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Moriwaki et al.(10) **Pub. No.: US 2008/0098758 A1**(43) **Pub. Date: May 1, 2008**(54) **REFRIGERATION APPARATUS****Publication Classification**(76) Inventors: **Michio Moriwaki**, Osaka (JP);
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Yoshinari Sasaki, Osaka (JP)(51) **Int. Cl.**
F25B 1/00 (2006.01)
F25B 41/00 (2006.01)
(52) **U.S. Cl.** **62/222**(57) **ABSTRACT**

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FALLS CHURCH, VA 22040-0747(21) Appl. No.: **11/661,315**(22) PCT Filed: **Aug. 30, 2005**(86) PCT No.: **PCT/JP05/15781**§ 371 (c)(1),
(2), (4) Date: **Feb. 27, 2007**(30) **Foreign Application Priority Data**

Aug. 31, 2004 (JP) 2004-252938

In an air conditioner (10), a refrigerant adjustment tank (14) is disposed in a refrigerant circuit (11). The refrigerant adjustment tank (14) is disposed just after an expander (16). In the refrigerant circuit (11), a liquid injection line (31) and a gas injection line (33) are arranged. When a liquid side control valve (32) is placed in the open state, liquid refrigerant in the refrigerant adjustment tank (14) is supplied through the liquid injection line (31) to the suction side of a compressor (15). On the other hand, when a gas side control valve (34) is placed in the open state, gas refrigerant in the refrigerant adjustment tank (14) is supplied through the gas injection line (33) to the suction side of the compressor (15). The opening of the liquid and gas side control valves (32, 34) is controlled to thereby make a change in the state of refrigerant drawn into the compressor (15), whereby the amount of refrigerant passing through the compressor (15) and the amount of refrigerant passing through the expander (16) are balanced with each other.

