into the compressor casing (24). The high-pressure refrigerant in the compressor casing (24) is discharged from the compressor (20) through the discharge pipe (26). The refrigerant discharged from the compressor (20) is sent to the indoor heat exchanger (15). In the indoor heat exchanger (15), the inflow refrigerant dissipates heat into the indoor air, thereby heating the indoor air. The high-pressure refrigerant which has dissipated heat in the indoor heat exchanger (15) flows into the expander (30).

[0080] In the expander (30), the high-pressure refrigerant which has flown into the expansion mechanism (31) through the inflow pipe (35) is expanded, thereby rotating the electric generator (33). Power generated by the elec-

tric generator (33) is supplied to the electric motor (23) of the compressor (20). The refrigerant expanded by the expansion mechanism (31) passes through the outflow pipe (36), and is sent from the expander (30). The refrigerant from the expander (30) is sent to the outdoor heat exchanger (14). In the outdoor heat exchanger (14), the inflow refrigerant takes heat from the outdoor air, and evaporates. The low-pressure refrigerant from the outdoor heat exchanger (14) flows into the suction pipe (25) of the compressor (20).

<Lubricating Operation of Compressor and Expander>

[0081] It is now described how the compressor (20) and the expander (30) are lubricated with refrigeration oil.

[0082] In the compressor (20), the internal pressure of the compressor casing (24) is approximately equal to the pressure of refrigerant discharged from the compression mechanism (21). Accordingly, the pressure of refrigeration oil which has accumulated in the bottom of the compressor casing (24) is approximately equal to the pressure of the refrigerant discharged from the compression mechanism (21). On the other hand, the compression mechanism (21) sucks low-pressure refrigerant from the suction pipe (25). Accordingly, the compression mechanism (21) has a portion having a lower pressure than the internal pressure of the compressor casing (24). Accordingly, the refrigeration oil in the bottom of the compressor casing (24) flows into the compression mechanism (21) through the oil supply passageway (90) in the driving shaft (22), and is used for lubricating the compression mechanism (21). The refrigeration oil supplied to the compression mechanism (21) is discharged into the compressor casing (24) together with compressed refrigerant, and returns to the bottom of the compressor casing (24) again.

[0083] The pressure of refrigerant circulating in the refrigerant circuit (11) decreases to some extent, while traveling from the compressor (20) to the expander (30). Accordingly, the pressure of refrigerant passing through the expansion mechanism (31) is always lower than the internal pressure of the compressor casing (24). Thus, the refrigeration oil in the bottom of the compressor casing (24) flows into the expansion mechanism (31) through the oil supply pipe (41). At this time, the refrigeration oil which has flown into the oil supply pipe (41) is cooled through heat exchange by the cooling heat exchanger (46) with refrigerant in the suction-side pipe (16), and then flows into the expansion mechanism (31).

[0084] The refrigeration oil which has flown into the expansion mechanism (31) is used for lubricating the expansion mechanism (31). Thereafter, part of this refrigeration oil leaks from the expansion mechanism (31), and accumulates in the bottom of the expander casing (34), whereas the other part of the refrigeration oil flows from the expander (30) together with expanded refrigerant. The refrigeration oil which has flown from the expander (30) together with the refrigerant flows into the refrigerant

circuit (11) together with the refrigerant, and is sucked into the compressor (20). On the other hand, the refrigeration oil which has accumulated in the bottom of the expander casing (34) flows into the suction-side pipe (16) through the oil return pipe (42), and is sucked into the compressor (20) together with refrigerant. The refrigerant flowing in the suction-side pipe (16) has the lowest pressure in the refrigerant circuit (11). Accordingly, the refrigeration oil in the expander casing (34) passes through the oil return pipe (42), and flows into the suction-side pipe (16).

[0085] The refrigeration oil sucked into the compression mechanism (21) of the compressor (20) together with the refrigerant is discharged from the compression mechanism (21) into the internal space of the compressor casing (24) together with the compressed refrigerant, and then flows down to the bottom of the compressor casing (24).

<Operation of Expansion Mechanism>

[0086] It is now described how the expansion mechanism (31) operates with reference to FIG. 4.

[0087] First, a process in which high-pressure refrigerant in a supercritical state flows into the first high-pressure chamber (73) of the first rotary mechanism part (70) is described. When the output shaft (32) is slightly rotated from a state at a rotation angle of 0°, the portion at which the first piston (75) and the first cylinder (71) are in contact with each other passes by the opening of the inflow port (67), and high-pressure refrigerant starts to flow from the inflow port (67) into the first high-pressure chamber (73). Then, while the rotation angle of the output shaft (32) increases to 90°, 180°, and 270°, the high-pressure refrigerant flows into the first high-pressure chamber (73). This high-pressure refrigerant continues to flow into the first high-pressure chamber (73) until the rotation angle of the output shaft (32) reaches 360°.

[0088] Next, a process in which refrigerant is expanded by the expansion mechanism (31) is described. When the output shaft (32) is slightly rotated from a state at a rotation angle of 0°, the first low-pressure chamber (74) and the second high-pressure chamber (83) communicate with each other through the communication path (64), and refrigerant starts to flow from the first low-pressure chamber (74) into the second high-pressure chamber (83). As the rotation angle of the output shaft (32) increases to 90°, 180°, and 270°, the volume of the first low-pressure chamber (74) decreases, whereas the volume of the second high-pressure chamber (83) increases, resulting in an increase in the volume of the expansion chamber (66). This increase in the volume of the expansion chamber (66) continues immediately before the rotation angle of the output shaft (32) reaches 360°. While the volume of the expansion chamber (66) increases, refrigerant in the expansion chamber (66) is expanded, thereby rotating the output shaft (32). In this manner, refrigerant in the first low-pressure chamber (74) contin-

ues to be expanded, and flows into the second high-pressure chamber (83) through the communication path (64).

[0089] Then, a process in which refrigerant flows from the second low-pressure chamber (84) of the second rotary mechanism part (80) is described. The second low-pressure chamber (84) starts to communicate with the outflow port (68) at the time when the rotation angle of the output shaft (32) is 0°. That is, refrigerant starts to flow from the second low-pressure chamber (84) into the outflow port (68). Thereafter, the rotation angle of the output shaft (32) gradually increases to 90°, 180°, and 270°, and expanded low-pressure refrigerant continues to flow from the second low-pressure chamber (84) until the rotation angle reaches 360°.

[0090] In the expansion mechanism (31), refrigeration oil supplied through the oil supply pipe (41) is introduced into the upper oil reservoir (101). The refrigeration oil introduced into the upper oil reservoir (101) is distributed among the oil supply passageway (90) of the output shaft (32), sliding portions of the output shaft (32) and the rear head (62), and the recessed trench (103).

[0091] Part of the refrigeration oil which has flown into the oil supply passageway (90) of the output shaft (32) is supplied to sliding portions of the eccentric portions (79, 89) and the pistons (75, 85) through the branch passageways (91, 92), and the other part of the refrigeration oil flows into the lower oil reservoir (102). The refrigeration oil which has flown into the lower oil reservoir (102) is supplied to sliding portions of the output shaft (32) and the front head (61).

[0092] The refrigeration oil which has flown into the recessed trench (103) passes through the first oil passageway (111), and flows into the bushing hole (88) of the second cylinder (81). Part of the refrigeration oil which has flown into the bushing hole (88) is supplied to sliding portions of the second cylinder (81) and the bushings (87) and to sliding portions of the second blade (86) and the bushings (87). The other part of the refrigeration oil which has flown into the bushing hole (88) flows into the bushing hole (78) of the first cylinder (71) through the second oil passageway (112). Part of this refrigeration oil which has flown into the bushing hole (78) is supplied to sliding portions of the first cylinder (71) and the bushings (77) and to sliding portions of the first blade (76) and the bushings (77). The other part of the refrigeration oil which has flown into the bushing hole (78) is supplied to a gap between the front head (61) and the output shaft (32) through the third oil passageway (113).

-Advantages of EMBODIMENT 1-

[0093] In this embodiment, refrigeration oil is stored in the compressor casing (24) whose internal pressure is equal to the pressure of refrigerant immediately after being discharged from the compression mechanism (21), and this refrigeration oil is supplied to both the compression mechanism (21) and the expansion mechanism (31). In other words, in this embodiment, refrigeration oil

is stored in a part having the highest pressure in the refrigerant circuit (11), and this refrigeration oil is supplied to the compression mechanism (21) and the expansion mechanism (31) each having a portion whose pressure is lower than the internal pressure of the compressor casing (24). Accordingly, the source of refrigeration oil has a higher pressure than the destination thereof, thus ensuring the supply of refrigeration oil to the compression mechanism (21) and the expansion mechanism (31). Thus, in this embodiment, a sufficient amount of refrigeration oil is supplied to the compression mechanism (21) and the expansion mechanism (31), thus preventing troubles such as seizing of the compression mechanism (21) and the expansion mechanism (31). As a result, high reliability of the air conditioner (10) can be obtained.

[0094] In addition, in this embodiment, refrigeration oil which has accumulated in the expander casing (34) returns to the compressor (20) through the oil return pipe (42). Since the amount of refrigeration oil contained in the refrigerant circuit (11) is constant, an increase in the amount of refrigeration oil in the expander casing (34) causes a decrease in the amount of refrigeration oil stored in the compressor casing (24) accordingly. Thus, an insufficient amount of refrigeration oil might be supplied to the compression mechanism (21) and the expansion mechanism (31). On the other hand, in the present invention, refrigeration oil in the expander casing (34) is sent back to the compression mechanism (21) through the oil return pipe (42). Accordingly, in this embodiment, a sufficient amount of refrigeration oil is stored in the compressor casing (24), thus further ensuring the supply of refrigeration oil to the compression mechanism (21) and the expansion mechanism (31).