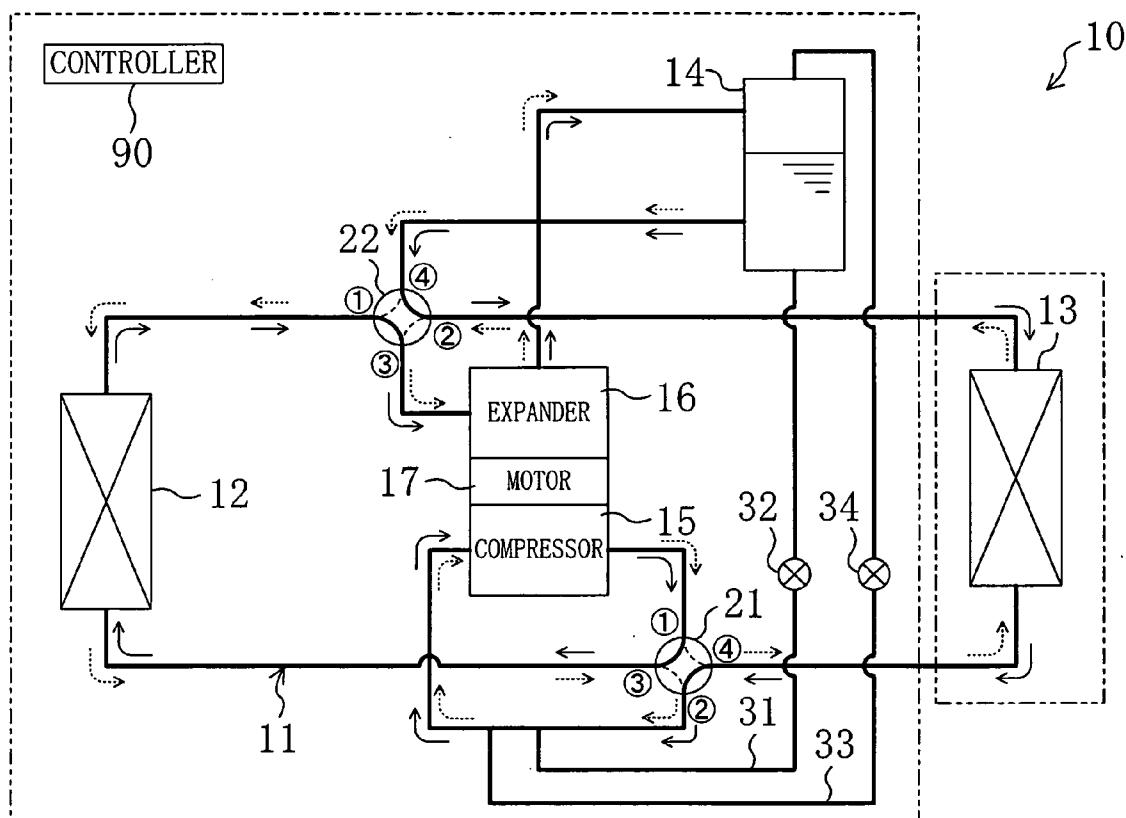


FIG. 1

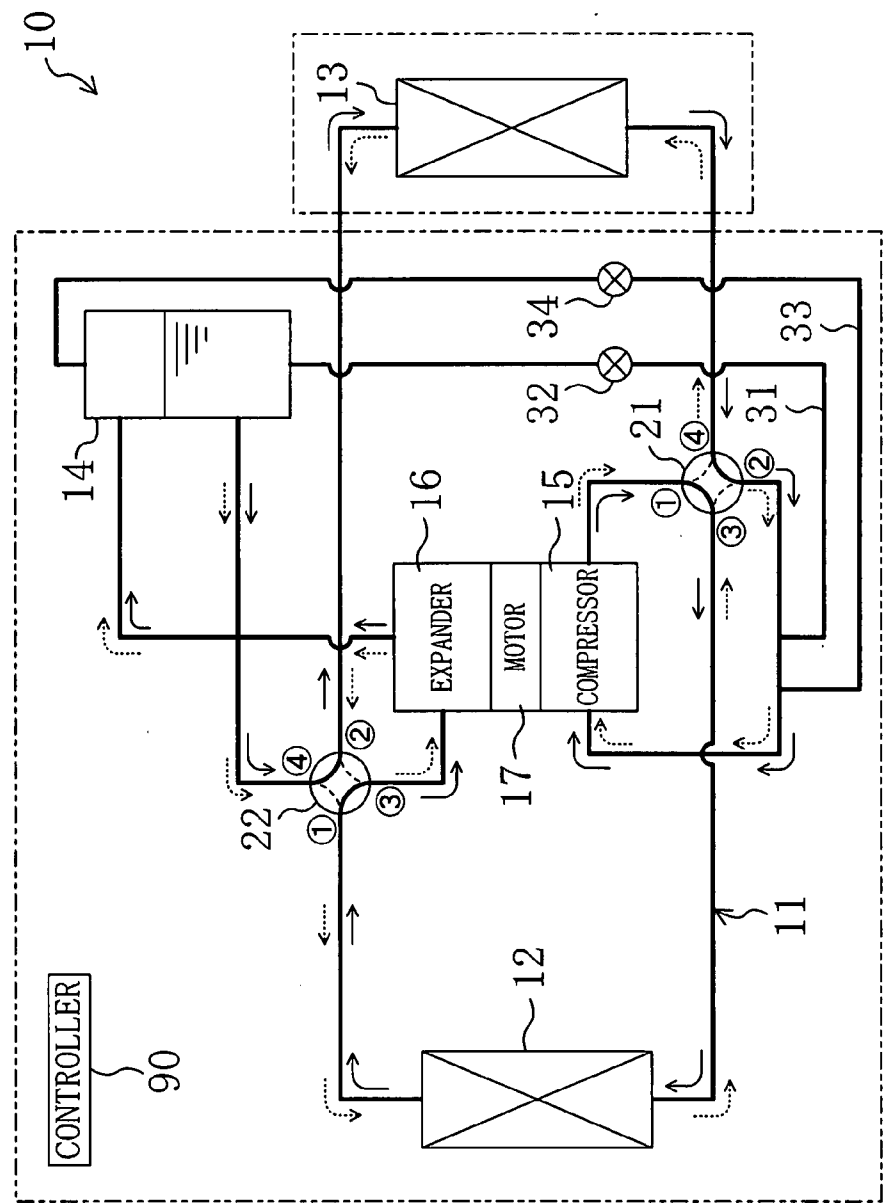


FIG. 2

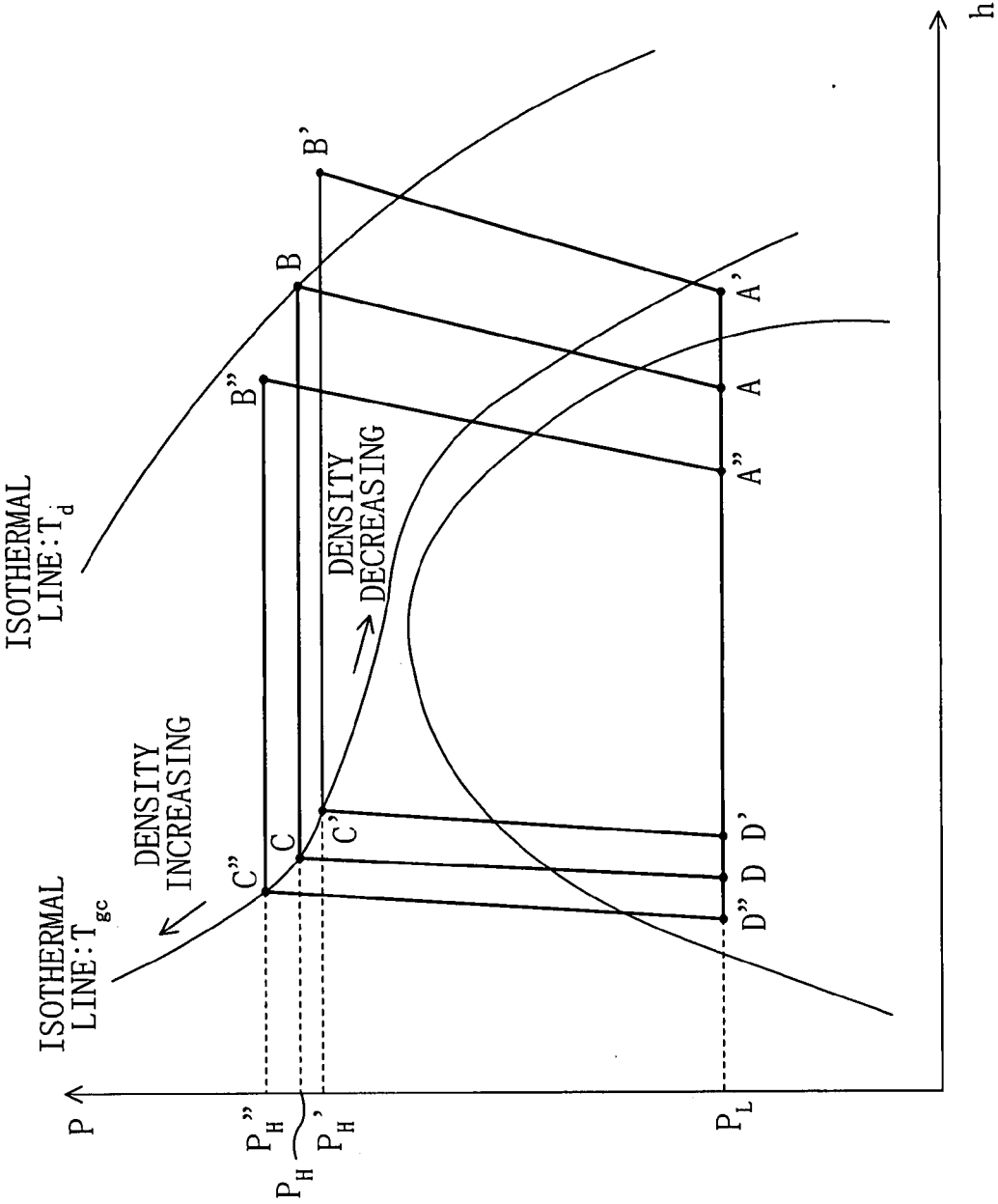


FIG. 3

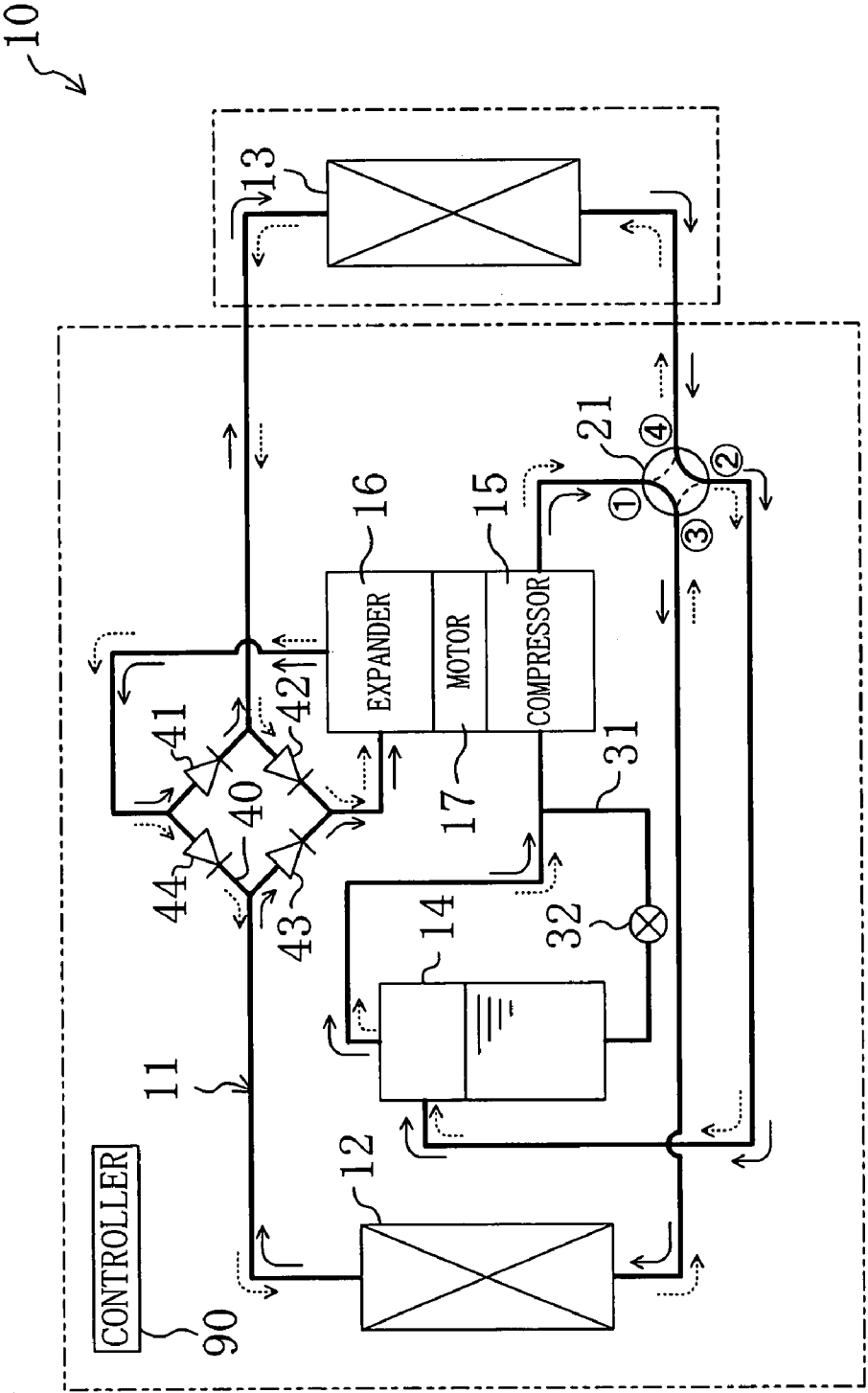


FIG. 4

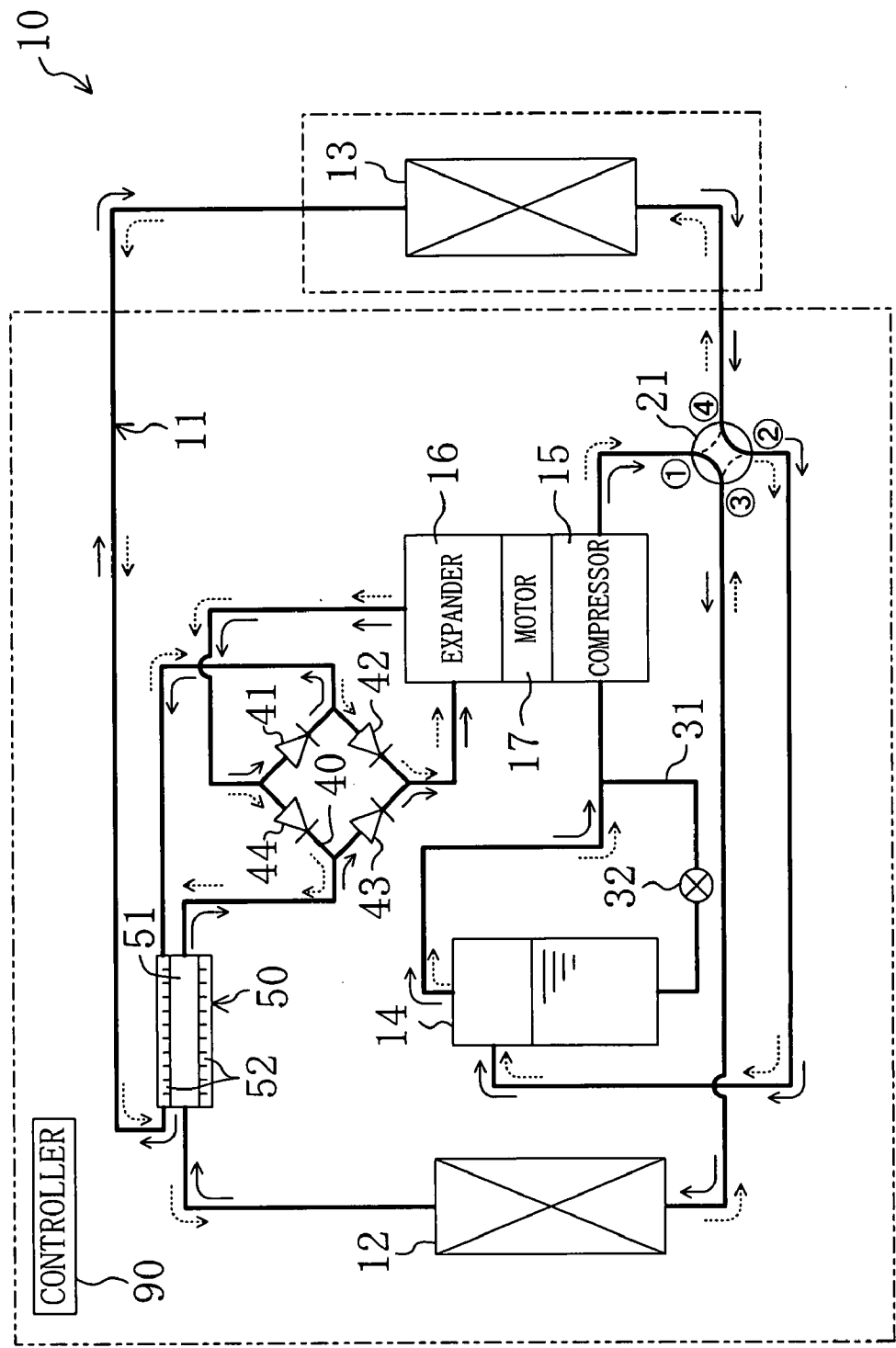


FIG. 5

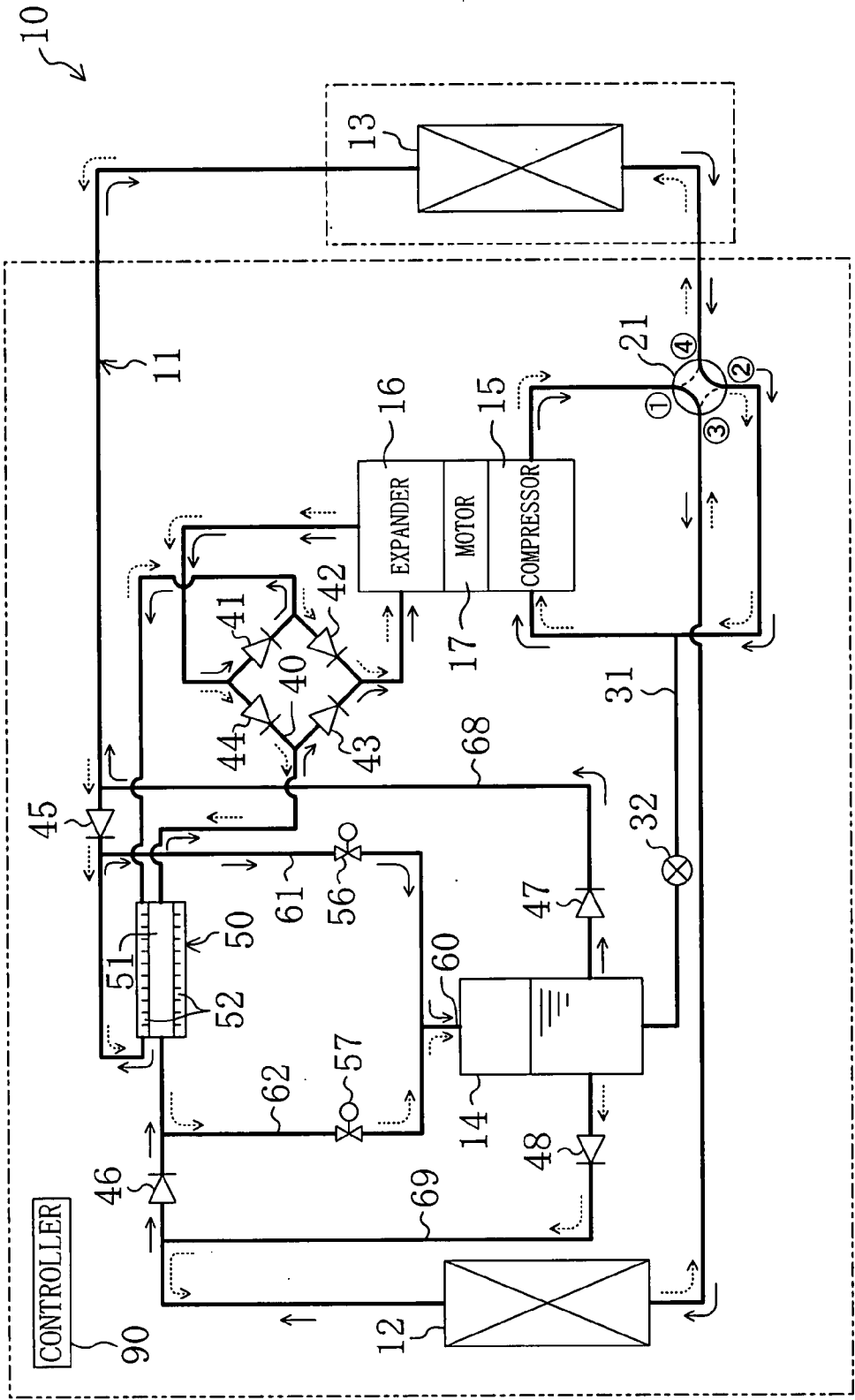


FIG. 6

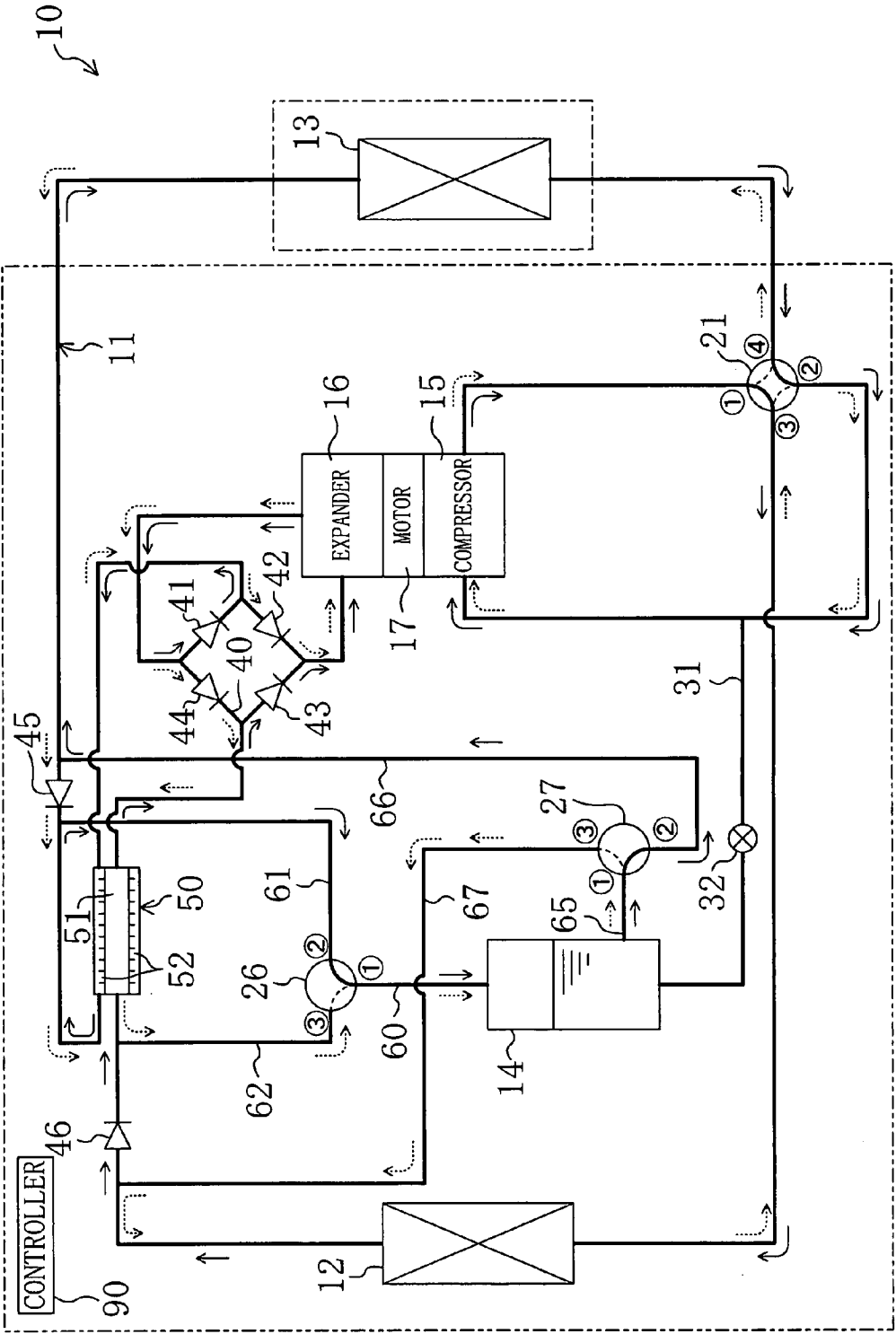


FIG. 7

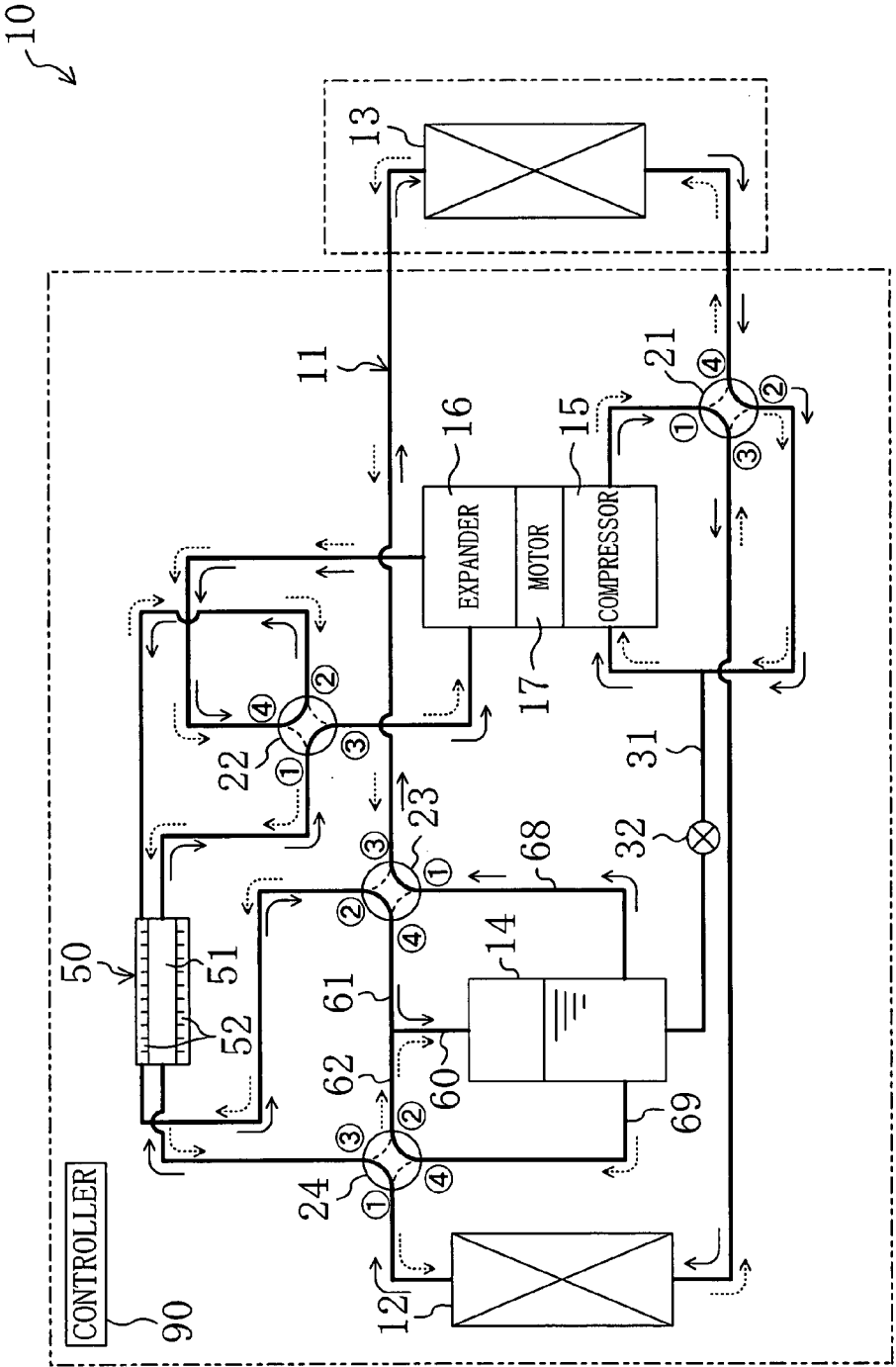


FIG. 8

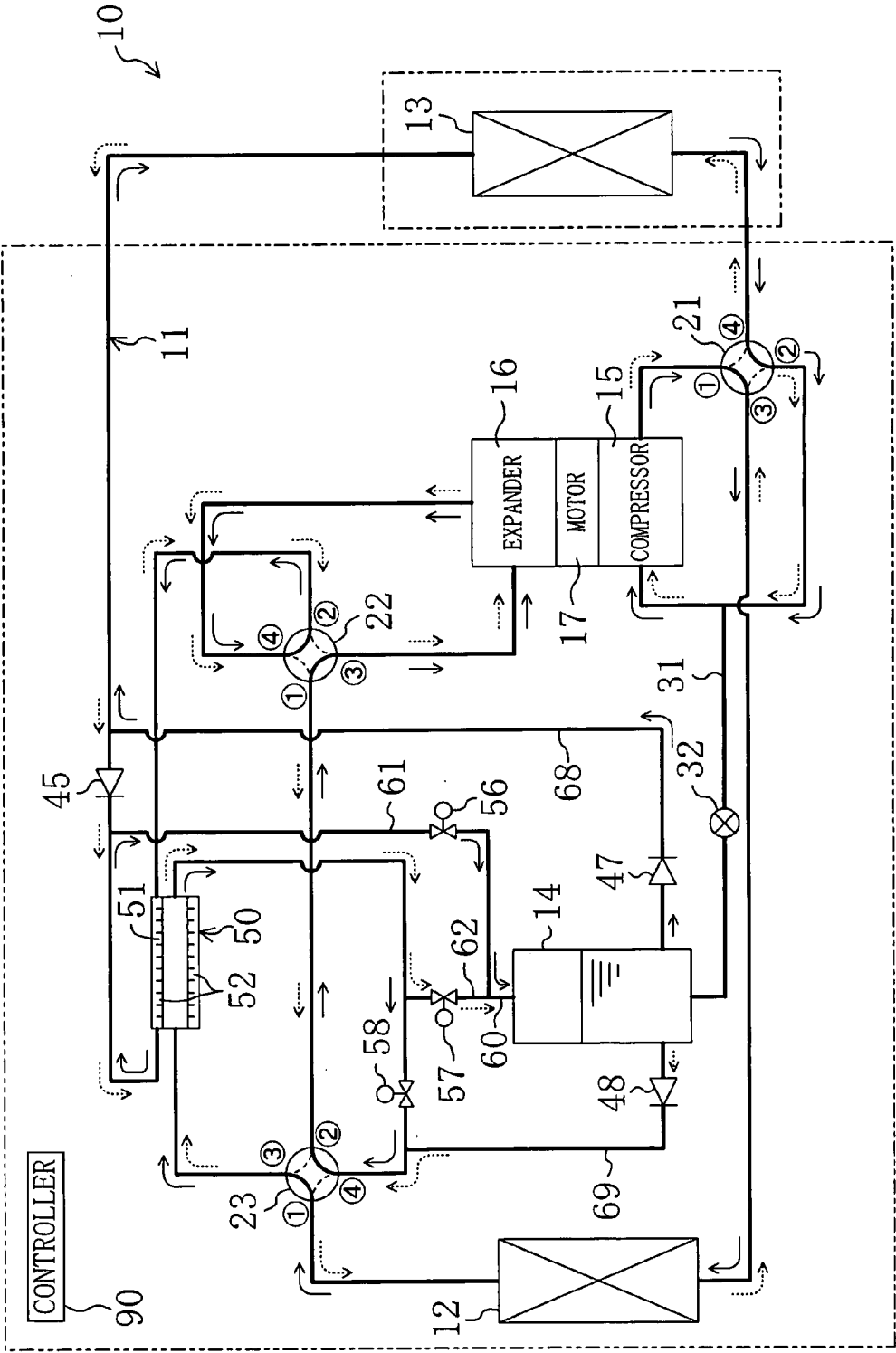


FIG. 9

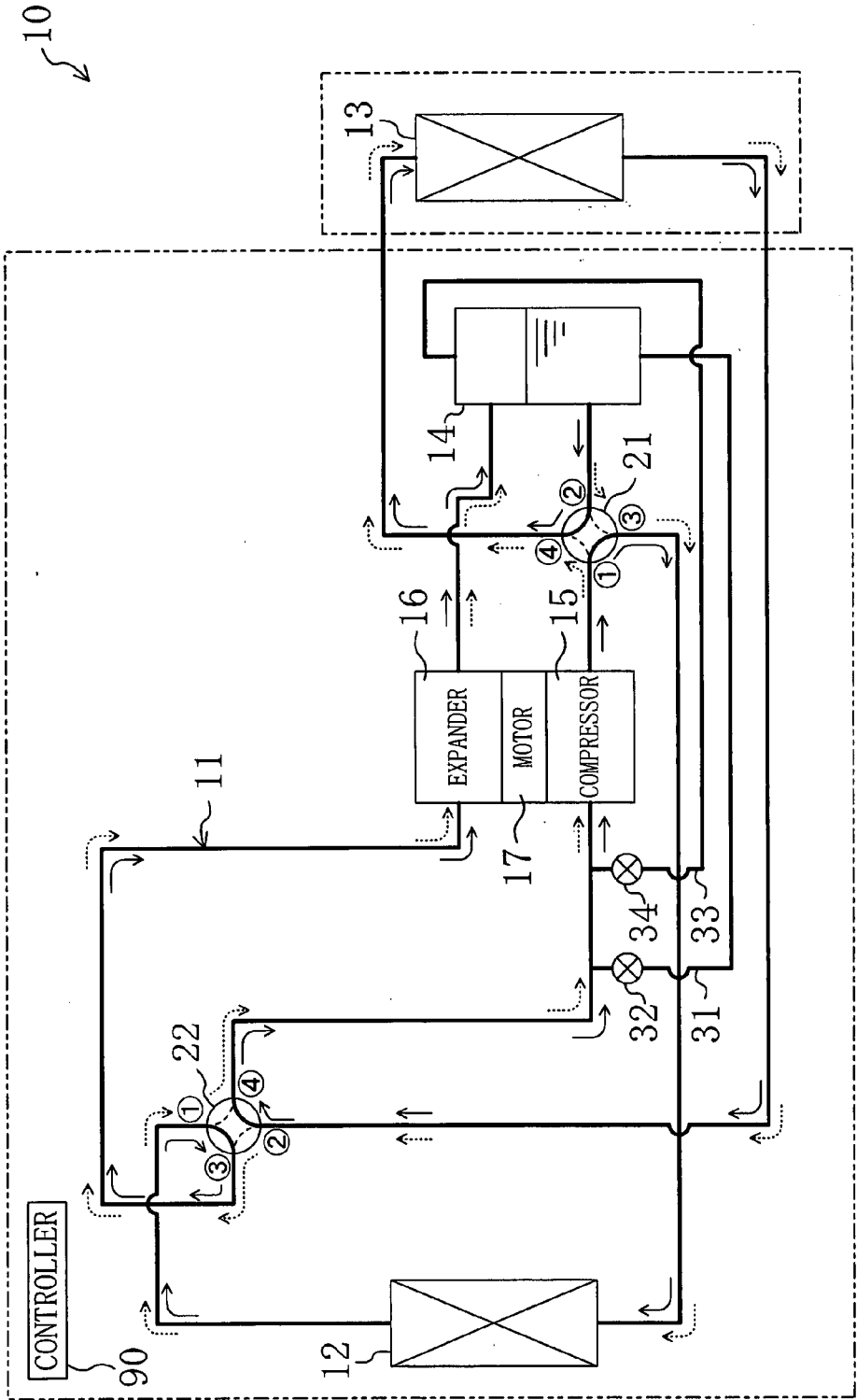


FIG. 10

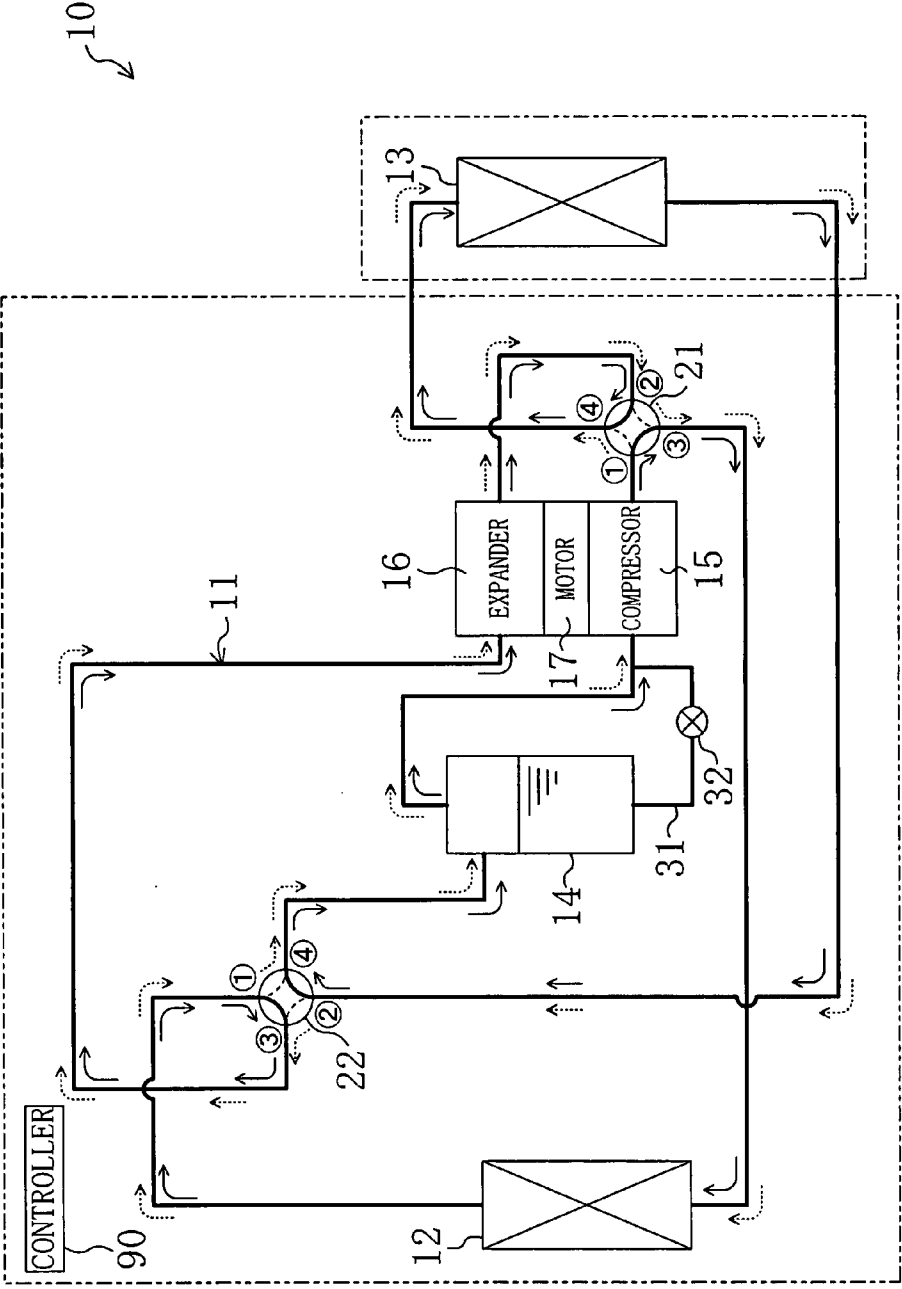


FIG. 11

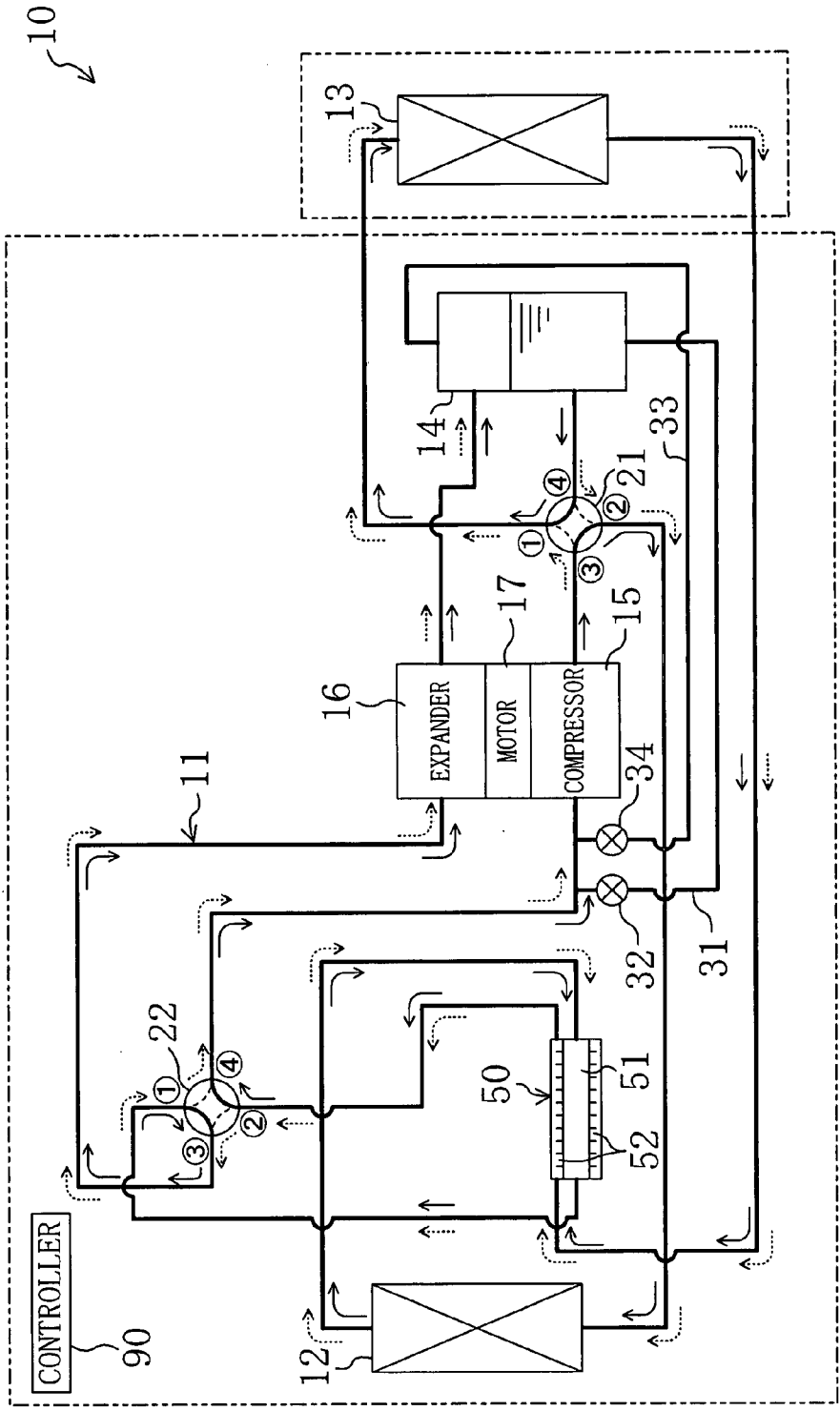


FIG. 12

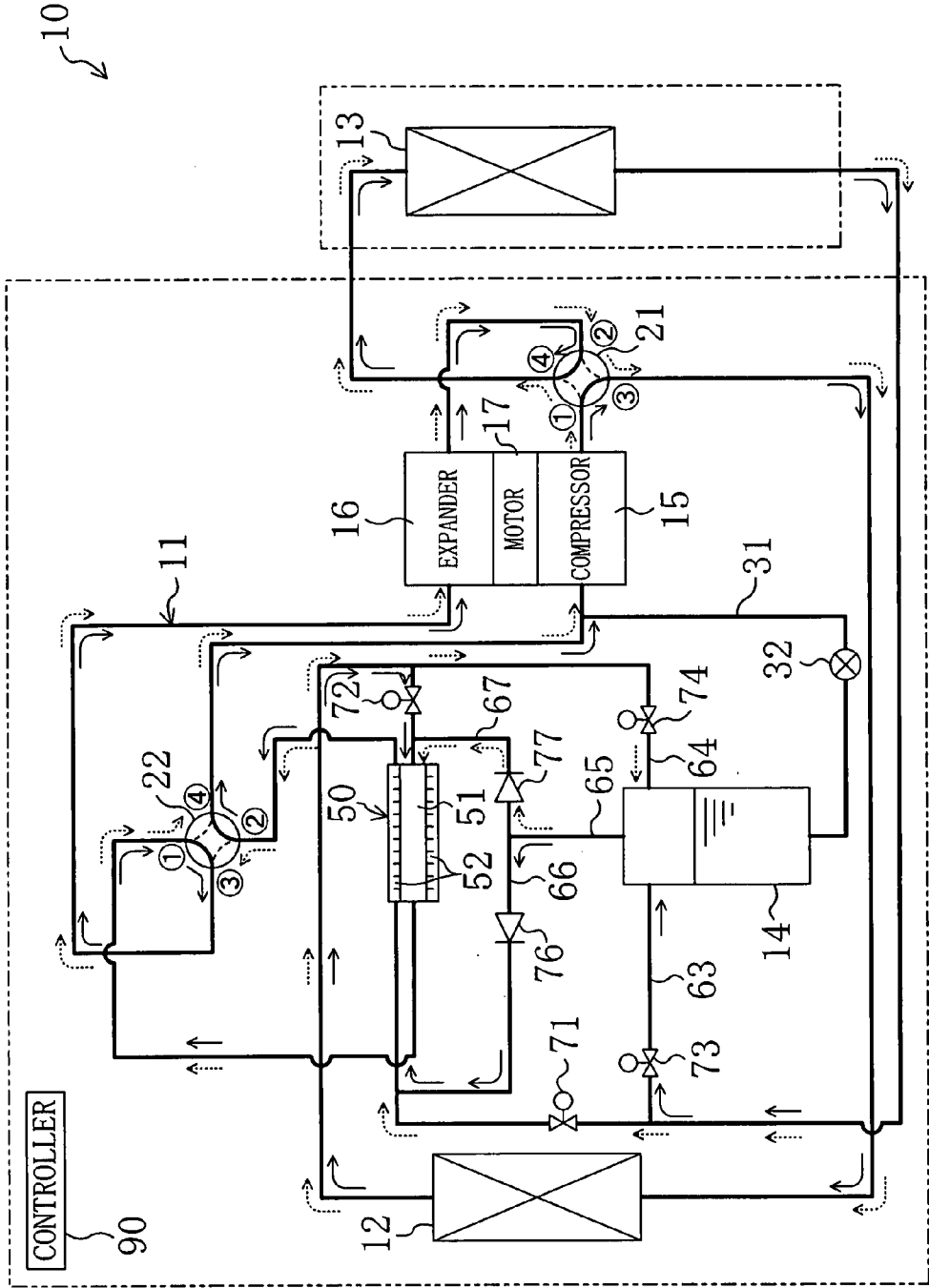


FIG. 13

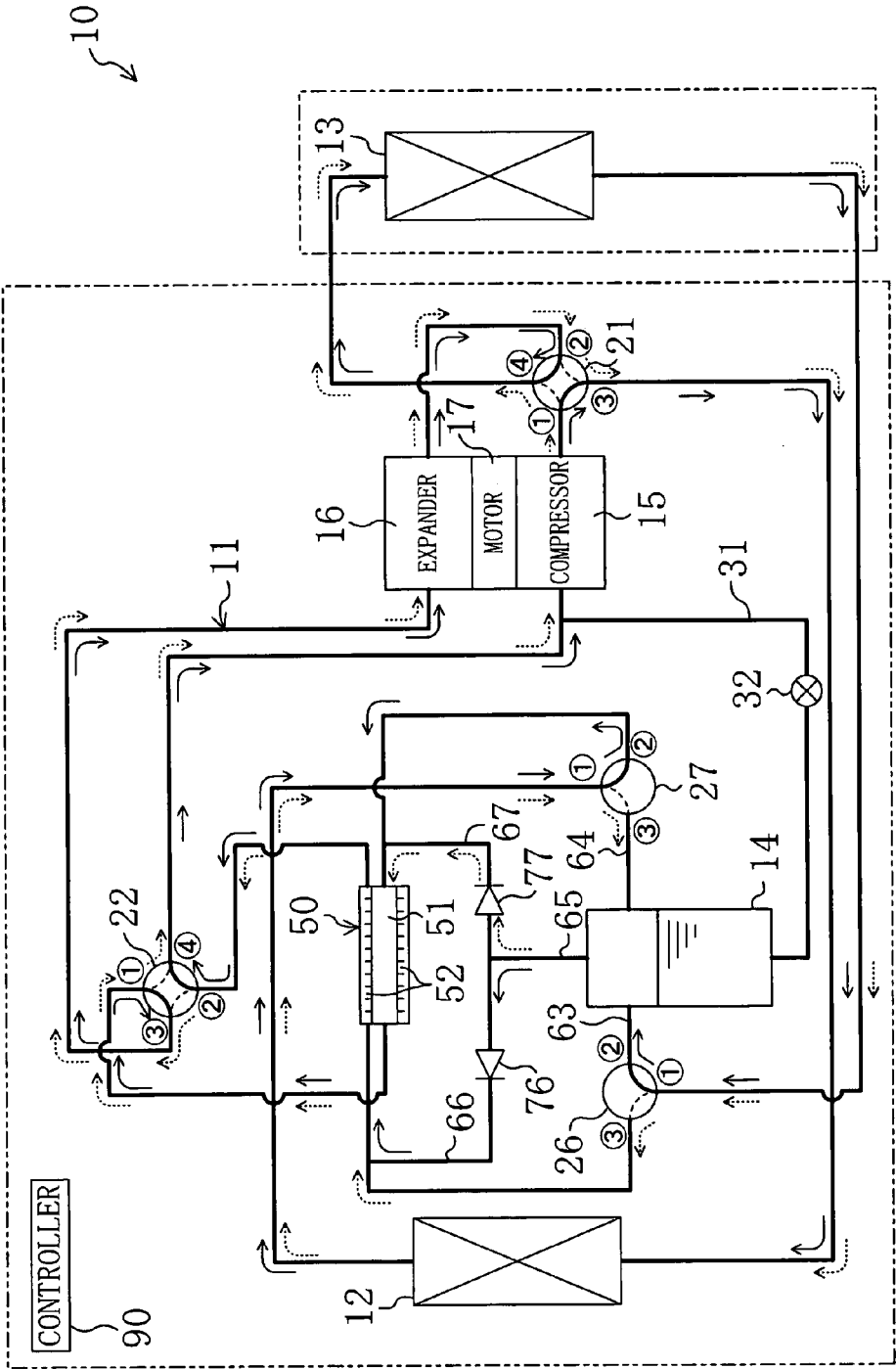


FIG. 14

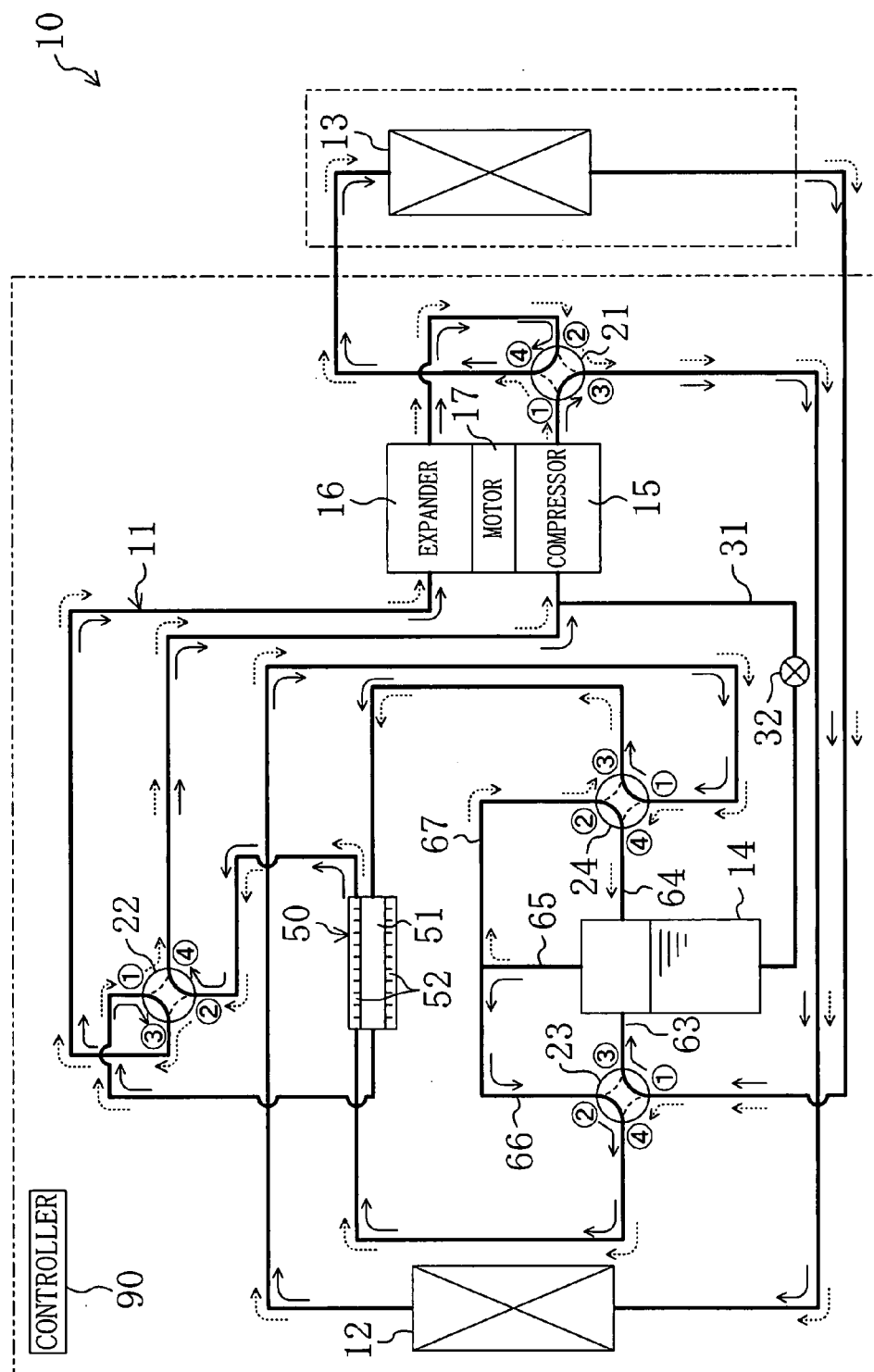


FIG. 15

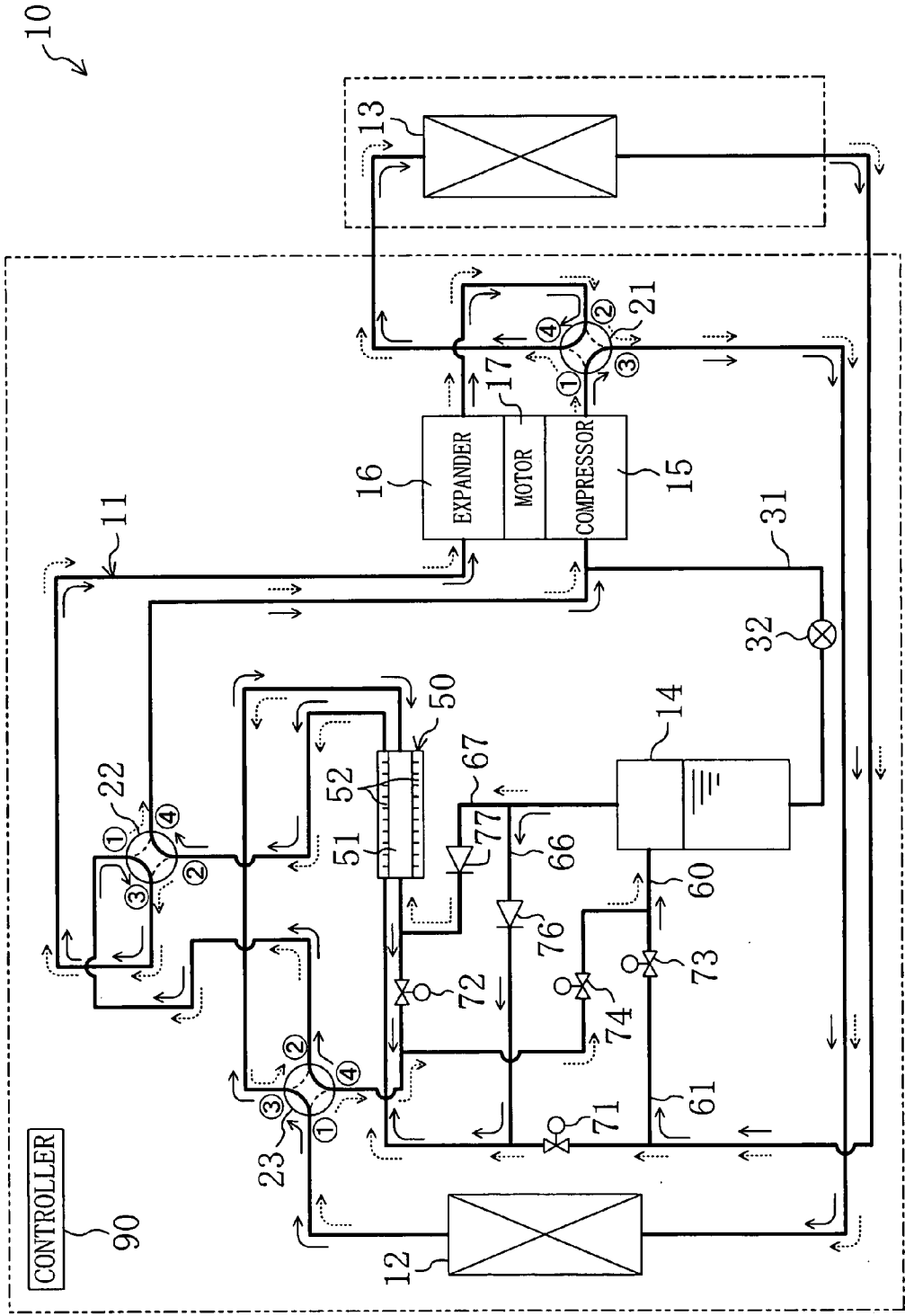


FIG. 16

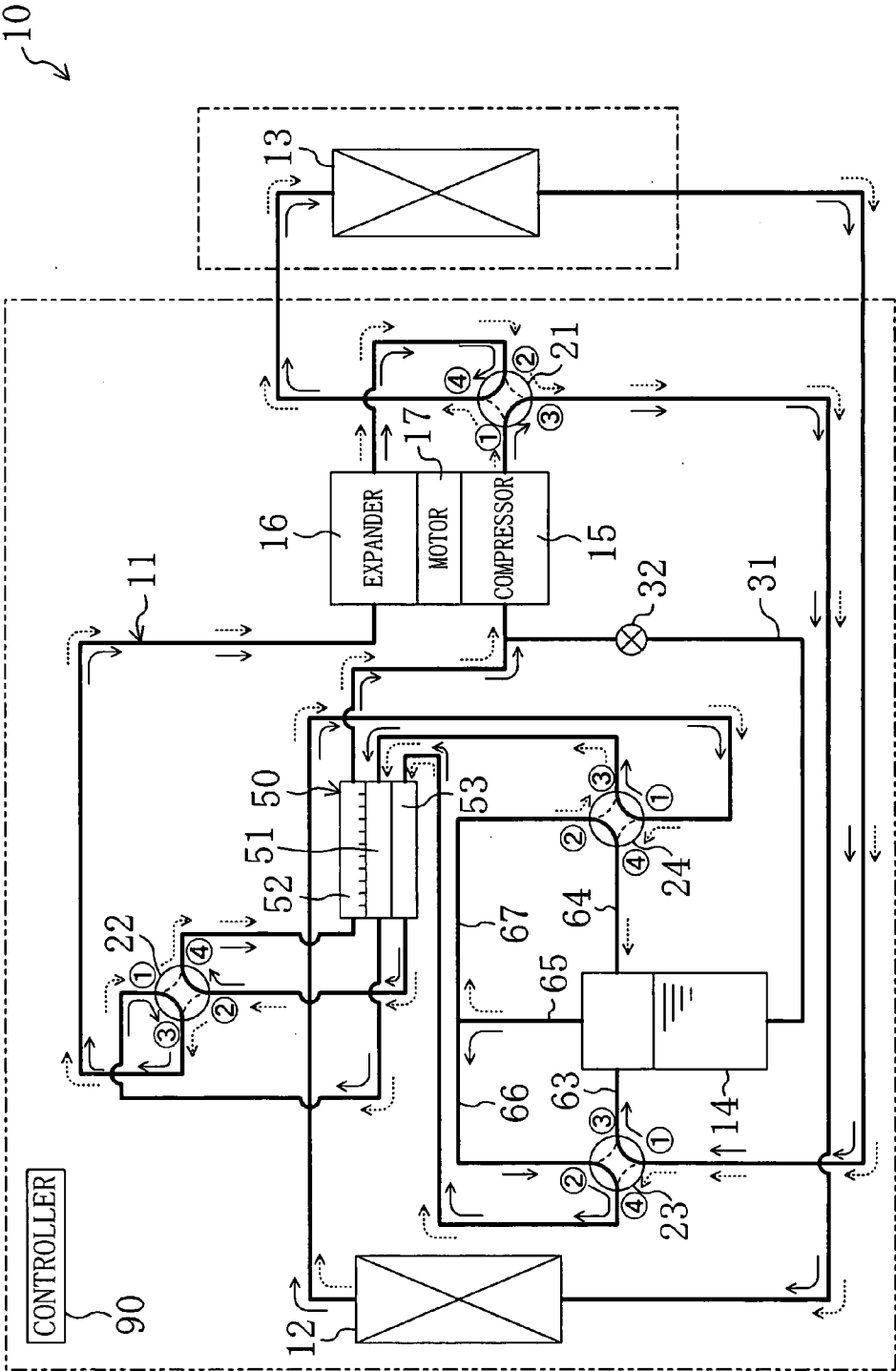


FIG. 17

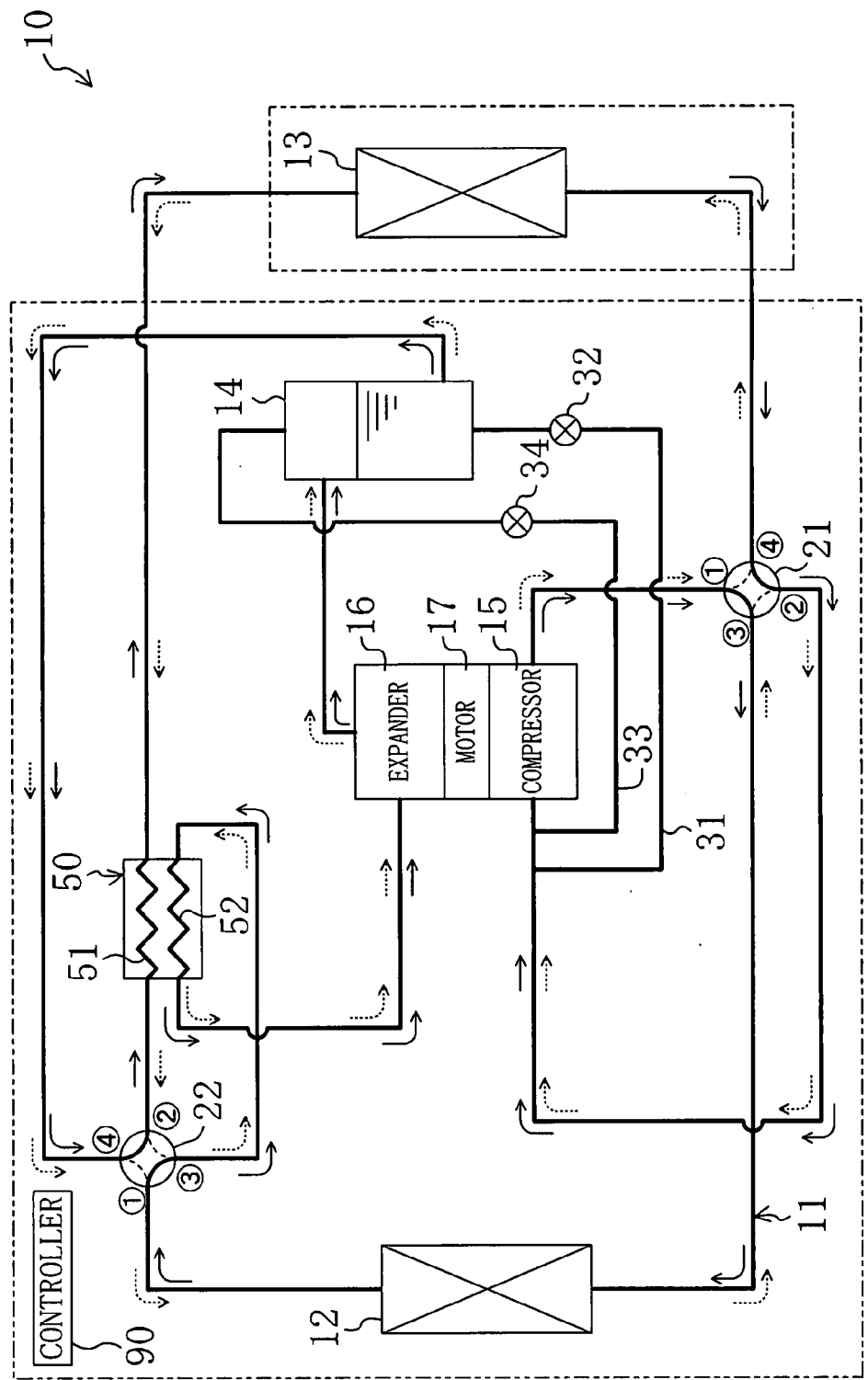


FIG. 18

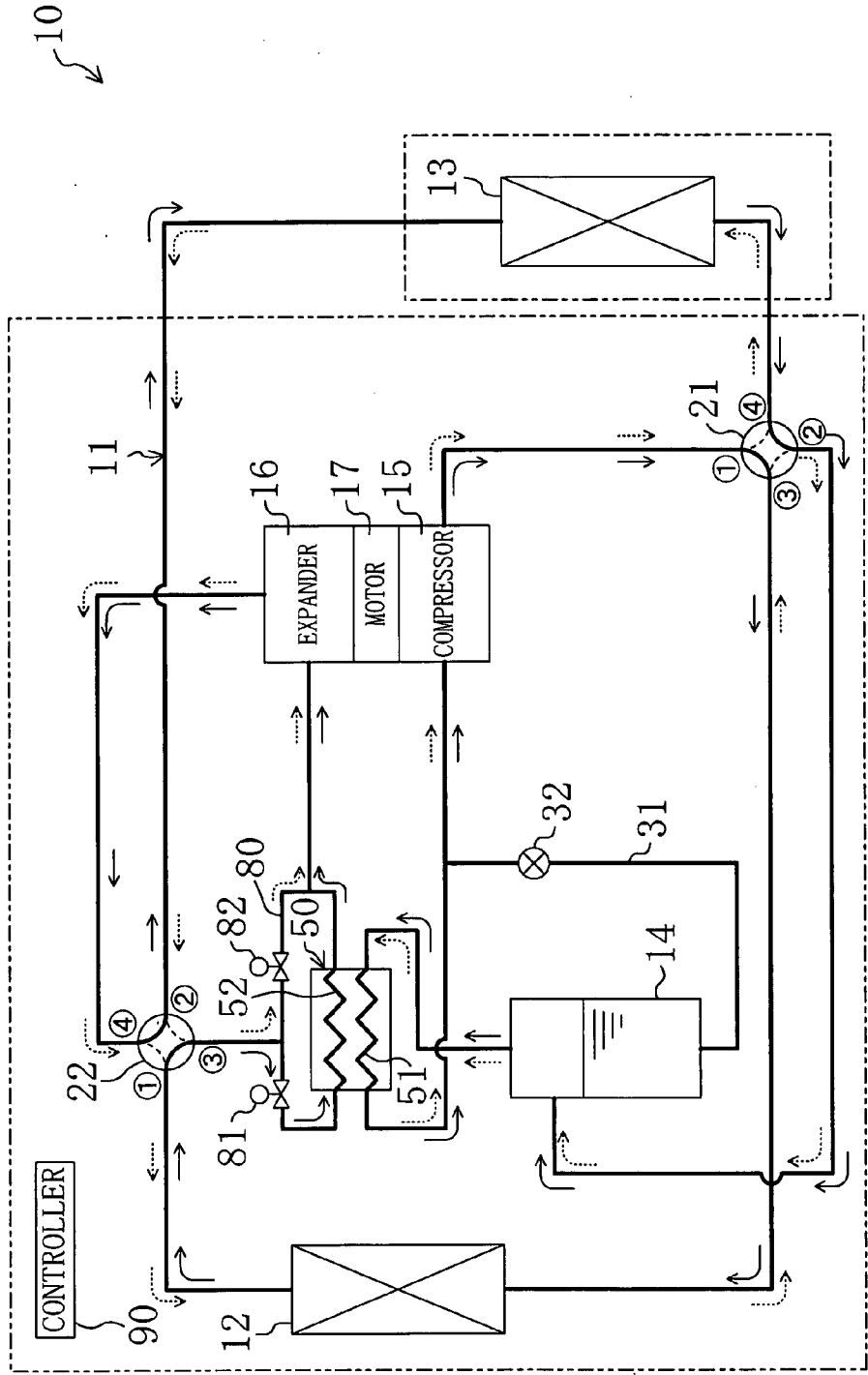


FIG. 19

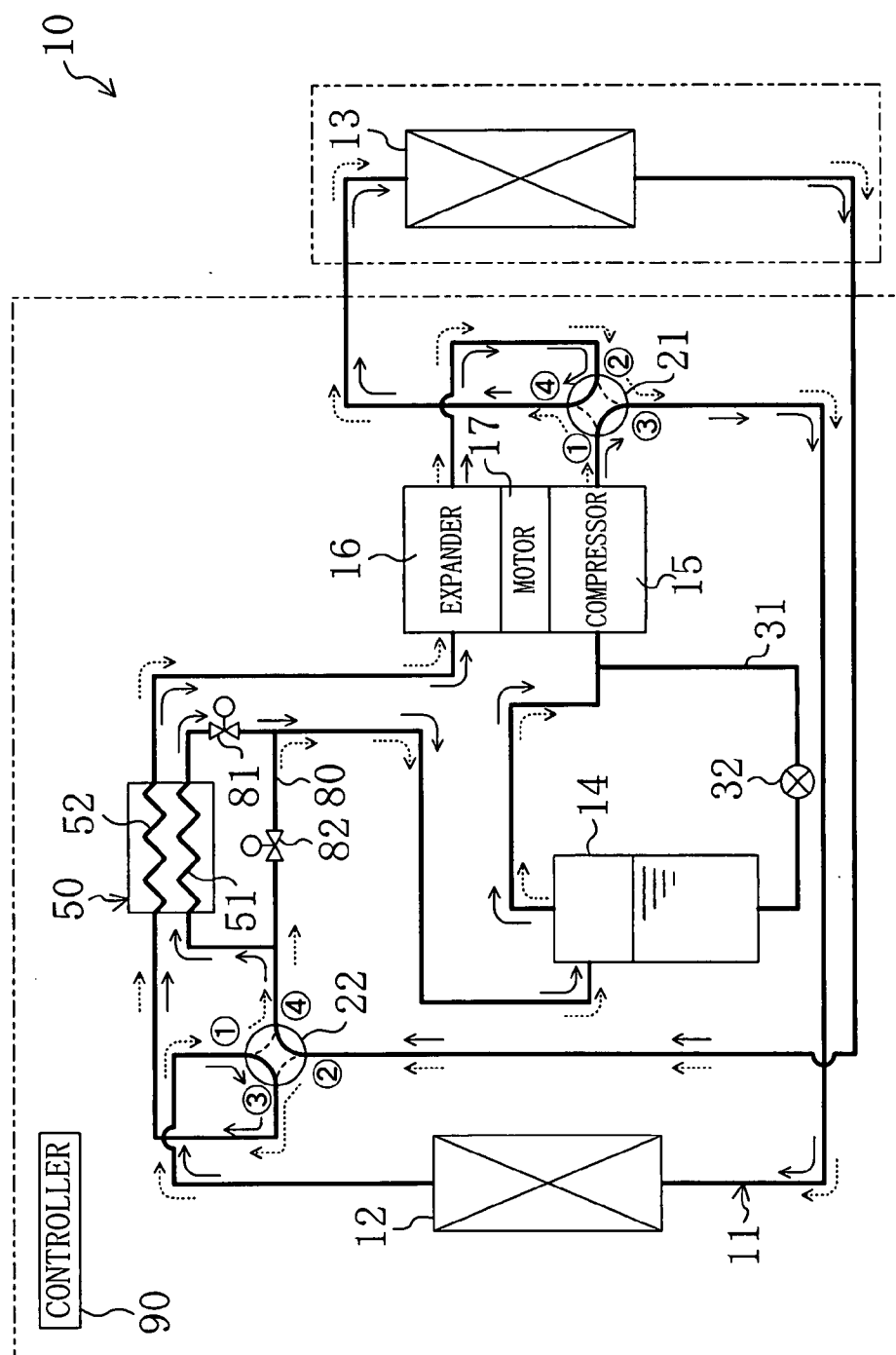
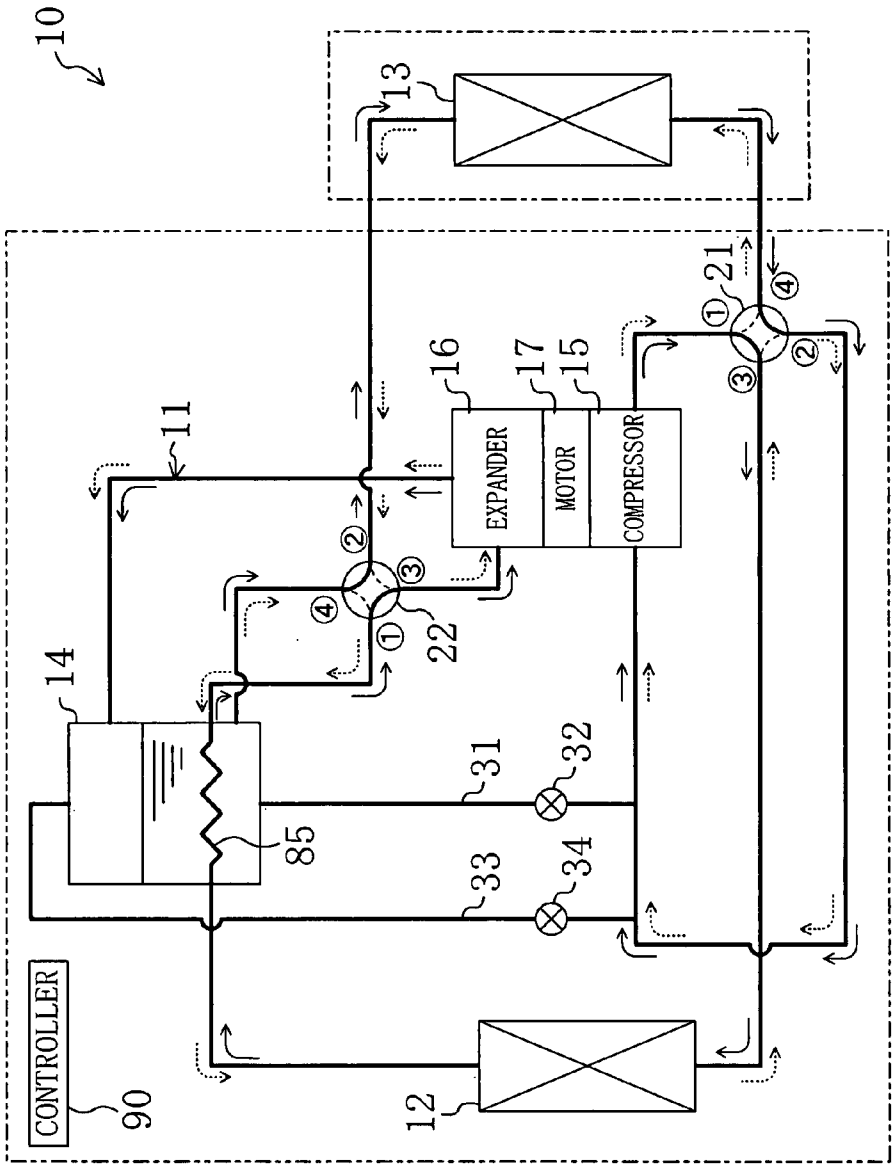


FIG. 20



REFRIGERATION APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus equipped with a refrigerant circuit in which is connected an expander for the recovery of power.

BACKGROUND ART

[0002] Refrigeration apparatuses, such as those disclosed in JP-A-2001-116371 and JP-A-2003-121018, have been well known in the conventional technology. A typical such refrigeration apparatus is provided with a refrigerant circuit in which an expander for the recovery of power is connected and refrigerant is circulated in the refrigerant circuit to thereby perform a refrigeration cycle. In this type of refrigeration apparatus, the expander is mechanically coupled to a compressor by a shaft or the like. And, power produced by the expansion of refrigerant in the expander is utilized to activate the compressor and the input to a motor which activates the compressor is reduced with a view to accomplishing improvements in COP (coefficient of performance).

[0003] In the above-described refrigeration apparatus, the compressor and the expander are connected in the refrigerant circuit which is a closed circuit. This arrangement requires that the refrigerant mass flow rate through the compressor be always equal to the refrigerant mass flow rate through the expander. However, refrigerant which is drawn into the compressor and refrigerant which flows into the expander change their state (temperature, pressure, density et cetera) depending on the operational state of the refrigeration apparatus. Consequently, if the rotational speed of the compressor and the rotational speed of the expander cannot be set individually from each other, this may create an imbalance between the amount of refrigerant passing through the compressor and the amount of refrigerant passing through the expander. As a result, it becomes impossible to perform a refrigeration cycle in a proper condition.

[0004] The refrigeration apparatus disclosed in JP-A-2001-116371 therefore incorporates therein a bypass passageway which bypasses the expander. In an operational state in which the amount of refrigerant passing through the expander is relatively too small, refrigerant is made to flow also into the bypass passageway, thereby establishing a balance between the amount of refrigerant passing through the compressor and the amount of refrigerant passing through the expander. In the refrigeration apparatus disclosed in JP-A-2003-121018, an expansion valve is disposed in series with the expander. In an operational state in which the amount of refrigerant passing through the expander is relatively too large, refrigerant is expanded by both the expander and the expansion valve, thereby establishing a balance between the amount of refrigerant passing through the compressor and the amount of refrigerant passing through the expander.

DISCLOSURE OF THE INVENTION

Problems that the Invention Intends to Solve

[0005] As described above, in a conventional refrigeration apparatus including an expander, the amount of refrigerant passing through the expander and the amount of refrigerant passing through the compressor are balanced with each other by making a change in the state of refrigerant passing through the expander. Consequently, the amount of power recoverable

from refrigerant in the expander is reduced, therefore producing the possibility of resulting in insufficient improvement in COP. In other words, if a portion of the refrigerant bypasses the expander, the amount of refrigerant passing through the expander decreases, and the amount of power which is obtained in the expander decreases. On the other hand, if refrigerant is subjected to expansion by both the expansion valve and the expander, this reduces the difference in pressure between the inlet and the outlet of the expander. Also, in this case, the amount of power which is obtained in the expander decreases.