[0095] Moreover, in this embodiment, refrigeration oil which has accumulated in the expander casing (34) is sent to the suction-side pipe (16). The suction-side pipe (16) connected to the suction pipe (25) of the compression mechanism (21) has the lowest pressure in the refrigerant circuit (11). More specifically, a pressure difference occurs between the internal space of the expander casing (34) in which refrigeration oil accumulates and the destination to which the refrigeration oil returns. Accordingly, in this embodiment, refrigeration oil in the expander casing (34) is sent back to the compressor (20) as intended, resulting in that a sufficient amount of refrigeration oil is stored in the compressor casing (24).

[0096] In the internal space of the compressor casing (24), both refrigeration oil and refrigerant discharged from the compression mechanism (21) are present. Accordingly, the temperature of the refrigeration oil stored in the compressor casing (24) is approximately equal to that of the refrigerant discharged from the compression mechanism (21). On the other hand, the temperature of refrigerant immediately after being discharged from the compression mechanism (21) is about 80°C to about 100°C in some cases, and is highest among portions of refrigerant circulating in the refrigerant circuit (11). Thus, if high-temperature refrigeration oil stored in the compres-

sor casing (24) were supplied to the expansion mechanism (31) without any treatment, refrigerant passing through the expansion mechanism (31) at a temperature of about 0°C to about 30°C would be heated by this refrigeration oil, thus increasing the enthalpy of the refrigerant flowing from the expansion mechanism (31). The increase in the enthalpy of the refrigerant flowing from the expansion mechanism (31) might reduce the amount of heat absorbed in the indoor heat exchanger (15) and the outdoor heat exchanger (14) to cause performance degradation of the air conditioner (10).

[0097] On the other hand, in this embodiment, refrigeration oil discharged from the compressor casing (24) and sent through in the oil supply pipe (41) is cooled by the cooling heat exchanger (46), and then is supplied to the expansion mechanism (31). Accordingly, the amount of heat entering into refrigerant passing through the expansion mechanism (31) from the refrigeration oil supplied through the oil supply pipe (41) can be smaller than that in a case where refrigeration oil stored in the compressor casing (24) is introduced into the expansion mechanism (31) without any treatment. Thus, in this embodiment, the enthalpy of the refrigerant flowing from the expansion mechanism (31) can be reduced, thus suppressing degradation of cooling or heating performance of the air conditioner (10).

[0098] In particular, in this embodiment, the cooling heat exchanger (46) performs heat exchange between refrigerant sucked into the compression mechanism (21) (i.e., refrigerant having the lowest temperature among portions of refrigerant circulating in the refrigerant circuit (11)) and refrigeration oil flowing in the oil supply pipe (41). Accordingly, in this embodiment, it is possible to ensure a reduction in the temperature of refrigeration oil introduced into the expansion mechanism (31) through the oil supply pipe (41), thus further ensuring suppression of performance degradation of the air conditioner (10).

-Modified Example of EMBODIMENT 1-

[0099] As illustrated in FIG. 5, the air conditioner (10) of this embodiment may include a cooling heat exchanger (47) connected to the oil supply pipe (41) and the oil return pipe (42), in addition to the cooling heat exchanger (46) connected to the oil supply pipe (41) and the suction-side pipe (16). This cooling heat exchanger (47) performs heat exchange between refrigeration oil flowing in the oil supply pipe (41) and refrigerant flowing in the oil return pipe (42).

[0100] As described above, the temperature of refrigerant passing through the expansion mechanism (31) is in the range from about 0°C to about 30°C. Accordingly, the temperature of refrigeration oil which has leaked from the expansion mechanism (31) and accumulated in the expander casing (34) is relatively low at approximately the same level as the refrigerant passing through the expansion mechanism (31). The cooling heat exchanger (47) performs heat exchange between refrigeration oil

having a relatively high temperature and flowing through the oil supply pipe (41) from the compressor casing (24) and refrigeration oil having a relatively low temperature and flowing in the oil return pipe (42) from the expander casing (34).

[0101] The expansion mechanism (31) receives refrigeration oil which has been sequentially cooled by those two cooling heat exchanger (46, 47). Thus, the temperature of refrigeration oil introduced into the expansion mechanism (31) through the oil supply pipe (41) can be further reduced, thus further ensuring suppression of performance degradation of the air conditioner (10).

-Modified Example 2 of EMBODIMENT 1-

[0102] As illustrated in FIG. 6, the air conditioner (10) of this embodiment may include a cooling heat exchanger (48) configured to perform heat exchange between refrigeration oil in the oil supply pipe (41) and the outdoor air, in addition to the cooling heat exchanger (46) connected to the oil supply pipe (41) and the suction-side pipe (16). This cooling heat exchanger (48) is located on the oil supply pipe (41) upstream from the cooling heat exchanger (46) connected to the oil supply pipe (41) and the suction-side pipe (16).

[0103] As described above, the temperature of refrigerant immediately after being discharged from the compression mechanism (21) is about 80°C to about 100°C. The temperature of refrigeration oil stored in the compressor casing (24) is also approximately equal to this temperature. On the other, the temperature of the outdoor air is normally about 30°C to 40°C even in summer, and seldom exceeds 50°C. That is, the temperature of refrigeration oil flowing in the oil supply pipe (41) is higher than that of the outdoor air. Accordingly, in the cooling heat exchanger (48), the refrigeration oil flowing in the oil supply pipe (41) is cooled by the outdoor air.

[0104] The expansion mechanism (31) receives refrigeration oil which has been sequentially cooled by those two cooling heat exchangers (48, 46). Accordingly, the temperature of the refrigeration oil introduced into the expansion mechanism (31) through the oil supply pipe (41) can be further reduced, thus further ensuring suppression of performance degradation of the air conditioner (10).

«EMBODIMENT 2»

[0105] A second embodiment of the present invention is now described. In this embodiment, an expander casing (34) also functions as an accumulator. Now, aspects of an air conditioner (10) of this embodiment different from those in the first embodiment are described.

[0106] As illustrated in FIG. 7, in a refrigerant circuit (11) of this embodiment, a suction-side pipe (16) is constituted by a first pipe (17) and a second pipe (18).

[0107] An end of the first pipe (17) is connected to a second port of a first four-way selector valve (12). The

other end of the first pipe (17) is connected to the expander casing (34), and is open to the internal space of the expander casing (34) at a location between an expansion mechanism (31) and an electric generator (33).

5 This first pipe (17) constitutes a first suction-side passageway for establishing communication between one of an indoor heat exchanger (15) and an outdoor heat exchanger (14) which serves as an evaporator, and the internal space of the expander casing (34).

10 **[0108]** An end of the second pipe (18) is connected to the expander casing (34), and is open to the internal space of the expander casing (34) at a location between the expansion mechanism (31) and the electric generator (33). The other end of the second pipe (18) is connected to a suction pipe (25) of a compressor (20). This second pipe (18) constitutes a second suction-side passageway for establishing communication between the internal space of the expander casing (34) and the suction side of the compressor (20). In this embodiment, the oil return pipe (42) is connected to a portion of the second pipe (18) upstream from the cooling heat exchanger (46).

20 **[0109]** In one of the indoor heat exchanger (15) and the outdoor heat exchanger (14) serving as an evaporator, refrigerant which has flown therein does not completely evaporate, and part of the refrigerant remains in the state of liquid refrigerant and flows therefrom, in some cases. In such cases, if a large amount of liquid refrigerant flows from the heat exchanger (14, 15), the liquid refrigerant might be sucked into the compression mechanism (21) to cause damage on the compression mechanism (21).

25 **[0110]** On the other hand, in this embodiment, even if refrigerant in a gas-liquid two-phase state flows from the first pipe (17) into the internal space of the expander casing (34), this refrigerant is separated into gas refrigerant and liquid refrigerant in the expander casing (34), and the gas refrigerant is sent to the compression mechanism (21) through the second pipe (18). Accordingly, most of the refrigerant sucked into the compression mechanism (21) is gas refrigerant. That is, in this embodiment, the expander casing (34) also functions as an accumulator, and it is possible to prevent damage on the compressor (20) due to liquid back without providing any additional accumulator.

45

-Modified Example of EMBODIMENT 2-

[0111] In this embodiment, the location on the expander casing (34) to which the first pipe (17) is connected may be changed.

50 **[0112]** As illustrated in FIG. 8, the first pipe (17) of this modified example is connected to a lower portion of the expander casing (34), and is open to the internal space of the expander casing (34) at a location below the electric generator (33). In this modified example, refrigerant which has flown into the internal space of the expander casing (34) through the first pipe (17) passes upward through a gap between the rotor and the stator, for ex-

ample, in the electric generator (33), and then flows into the second pipe (18).

[0113] When the refrigerant passes through the electric generator (33), liquid refrigerant in this refrigerant flows downward, being in contact with the electric generator (33), and gas refrigerant in this refrigerant mainly reaches the second pipe (18) through the electric generator (33). Accordingly, in this modified example, it is possible to ensure separation into gas refrigerant and liquid refrigerant in the internal space of the expander casing (34), thus further ensuring prevention of damage on the compressor (20) due to liquid back.

[0114] In addition, in this modified example, since refrigerant passes through the electric generator (33), the electric generator (33) is cooled by this refrigerant. Accordingly, in this modified example, a temperature rise in the electric generator (33) can be suppressed, thus enhancing the efficiency of the electric generator (33).