[0006] With the above problems in mind, the present invention was made. Accordingly, an object of the present invention is that, in a refrigeration apparatus equipped with an expander, the amount of refrigerant passing through the compressor and the amount of refrigerant passing through the expander can be balanced with each other, regardless of the operational state and without reducing the amount of power recoverable in the expander.

Means for Solving the Problems

[0007] The present invention provides, as a first aspect, a refrigeration apparatus, equipped with a refrigerant circuit (11) in which an expander (16) for the recovery of power is connected, for performing a refrigeration cycle by causing refrigerant to circulate within the refrigerant circuit (11). The refrigeration apparatus of the first aspect comprises: (a) a refrigerant adjustment tank (14), disposed along a refrigerant circulation pathway extending from the expander (16) to a compressor (15) in the refrigerant circuit (11), for controlling the amount of refrigerant circulating in the refrigerant circuit (11); (b) a liquid injection passageway (31) for supplying liquid refrigerant in the refrigerant adjustment tank (14) to the suction side of the compressor (15); and (c) a liquid flow rate control mechanism (32) for controlling the flow rate of refrigerant in the liquid injection passageway (31).

[0008] The present invention provides, as a second aspect according to the aforesaid first aspect, a refrigeration apparatus in which the refrigerant adjustment tank (14) is disposed downstream of an evaporator in a refrigerant circulation pathway extending from the expander (16) to the compressor (15).