«EMBODIMENT 3»

[0115] A third embodiment of the present invention is now described. An air conditioner (10) according to this embodiment is obtained by changing the configuration of the expander (30) of the first embodiment. Now, aspects of an expander (30) of this embodiment different from those in the first embodiment are described.

[0116] As illustrated in FIG. 9, an output shaft (32) has one eccentric portion (59) at the top thereof. This eccentric portion (59) has a diameter larger than that of a main shaft portion (38) of the output shaft (32). The output shaft (32) includes an oil supply passageway (90). The oil supply passageway (90) extends along the axis of the output shaft (32). An end of the oil supply passageway (90) is open at the top surface of the output shaft (32). The other end of the oil supply passageway (90) is bent at a right angle, then extends in the direction along the diameter of the output shaft (32), and is open at the outer periphery of the output shaft (32) at a location slightly below the eccentric portion (59). The oil supply passageway (90) includes one branch passageway (93) extending in the direction along the diameter of the output shaft (32). This branch passageway (93) is open at the outer periphery of the eccentric portion (59).

[0117] The expansion mechanism (31) is a so-called rotary fluid machine of a swinging piston type. This expansion mechanism (31) includes a front head (61), a cylinder (51), a piston (55), a rear head (62), and an upper plate (65).

[0118] The front head (61), the cylinder (51), the rear head (62), and the upper plate (65) are stacked in this order in the expansion mechanism (31). In this state, the lower surface of the cylinder (51) is closed with the front head (61), and the upper surface of the cylinder (51) is closed with the rear head (62).

[0119] The output shaft (32) penetrates the stack of the front head (61), the cylinder (51), and the rear head (62). The eccentric portion (59) of the output shaft (32)

is located in the cylinder (51).

[0120] As also illustrated in FIG. 10, the piston (55) is provided in the cylinder (51). This piston (55) is in the shape of a ring or a cylinder. The inner diameter of the piston (55) is approximately equal to the outer diameter of the eccentric portion (59). The eccentric portion (59) of the output shaft (32) penetrates the piston (55).

[0121] The outer periphery of the piston (55) is in slidable contact with the inner periphery of the cylinder (51). An end surface of the piston (55) is in slidable contact with the front head (61), and the other end of the piston (55) is in slidable contact with the rear head (62). In the cylinder (51), a fluid chamber (52) is formed between the inner periphery of the cylinder (51) and the outer periphery of the piston (55).

[0122] The piston (55) is provided with, and continuous to, a blade (56). The blade (56) is in the shape of a plate extending in the radius direction of the piston (55), and projects outward from the outer periphery of the piston (55). This blade (56) is inserted into a bushing hole (58) of the cylinder (51). The bushing hole (58) of the cylinder (51) penetrates the cylinder (51) along the thickness direction of the cylinder (51), and is open at the inner periphery of the cylinder (51).

[0123] The cylinder (51) includes a pair of bushings (57). Each of the bushings (57) is a small piece whose inner surface is flat and outer surface forms an arc. In the cylinder (51), the pair of bushings (57) is inserted in the bushing hole (58) to sandwich the blade (56). The inner surfaces of the bushings (57) are in slidable contact with the blade (56), and the outer peripheries of the bushings (57) are slidable along the cylinder (51). The blade (56) continuous to the piston (55) is supported by the cylinder (51) with the bushings (57) interposed therebetween, and is rotatable about, and movable forward and away from, the cylinder (51).

[0124] The fluid chamber (52) in the cylinder (51) is partitioned by the blade (56) continuous to the piston (55). In FIG. 10, the portion at the left of the blade (56) is a high-pressure chamber (53) having a higher pressure, and the portion at the right of the blade (56) is a low-pressure chamber (54) having a lower pressure. The front head (61) has an inflow port (67). The inflow port (67) is open at a portion of the upper surface of the front head (61) facing the high-pressure chamber (53). The opening of the inflow port (67) is located near the inner periphery of the cylinder (51), and at the left of the blade (56) in FIG. 10. The cylinder (51) includes an outflow port (68). The outflow port (68) is open at a portion of the inner periphery of the cylinder (51) slightly at the right of the bushings (57) in FIG. 10. This outflow port (68) can communicate with the low-pressure chamber (54).

[0125] The front head (61) is shaped such that a center portion of the front head (61) projects downward. A through hole is formed in the center portion of the front head (61), and the main shaft portion (38) of the output shaft (32) is inserted in this through hole. The front head (61) constitutes a sliding bearing which supports the bot-

tom of the eccentric portion (59) of the output shaft (32). The front head (61) has a circumferential trench in a lower portion of the through hole in which the output shaft (32) is inserted. This circumferential trench is positioned to face the end of the oil supply passageway (90) which is open at the outer periphery of the output shaft (32), and constitutes a lower oil reservoir (102). The entire shape of the front head (61) and formation of the lower oil reservoir (102) in the front head (61) are the same as in the first embodiment.

[0126] A through hole is formed in a center portion of the rear head (62). The main shaft portion (38) of the output shaft (32) is inserted in this through hole. The rear head (62) constitutes a sliding bearing which supports the top of the eccentric portion (59) of the output shaft (32). A circular recess is also formed in the center portion of the upper surface of the rear head (62) on the same axis as the through hole. This circular recess constitutes an upper oil reservoir (101) for storing refrigeration oil supplied from the oil supply pipe (41). In addition, a recessed trench (103) is formed in the upper surface of the rear head (62). The recessed trench (103) extends from the rim of the upper oil reservoir (101) toward the outer periphery of the rear head (62).

[0127] The upper plate (65) is in the shape of a relatively thick disk, and is placed on the rear head (62). The upper plate (65) is connected to the terminal end of the oil supply pipe (41). The terminal end of the oil supply pipe (41) penetrates the upper plate (65) downward, and is open to the upper oil reservoir (101).

[0128] In the expansion mechanism (31), the rear head (62) includes a first oil passageway (121), and the front head (61) has a second oil passageway (122). The first oil passageway (121) penetrates the rear head (62) in the thickness direction of the rear head (62), and establishes communication between the terminal end of the recessed trench (103) and the bushing hole (58) of the cylinder (51). In the front head (61), an end of the second oil passageway (122) is open at a location on the upper surface of the front head (61) facing the bushing hole (58) of the cylinder (51). In the front head (61), the other end of the second oil passageway (122) is open at the inner periphery of the through hole in which the output shaft (32) is inserted.

-Operation-

[0129] Cooling operation and heating operation of the air conditioner (10), and the supply of refrigeration oil to the compression mechanism (21) and the expansion mechanism (31) are the same as those in the first embodiment. It is now described how the expansion mechanism (31) of this embodiment recovers power from refrigerant with reference to FIG. 10.

[0130] When the output shaft (32) is slightly rotated in the counterclockwise direction in FIG. 10 from the state labeled as (a) (i.e., at a rotation angle of 0°), the inflow port (67) communicates with the high-pressure chamber

(53), and thus high-pressure refrigerant flows from the inflow port (67) into the high-pressure chamber (53). At this time, the low-pressure chamber (54) communicates with the outflow port (68), and the pressure of the low-pressure chamber (54) is approximately equal to the low pressure in the refrigeration cycle. Accordingly, the piston (55) is pushed by the refrigerant which has flown into the high-pressure chamber (53), thereby allowing the output shaft (32) to be continuously rotated in the counterclockwise direction in FIG. 10.

[0131] Then, as sequentially shown in (b) through (d) in FIG. 10, the volume of the high-pressure chamber (53) increases as the piston (55) moves, whereas the volume of the low-pressure chamber (54) decreases as the piston (55) moves. Thereafter, although the piston (55) returns to the state (a) in FIG. 10, the piston (55) continues to be rotated by the inertial force. Then, at the same time when the inflow port (67) establishes communication with the high-pressure chamber (53) again, and the outflow port (68) start communicating with the low-pressure chamber (54), thereby allowing the output shaft (32) to be continuously rotated.

[0132] In the expansion mechanism (31), refrigeration oil supplied through the oil supply pipe (41) is introduced into the upper oil reservoir (101). The refrigeration oil introduced into the upper oil reservoir (101) is distributed among the oil supply passageway (90) of the output shaft (32), sliding portions of the output shaft (32) and the rear head (62), and the recessed trench (103).

[0133] Part of the refrigeration oil which has flown into the oil supply passageway (90) of the output shaft (32) is supplied to sliding surfaces of the eccentric portion (59) and the piston (55) through the branch passageway (93), and the other part of the refrigeration oil flows into the lower oil reservoir (102). The refrigeration oil which has flown into the lower oil reservoir (102) is supplied to sliding portions of the output shaft (32) and the front head (61).

[0134] The refrigeration oil which has flown into the recessed trench (103) flows into the bushing hole (58) of the cylinder (51) through the first oil passageway (121). Part of the refrigeration oil which has flown into the bushing hole (58) is supplied to sliding portions of the cylinder (51) and the bushings (57) and sliding portions of the blade (56) and the bushings (57). The other part of the refrigeration oil which has flown into the bushing hole (58) is supplied to a gap between the front head (61) and the output shaft (32) through the second oil passageway (122).

-Modified Example of EMBODIMENT 3-

[0135] In this embodiment, the oil supply pipe (41) may be connected to the front head (61) of the expansion mechanism (31).

[0136] As illustrated in FIG. 11, the oil supply pipe (41) is connected to the front head (61) from outside in the direction along the diameter of the front head (61) in the

expansion mechanism (31) in this modified example. This oil supply pipe (41) communicates with the second oil passageway (122) of the front head (61). The front head (61) of this modified example has a circumferential trench in an upper portion of the through hole in which the main shaft portion (38) of the output shaft (32) is inserted. This circumferential trench constitutes a lower oil reservoir (102). In this front head (61), the second oil passageway (122) communicates with the lower oil reservoir (102).