[0009] The present invention provides, as a third aspect according to the aforesaid first aspect, a refrigeration apparatus in which the refrigerant adjustment tank (14) is disposed upstream of an evaporator in a refrigerant circulation pathway extending from the expander (16) to the compressor (15).

[0010] The present invention provides, as a fourth aspect according to the aforesaid third aspect, a refrigeration apparatus comprising: (a) a gas injection passageway (33) for supplying gas refrigerant in the refrigerant adjustment tank (14) to the suction side of the compressor (15); and (b) a gas flow rate control mechanism (34) for controlling the flow rate of refrigerant in the gas injection passageway (33).

[0011] The present invention provides, as a fifth aspect according to any one of the aforesaid first, second, third, and fourth aspects, a refrigeration apparatus in which the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant.

[0012] The present invention provides, as a sixth aspect according to any one of the aforesaid first, second, and third aspects, a refrigeration apparatus in which:

(a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and

(b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) so that the temperature of refrigerant discharged from the compressor (15) has a predetermined control target value.

[0013] The present invention provides, as a seventh aspect according to the aforesaid fourth aspect, a refrigeration apparatus in which:

(a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and

(b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34) so that the temperature of refrigerant discharged from the compressor (15) has a predetermined control target value.

[0014] The present invention provides, as an eighth aspect according to any one of the aforesaid first, second, and third aspects, a refrigeration apparatus in which:

(a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and

(b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) so that the high pressure of the refrigeration cycle performed in the refrigerant circuit (11) has a predetermined control target value.

[0015] The present invention provides, as a ninth aspect according to the aforesaid fourth aspect, a refrigeration apparatus in which:

(a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and

(b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34) so that the high pressure of the refrigeration cycle performed in the refrigerant circuit (11) has a predetermined control target value.

[0016] The present invention provides, as a tenth aspect according to the aforesaid sixth aspect, a refrigeration apparatus in which the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

[0017] The present invention provides, as an eleventh aspect according to either the aforesaid seventh aspect or the aforesaid ninth aspect, a refrigeration apparatus in which the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

[0018] The present invention provides, as a twelfth aspect according to the aforesaid ninth aspect, a refrigeration apparatus in which the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle

performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

[0019] The present invention provides, as a thirteenth aspect according to any one of the aforesaid fifth to tenth aspects, a refrigeration apparatus in which the refrigerant circuit (11) is charged with carbon dioxide as a refrigerant.