[0137] In the output shaft (32) of this modified example, the bottom of the oil supply passageway (90) is open at a portion of the outer periphery of the output shaft (32) near the bottom of the eccentric portion (59), and communicates with the lower oil reservoir (102). In addition to the branch passageway (93) which is open at the outer periphery of the eccentric portion (59), the output shaft (32) has another branch passageway (94). This branch passageway (94) is open at a portion of the outer periphery of the output shaft (32) near the top of the eccentric portion (59).

[0138] In the expansion mechanism (31) of this modified example, refrigeration oil supplied through the oil supply pipe (41) is introduced into the second oil passageway (122). The refrigeration oil introduced into the second oil passageway (122) is distributed between the lower oil reservoir (102) and the bushing hole (58) of the cylinder (51).

[0139] The refrigeration oil which has flown into the lower oil reservoir (102) is distributed between the oil supply passageway (90) of the output shaft (32) and sliding portions of the output shaft (32) and the front head (61). Part of the refrigeration oil which has flown into the oil supply passageway (90) of the output shaft (32) is supplied to sliding portions of the eccentric portion (59) and the piston (55) through the branch passageway (93), another part of the refrigeration oil is supplied to sliding portions of the output shaft (32) and the rear head (62) through the branch passageway (94), and the other part of the refrigeration oil flows into the upper oil reservoir (101).

[0140] Part of the refrigeration oil which has flown into the bushing hole (58) of the cylinder (51) is supplied to sliding portions of the cylinder (51) and the bushings (57) and sliding portions of the blade (56) and the bushings (57). The other part of the refrigeration oil which has flown into the bushing hole (58) flows into the upper oil reservoir (101) through the first oil passageway (121).

«Other Embodiment»

[0141] In the foregoing embodiment, the expansion mechanism (31) may be a so-called rotary fluid machine of a rolling piston type. In this case, in the expansion mechanism (31), the blades (56, 76, 86) are separated from the pistons (55, 75, 85). The blades (56, 76, 86) are supported so as to move forward or away from the cylinders (51, 71, 81), and the tips of the blades (56, 76, 86)

are pressed against the outer peripheries of the pistons (55, 75, 85).

[0142] In the foregoing embodiments, the expansion mechanism (31) may be a fluid machine of a scroll type. In this case, in the expansion mechanism (31), refrigerant expands in an expansion chamber formed by a fixed scroll and a movable scroll, thereby rotating an output shaft engaged with the movable scroll.

[0143] In the foregoing embodiments, the refrigeration system constitutes the air conditioner. Alternatively, the refrigeration system may constitute a water heater with which water is heated by refrigerant discharged from the compressor (20) and hot water is produced.

[0144] In the first modified example of the first embodiment, the air conditioner (10) may include only the cooling heat exchanger (47) for performing heat exchange between refrigeration oil in the oil supply pipe (41) and refrigeration oil in the oil return pipe (42), with the cooling heat exchanger (46) for performing heat exchange between refrigeration oil in the oil supply pipe (41) and refrigerant in the suction-side pipe (16) omitted.

[0145] In the second modified example of the first embodiment, the air conditioner (10) may include only the cooling heat exchanger (48) for performing heat exchange between refrigeration oil in the oil supply pipe (41) and the outdoor oil, with the cooling heat exchanger (46) for performing heat exchange between refrigeration oil in the oil supply pipe (41) and refrigerant in the suction-side pipe (16) omitted.

[0146] The foregoing embodiments are merely preferred examples in nature, and are not intended to limit the scope, applications, and use of the invention.

INDUSTRIAL APPLICABILITY

[0147] As described above, the present invention is useful for refrigeration systems each including a compressor and an expander which are formed as separate units.

Claims

1. A refrigeration system, comprising a refrigerant circuit (11) including a compressor (20) and an expander (30), the refrigeration system performs a refrigeration cycle by circulating refrigerant in the refrigerant circuit (11), wherein
the compressor (20) includes a compressor casing (24) in the shape of a sealed vessel and a compression mechanism (21) housed in the compressor casing (24) and configured to compress sucked refrigerant and to discharge the compressed refrigerant into the compressor casing (24), and supplies lubricating oil stored in the compressor casing (24) to the compression mechanism (21),
the expander (30) includes an expansion mechanism (31) for generating power by expansion of in-

- flow refrigerant and an expander casing (34) housing the expansion mechanism (31), and an oil supply passageway (41) for supplying the lubricating oil stored in the compressor casing (24) to the expansion mechanism (31) is provided such that the expansion mechanism (31) is lubricated with the lubricating oil supplied through the oil supply passageway (41).
2. The refrigeration system of claim 1, further comprising an oil supply pipe (41) having an end connected to a bottom of the compressor casing (24) and another end connected to the expansion mechanism (31), wherein the oil supply pipe (41) forms the oil supply passageway. 15
 3. The refrigeration system of claim 1, further comprising an oil return passageway (42) for returning lubricating oil which has accumulated in the expander casing (34) to the compressor (20). 20
 4. The refrigeration system of claim 3, wherein the oil return passageway (42) is configured to introduce lubricating oil to a suction side of the compression mechanism (21). 25
 5. The refrigeration system of claim 1, further comprising a cooling heat exchanger (46) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with refrigerant sucked into the compression mechanism (21). 30
 6. The refrigeration system of claim 3, further comprising a cooling heat exchanger (47) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with lubricating oil flowing in the oil return passageway (42). 35
 7. The refrigeration system of claim 1, further comprising a cooling heat exchanger (48) for cooling lubricating oil flowing in the oil supply passageway (41) by performing heat exchange with outdoor air. 40
 8. The refrigeration system of one of claims 1 to 7, wherein the refrigerant circuit (11) includes a first suction-side passageway (17) for establishing communication between an evaporator of the refrigerant circuit (11) and internal space of the expander casing (34), and a second suction-side passageway (18) 50 for establishing communication between the internal space of the expander casing (34) and a suction side of the compression mechanism (21), and the expander casing (34) is configured to separate refrigerant from the first suction-side passageway (17) into gas refrigerant and liquid refrigerant, and to send the gas refrigerant to the second suction-side passageway (18). 55
 9. The refrigeration system of claim 8, wherein the expander (30) includes an electric generator (33) housed in the expander casing (34) and driven by the expansion mechanism (31), and the first suction-side passageway (17) communicates with a portion of the internal space of the expander casing (34) below the electric generator (33), whereas the second suction-side passageway (18) communicates with a portion of the internal space of the expander casing (34) above the electric generator (33).

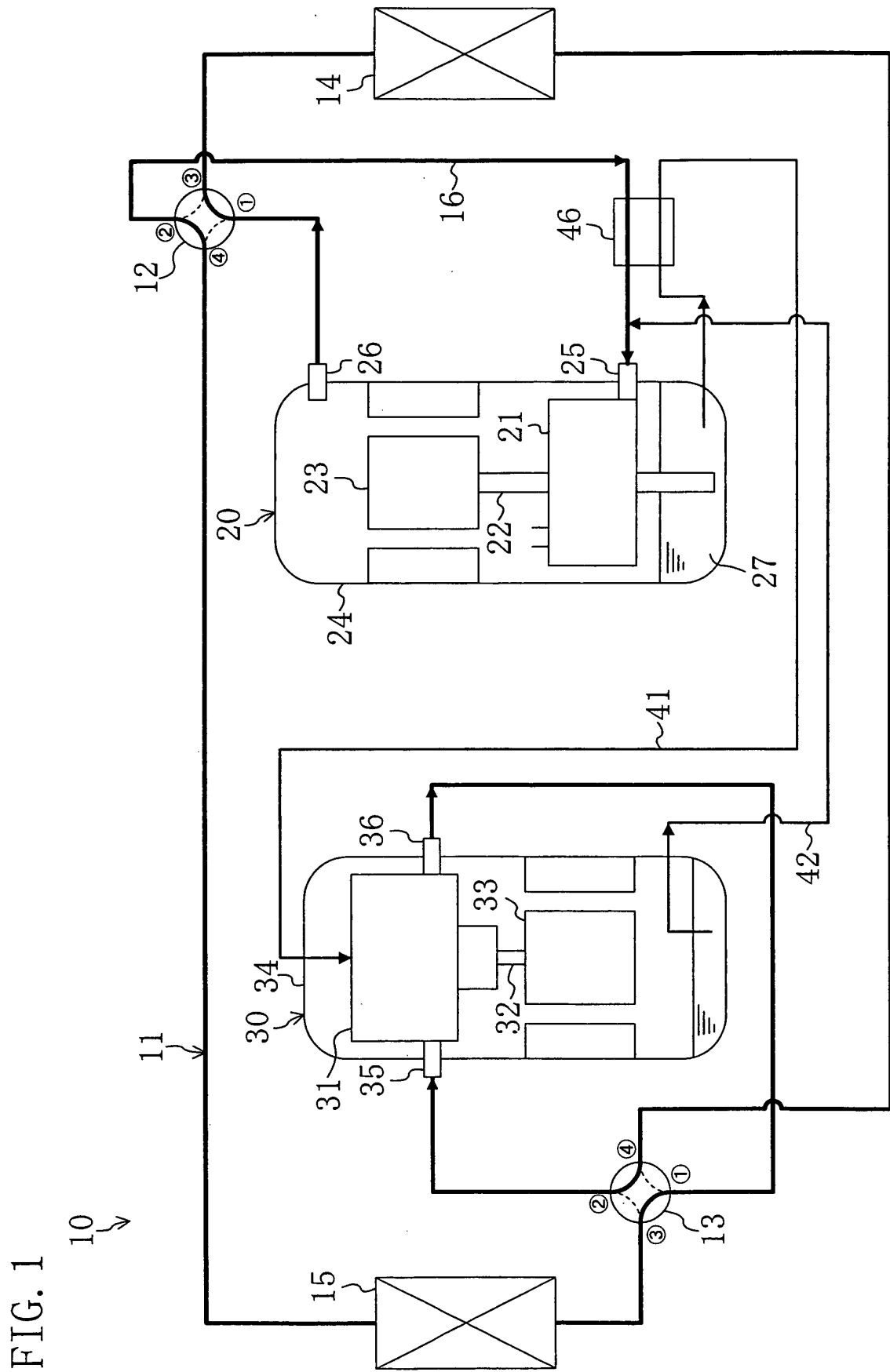


FIG. 2

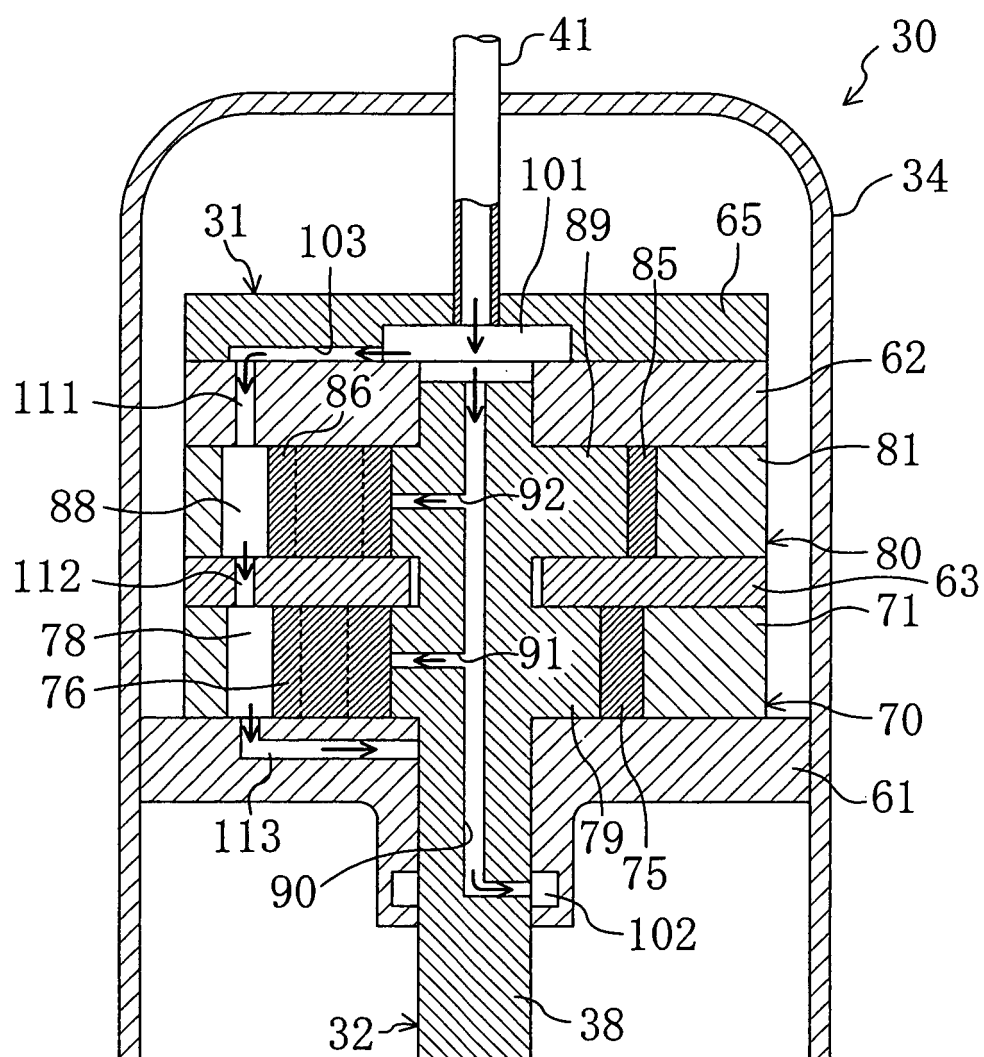


FIG. 3

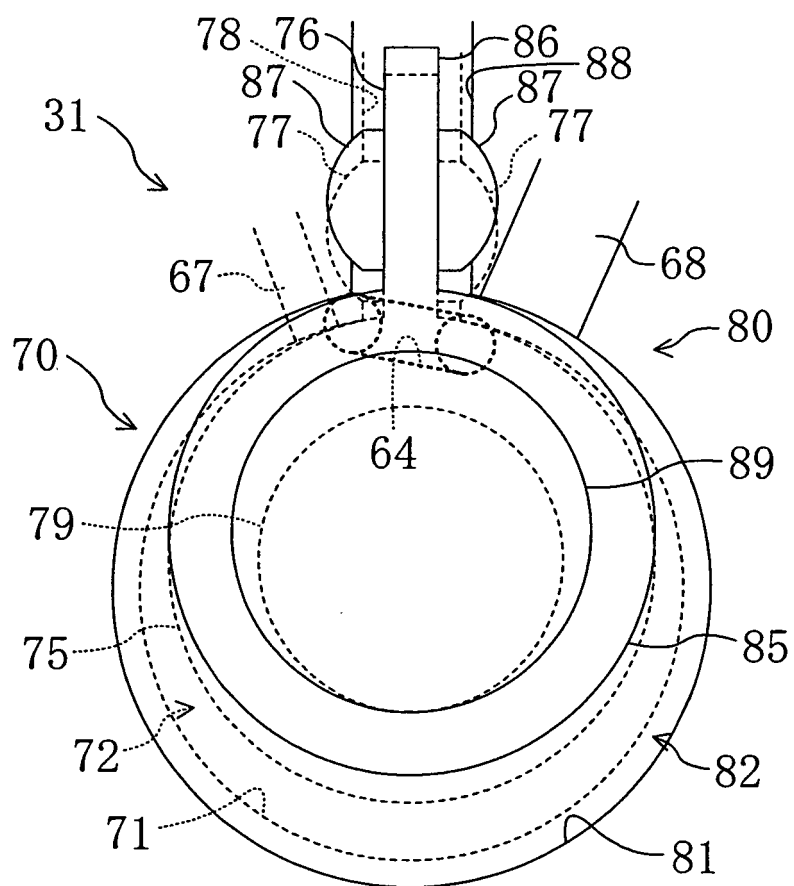


FIG. 4

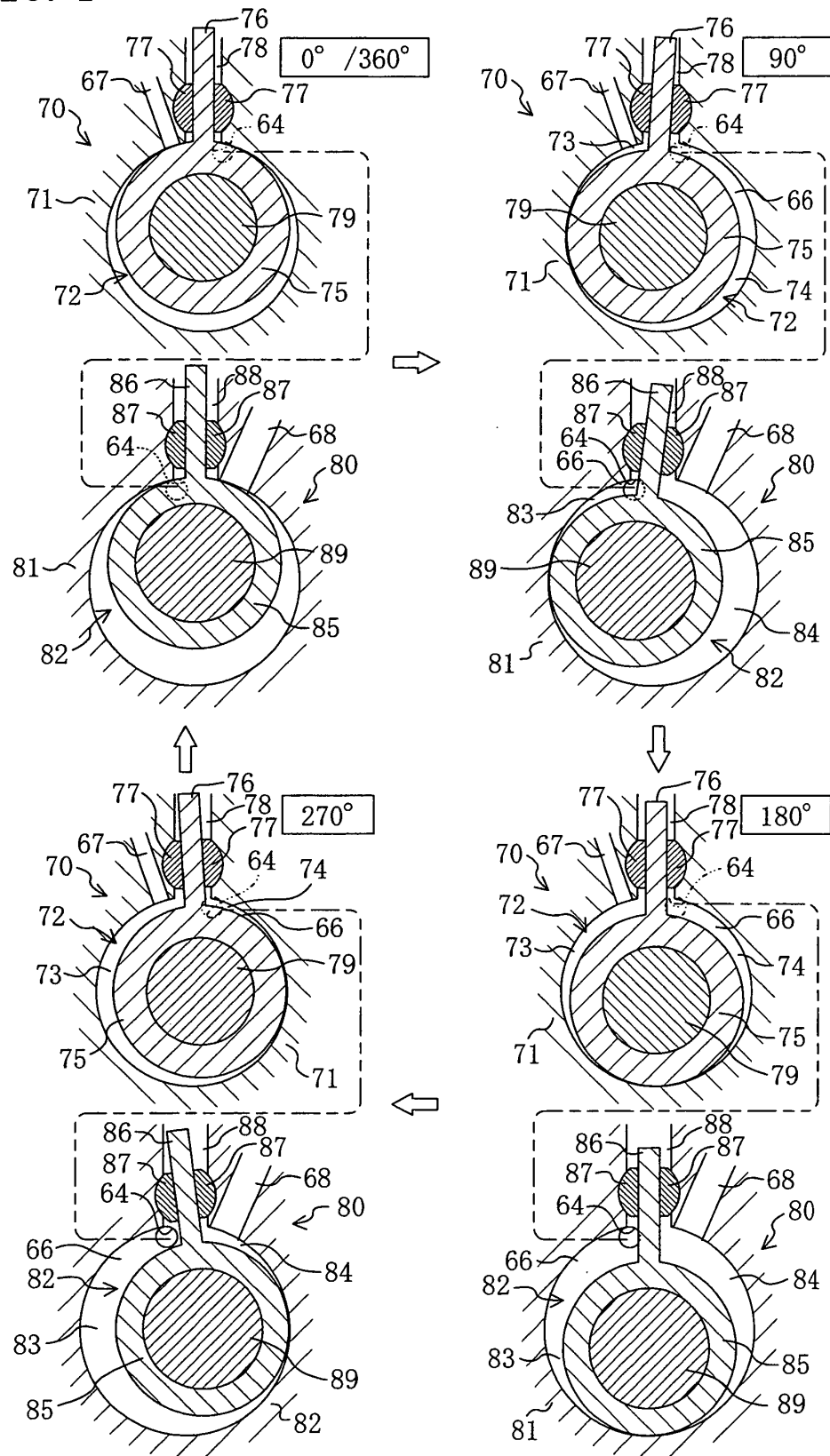


FIG. 5

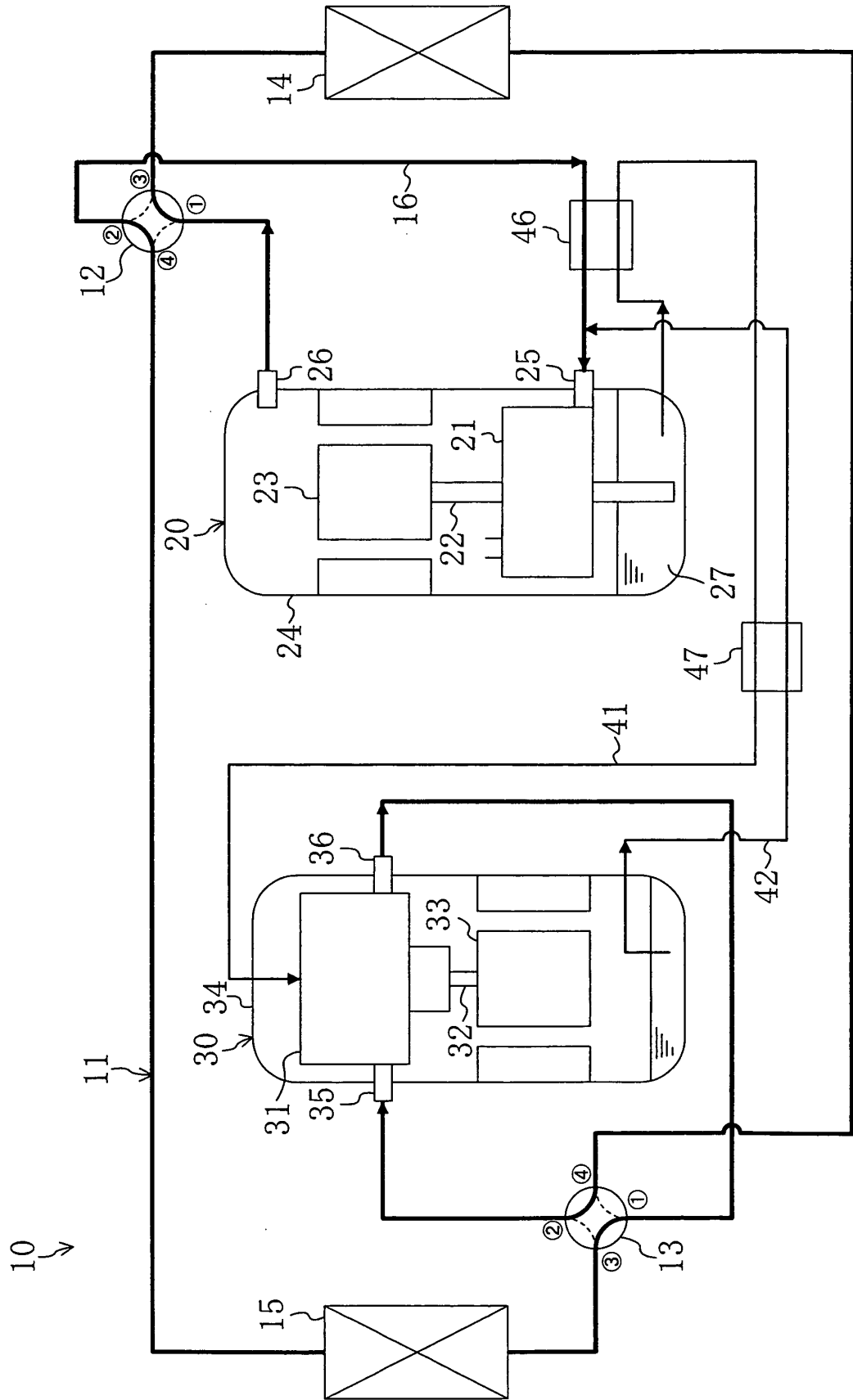


FIG. 6

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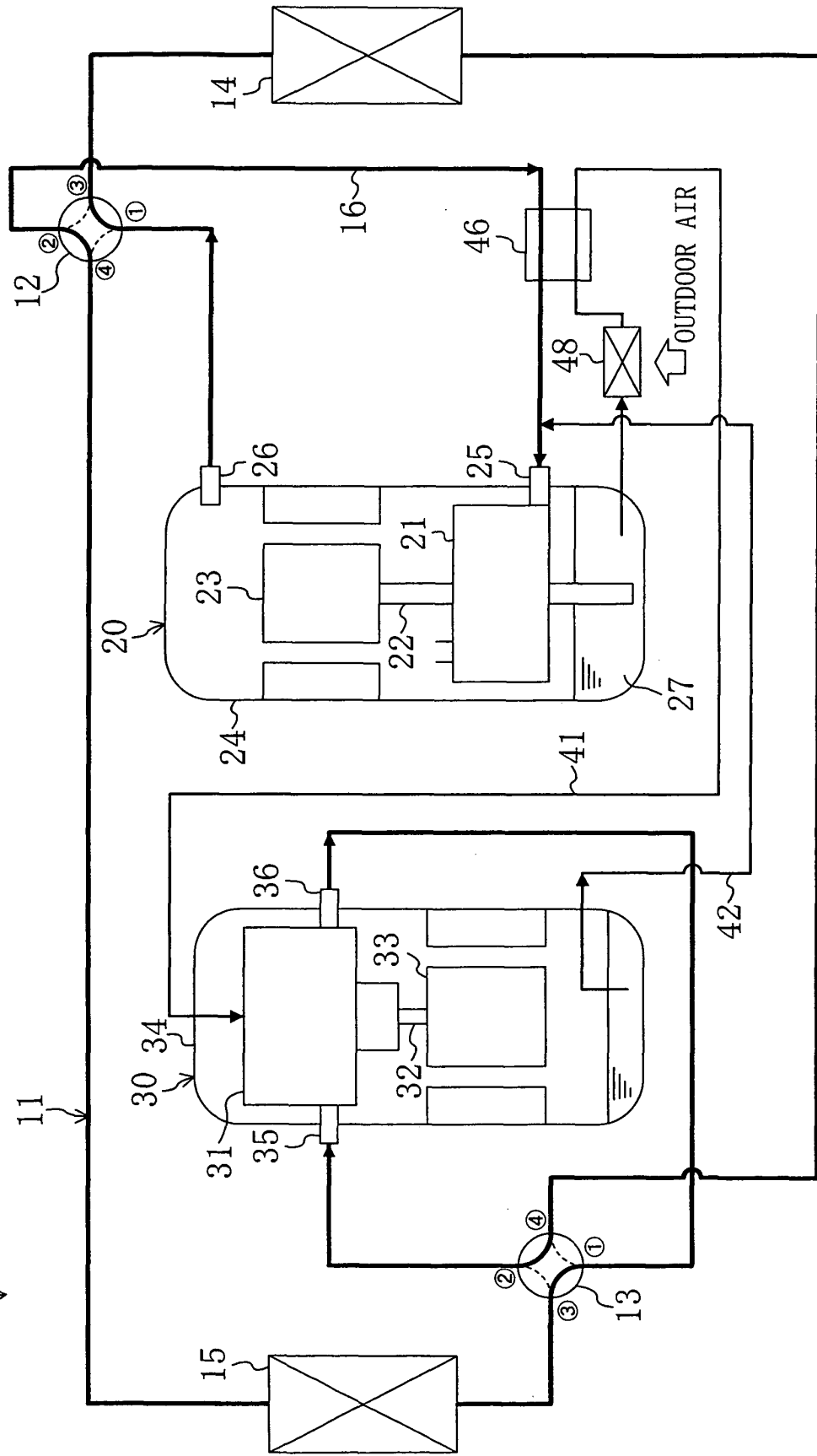


FIG. 7
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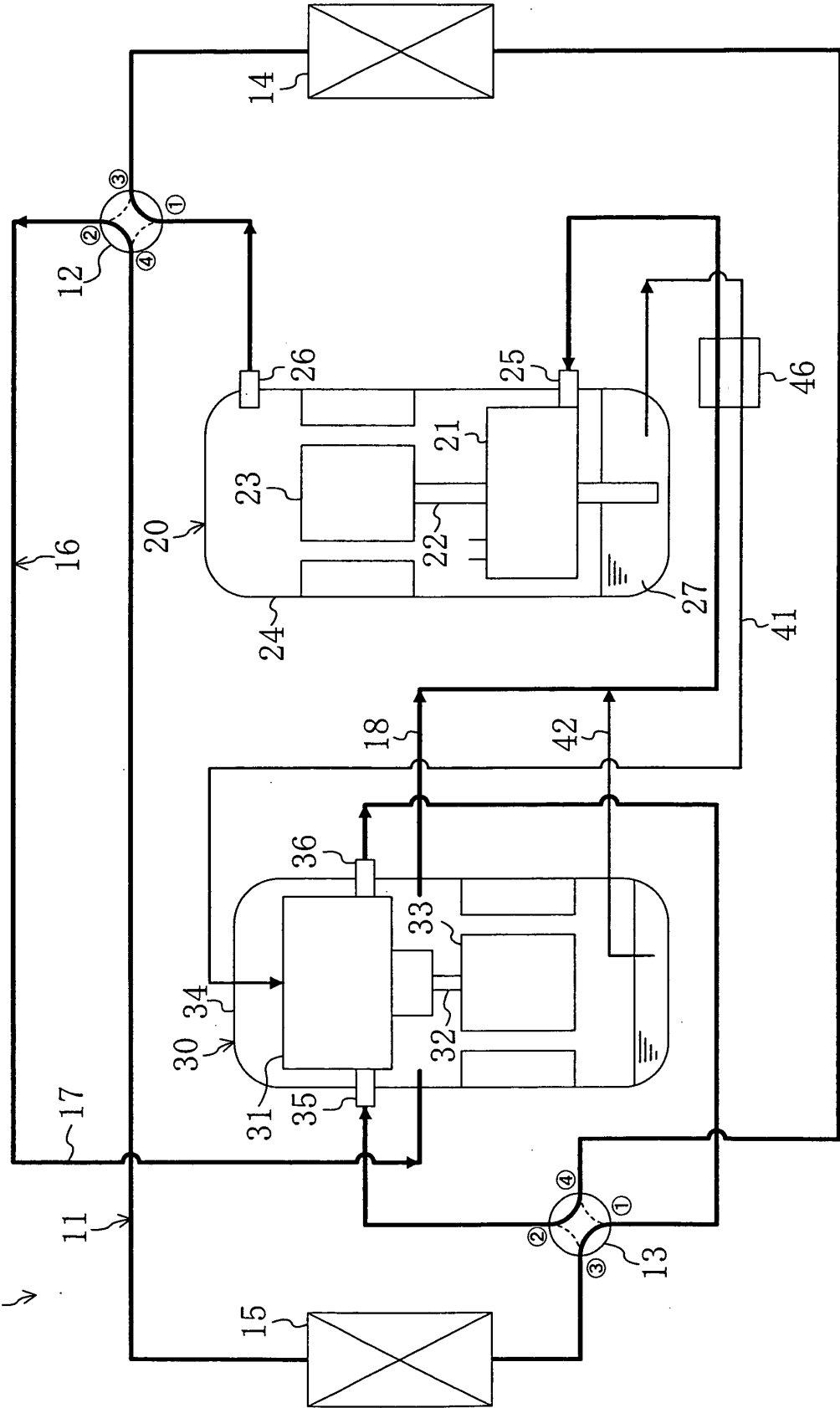


FIG. 8
10

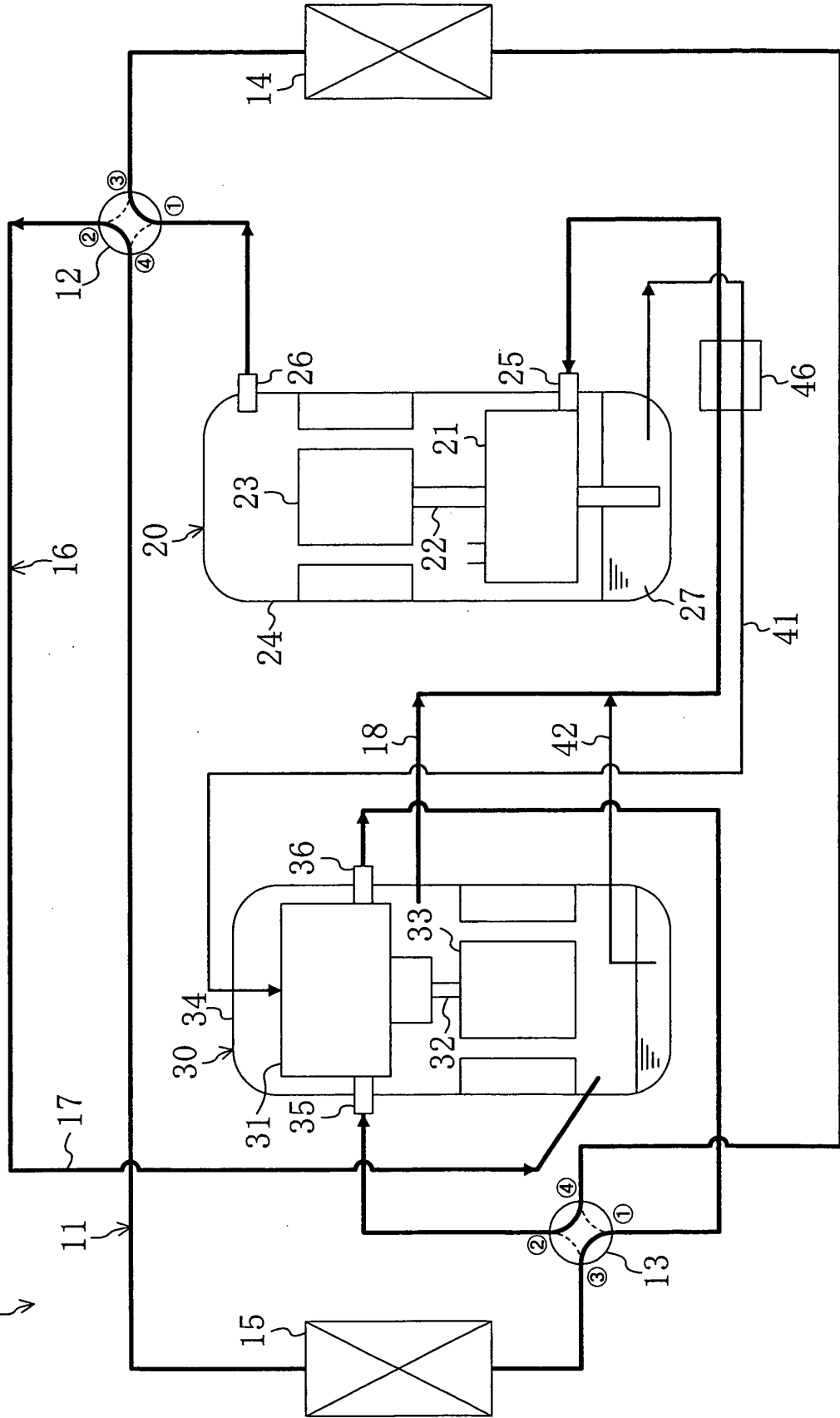


FIG. 9

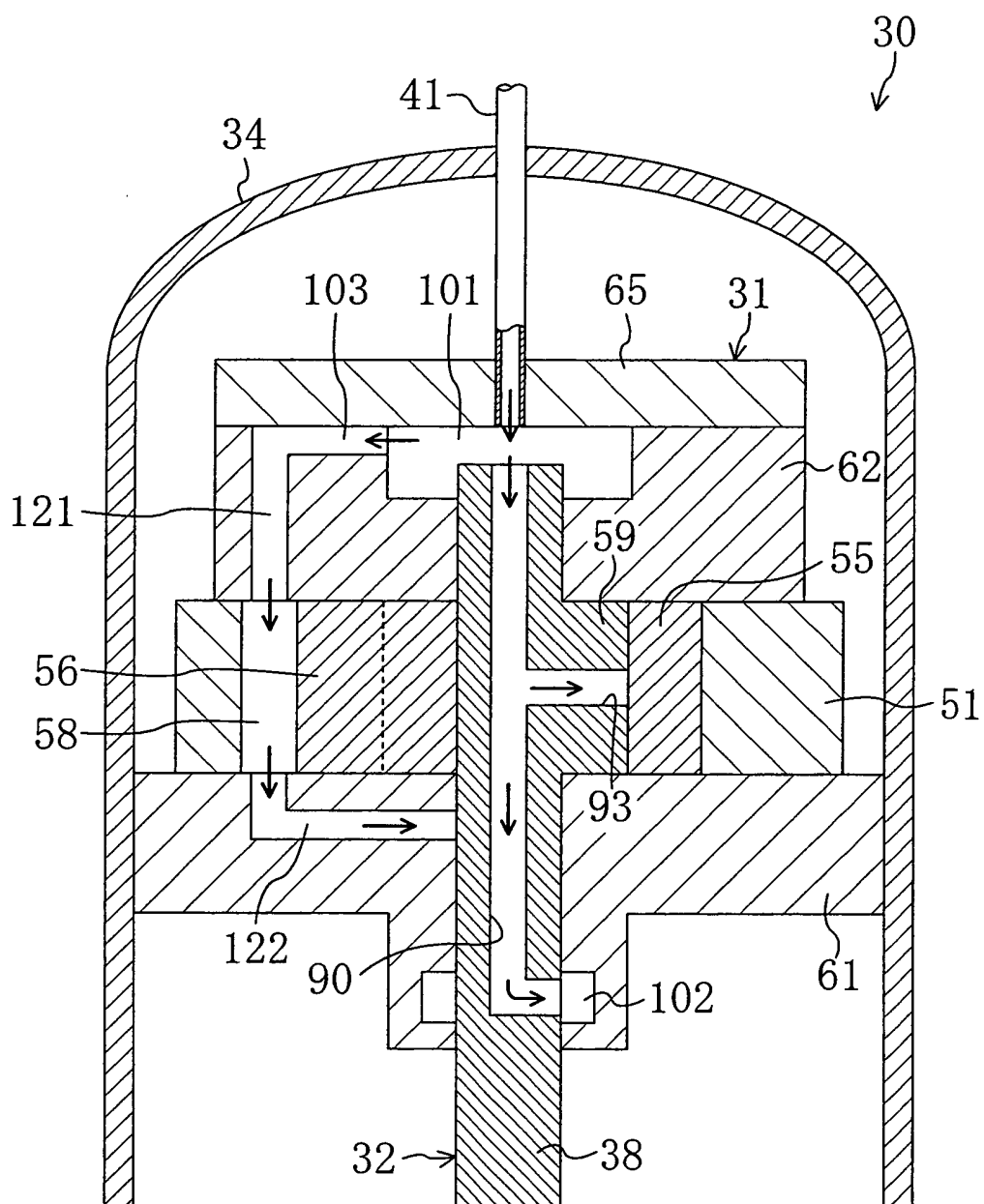


FIG. 10

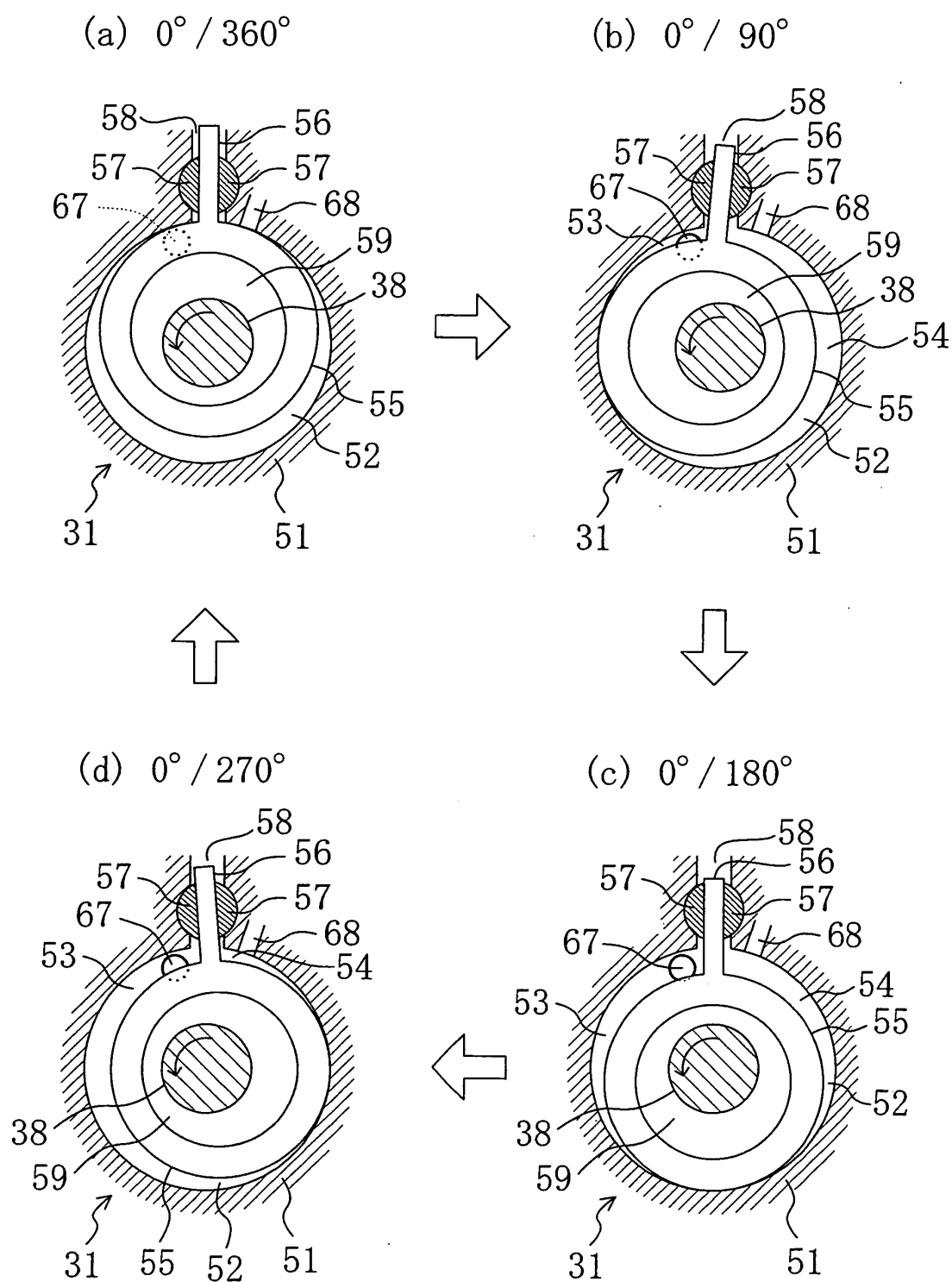
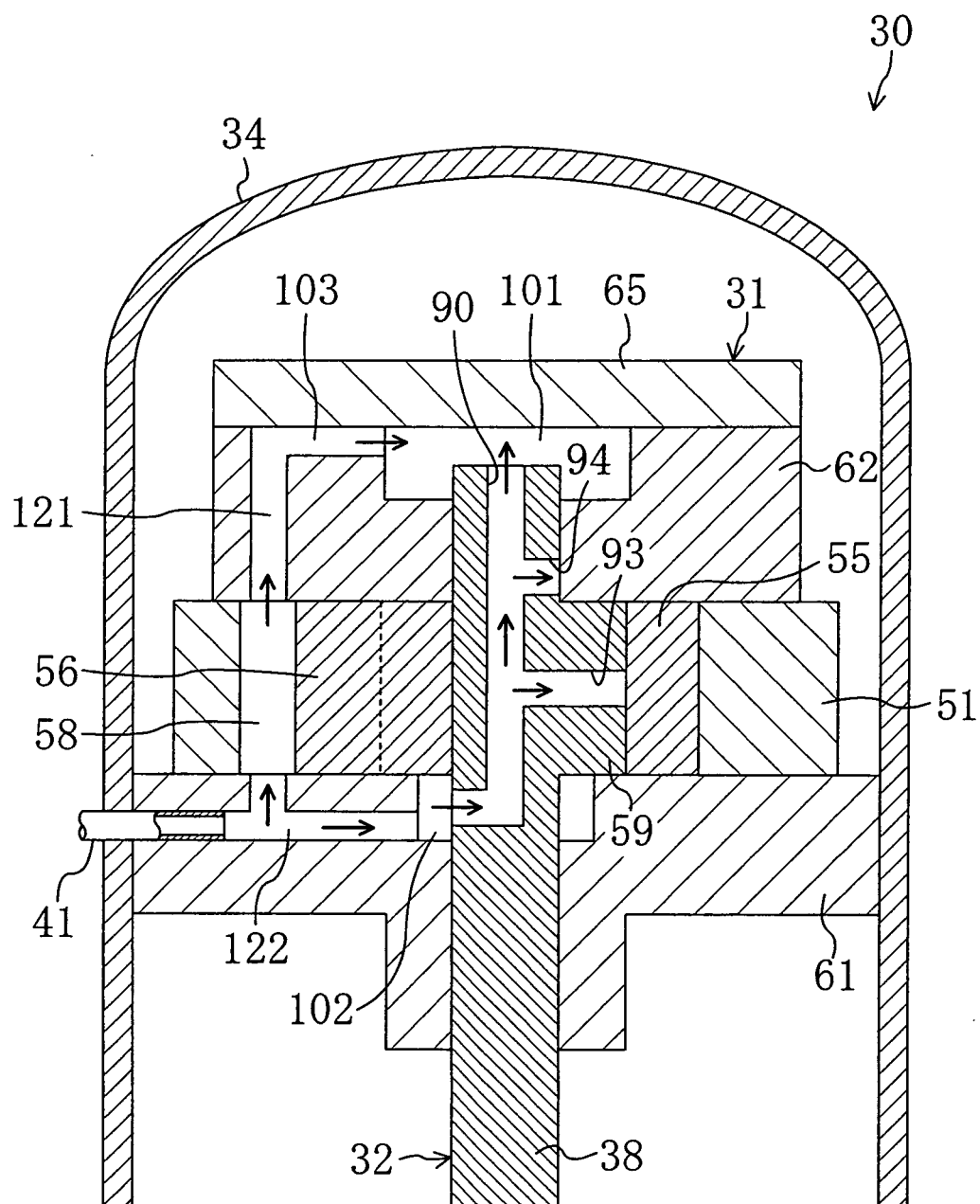


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/000159

A. CLASSIFICATION OF SUBJECT MATTER

F25B11/02(2006.01) i, F25B1/00(2006.01) i, F25B43/00(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B11/02, F25B1/00, F25B43/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2006/095572 A1 (Matsushita Electric Industrial Co., Ltd.), 14 September, 2006 (14.09.06), Figs. 1 to 6; Par. Nos. [0015] to [0059] (Family: none)	1, 2, 5, 7 3, 4, 6, 8, 9
Y	JP 2003-240366 A (Mitsubishi Electric Corp.), 27 August, 2003 (27.08.03), Figs. 1, 6 (Family: none)	3, 4, 6
Y	JP 2004-325019 A (Hitachi, Ltd.), 18 November, 2004 (18.11.04), Fig. 1 (Family: none)	8, 9

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search
17 March, 2008 (17.03.08)Date of mailing of the international search report
25 March, 2008 (25.03.08)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/000159

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 2006/126396 A1 (Matsushita Electric Industrial Co., Ltd.), 30 November, 2006 (30.11.06), Figs. 1 to 7 (Family: none)	3, 4, 6
A	JP 2007-24439 A (Matsushita Electric Industrial Co., Ltd.), 01 February, 2007 (01.02.07), Figs. 1 to 3 (Family: none)	1-9

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REFERENCES CITED IN THE DESCRIPTION

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