OPERATION

[0020] In the first aspect of the present invention, the expander (16) is disposed in the refrigerant circuit (11). In the refrigerant circuit (11), refrigerant discharged from the compressor (15) dissipates heat to, for example, outdoor air, is then expanded in the expander (16), is evaporated as it absorbs heat from air or the like, and is drawn into the compressor (15) where it is compressed. In this way, the refrigerant is circulated in the refrigerant circuit (11) whereby the refrigeration cycle is performed. The refrigerant adjustment tank (14) is disposed in the refrigerant circuit (11). The refrigerant adjustment tank (14) is a tank used to regulate the amount of refrigerant circulating in the refrigerant circuit (11) by causing a change in the amount of liquid refrigerant held inside the refrigerant adjustment tank (14).

[0021] In the refrigerant circuit (11) of the first aspect of the present invention, liquid refrigerant in the refrigerant adjustment tank (14) can be supplied through the liquid injection passageway (31) to the suction side of the compressor (15). The refrigerant flow rate in the liquid injection passageway (31) is controlled by operation of the liquid flow rate control mechanism (32). For example, if the density of refrigerant which is drawn into the compressor (15) becomes excessively low as the degree of superheat thereof increases, the amount of refrigerant passable through the compressor (15) becomes excessively small relative to the amount of refrigerant passable through the expander (16), thereby producing the possibility that the refrigeration cycle high pressure may not be set to a proper pressure level value. If, in such a case, liquid refrigerant is supplied through the liquid injection passageway (31) to the suction side of the compressor (15), this increases the density of refrigerant which is drawn into the compressor (15) whereby the amount of refrigerant passable through the compressor (15) is balanced with the amount of refrigerant passable through the expander (16).

[0022] In the second aspect of the present invention, the refrigerant adjustment tank (14) is disposed in a refrigerant circulation pathway extending from an evaporator to the compressor (15) in the refrigerant circuit (11). In the refrigerant circuit (11), the outflow of refrigerant from the evaporator once enters the refrigerant adjustment tank (14). And, the compressor (15) draws saturated gas refrigerant in the refrigerant adjustment tank (14).

[0023] In the third aspect of the present invention, the refrigerant adjustment tank (14) is disposed in a refrigerant circulation pathway extending from the expander (16) to an evaporator in the refrigerant circuit (11). In the refrigerant circuit (11), the outflow of refrigerant from the expander (16) once enters the refrigerant adjustment tank (14). And, saturated liquid refrigerant in the refrigerant adjustment tank (14) is supplied to the evaporator.

[0024] In the fourth aspect of the present invention, gas refrigerant in the refrigerant adjustment tank (14) can be supplied through the gas injection passageway (33) to the suction side of the compressor (15). The refrigerant flow rate in the gas injection passageway (33) is controlled by operation of the gas flow rate control mechanism (34). For example,

if the density of refrigerant which is drawn into the compressor (15) becomes excessively high as it enters the wet state, the amount of refrigerant passable through the compressor (15) becomes excessively large relative to the amount of refrigerant passable through the expander (16), thereby producing the possibility that the refrigeration cycle high pressure may not be set to a proper pressure level value. If, in such a case, gas refrigerant is supplied through the gas injection passageway (33) to the suction side of the compressor (15), this decreases the density of refrigerant which is drawn into the compressor (15) whereby the amount of refrigerant passable through the compressor (15) is balanced with the amount of refrigerant passable through the expander (16).

[0025] In each of the fifth, sixth, and seventh aspects of the present invention, the high pressure of the refrigeration cycle which is performed in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant. In other words, the refrigerant discharged from the compressor (15) is in the supercritical state.

[0026] In the sixth aspect of the present invention, the controller means (90) is provided which controls the liquid flow rate control mechanism (32). When the controller means (90) controls the liquid flow rate control mechanism (32), the flow rate of refrigerant which is supplied through the liquid injection passageway (31) to the suction side of the compressor (15) is varied. With such variation, the suction refrigerant of the compressor (15) changes its state and the refrigerant discharge temperature of the compressor (15) changes as well. And, in order that the temperature of refrigerant which is discharged from the compressor (15) may have a predetermined control target value, the controller means (90) controls the liquid flow rate control mechanism (32) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the liquid injection passageway (31).

[0027] In the seventh aspect of the present invention, the controller means (90) is provided which controls both the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34). When the controller means (90) controls the liquid flow rate control mechanism (32), the flow rate of refrigerant which is supplied through the liquid injection passageway (31) to the suction side of the compressor (15) is varied. On the other hand, when the controller means (90) controls the gas flow rate control mechanism (34), the flow rate of refrigerant which is supplied through the gas injection passageway (33) to the suction side of the compressor (15) is varied. With such variation, the suction refrigerant of the compressor (15) changes its density and the refrigerant discharge temperature of the compressor (15) changes as well. And, in order that the temperature of refrigerant which is discharged from the compressor (15) may have a predetermined control target value, the controller means (90) controls either the liquid flow rate control mechanism (32) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the liquid injection passageway (31) or the gas flow rate control mechanism (34) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the gas injection passageway (33).

[0028] In the eighth aspect of the present invention, the controller means (90) is provided which controls the liquid flow rate control mechanism (32). When the controller means (90) controls the liquid flow rate control mechanism (32), the flow rate of refrigerant which is supplied to the suction side of the compressor (15) from the liquid injection passageway (31) is varied, and the suction refrigerant of the compressor

(15) changes its state. And, since the discharge refrigerant of the compressor (15) changes its density, the density of refrigerant which flows into the expander (16) also changes. With such change, the refrigeration cycle high pressure undergoes a change. Therefore, the controller means (90) controls the liquid flow rate control mechanism (32) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the liquid injection passageway (31) in order that the high pressure of the refrigeration cycle which is performed in the refrigerant circuit (11) may have a predetermined control target value.

[0029] In the ninth aspect of the present invention, the controller means (90) is provided which controls both the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34). When the controller means (90) controls the liquid flow rate control mechanism (32), the flow rate of refrigerant which is supplied through the liquid injection passageway (31) to the suction side of the compressor (15) is varied. On the other hand, when the controller means (90) controls the gas flow rate control mechanism (34), the flow rate of refrigerant which is supplied through the gas injection passageway (33) to the suction side of the compressor (15) is varied. If the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34) are controlled in this way, the suction refrigerant of the compressor (15) changes its state. And, since the discharge refrigerant of the compressor (15) changes its density, the density of refrigerant which flows into the expander (16) also changes. With such change, the refrigeration cycle high pressure undergoes a change. Therefore, the controller means (90) controls either the liquid flow rate control mechanism (32) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the liquid injection passageway (31) or the gas flow rate control mechanism (34) to thereby regulate the amount of refrigerant which is supplied to the compressor (15) from the gas injection passageway (33), in order that the high pressure of the refrigeration cycle which is performed in the refrigerant circuit (11) may have a predetermined control target value.

[0030] In each of the tenth, eleventh, and twelfth aspects of the present invention, the controller means (90) sets, based on the operational state of the refrigeration cycle, a control target value. In so doing, the controller means (90) determines a control target value so that the refrigeration cycle high pressure has an optimal value obtainable in an operational state at the time.

[0031] In the thirteenth aspect of the present invention, carbon dioxide (CO₂) is used as a refrigerant with which the refrigerant circuit (11) is filled up.

WORKING EFFECTS OF THE INVENTION

[0032] In the present invention, the liquid injection passageway (31) is arranged in the refrigerant circuit (11), which arrangement makes it possible to provide a supply of liquid refrigerant to the suction side of the compressor (15) through the liquid injection passageway (31). Even in an operational state that will cause an imbalance between the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) unless a certain countermeasure is taken, these amounts are balanced with each other by supplying liquid refrigerant to the suction side of the compressor (15) to thereby control the

suction refrigerant density of the compressor (15) whereby the high pressure of the refrigeration cycle can be set to an adequate pressure level value.

[0033] In the way as described above, according to the present invention, the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) can be balanced with each other while introducing to the expander (16) the entire refrigerant after heat dissipation as it is. Accordingly, according to the present invention, it becomes possible to establish a balance between the amount of refrigerant passing through the compressor (15) and the amount of refrigerant passing through the expander (16), regardless of the operational state and without reducing the amount of power recoverable in the expander (16).

[0034] Especially, in the fourth aspect of the present invention, gas refrigerant in the refrigerant adjustment tank (14) can be supplied to the suction side of the compressor (15) by the gas injection passageway (33). Therefore, according to the fourth aspect of the present invention, even in an operational state that will cause the amount of refrigerant passable through the compressor (15) to become excessive relative to the amount of refrigerant passable through the expander (16) unless a certain countermeasure is taken, it becomes possible to establish a balance between the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) by supplying gas refrigerant to the suction side of the compressor (15) from the gas injection passageway (33).

[0035] In each of the tenth, eleventh, and twelfth aspects of the present invention, the controller means (90) sets a control target value which provides an optimal COP obtainable in an operational state at the time. Therefore, according to the tenth aspect of the present invention, not only the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) can be balanced with each other, but also the operational condition of the refrigeration cycle can be optimized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] In the drawings:

[0037] FIG. 1 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a first embodiment of the present invention;

[0038] FIG. 2 is a Mollier diagram (pressure-enthalpy diagram) which represents refrigeration cycles performed in the refrigerant circuit;

[0039] FIG. 3 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a second embodiment of the present invention;

[0040] FIG. 4 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a third embodiment of the present invention;

[0041] FIG. 5 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a fourth embodiment of the present invention;

[0042] FIG. 6 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a first exemplary variation of the fourth embodiment;

[0043] FIG. 7 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a second exemplary variation of the fourth embodiment;

[0044] FIG. 8 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a third exemplary variation of the fourth embodiment;

[0045] FIG. 9 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a fifth embodiment of the present invention;

[0046] FIG. 10 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a sixth embodiment of the present invention;

[0047] FIG. 11 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a seventh embodiment of the present invention;

[0048] FIG. 12 is a plumbing diagram of a refrigerant circuit in an air conditioner according to an eighth embodiment of the present invention;

[0049] FIG. 13 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a first exemplary variation of the eighth embodiment;

[0050] FIG. 14 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a second exemplary variation of the eighth embodiment;

[0051] FIG. 15 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a third exemplary variation of the eighth embodiment;

[0052] FIG. 16 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a fourth exemplary variation of the eighth embodiment;

[0053] FIG. 17 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a ninth embodiment of the present invention;

[0054] FIG. 18 is a plumbing diagram of a refrigerant circuit in an air conditioner according to a tenth embodiment of the present invention;

[0055] FIG. 19 is a plumbing diagram of a refrigerant circuit in an air conditioner according to an exemplary variation of the tenth embodiment; and

[0056] FIG. 20 is a plumbing diagram of a refrigerant circuit in an air conditioner according to an eleventh embodiment of the present invention.

REFERENCE NUMERALS IN THE DRAWINGS

- [0057] 10 air conditioner (refrigeration apparatus)
- [0058] 11 refrigerant circuit
- [0059] 14 refrigerant adjustment tank
- [0060] 15 compressor
- [0061] 16 expander
- [0062] 31 liquid injection line (liquid injection passageway)
- [0063] 32 liquid side control valve (liquid flow rate control mechanism)
- [0064] 33 gas injection line (gas injection passageway)
- [0065] 34 gas side control valve (gas flow rate control mechanism)
- [0066] 90 controller (controller means)

BEST EMBODIMENT MODE FOR CARRYING OUT THE INVENTION

[0067] Hereinafter, exemplary embodiments of the present invention are described in detail with reference to the accompanying drawings.

First Embodiment of the Invention

[0068] Hereinafter, description will be made in regard to a first embodiment of the present invention. An air conditioner

(10) of the first embodiment is composed of a refrigeration apparatus according to the present invention.

[0069] As shown in FIG. 1, the air conditioner (10) is provided with a refrigerant circuit (11). The refrigerant circuit (11) is a closed circuit charged with carbon dioxide (CO₂) as a refrigerant. The refrigerant circuit (11) includes a compressor (15), an expander (16), an outdoor heat exchanger (12), an indoor heat exchanger (13), and a refrigerant adjustment tank (14). In addition, the refrigerant circuit (11) further includes two four-way switch valves (21, 22).

[0070] Both the compressor (15) and the expander (16) are implemented by positive-displacement fluid machines such as swinging piston type rotary fluid machines, rolling piston type rotary fluid machines, scroll fluid machines et cetera. Together with a motor (17), the compressor (15) and the expander (16) are housed in a single casing. Although not shown diagrammatically in FIG. 1, the compressor (15), the expander (16), and the motor (17) are coupled together by a single shaft.

[0071] Both the outdoor heat exchanger (12) and the indoor heat exchanger (13) are implemented by fin and tube heat exchangers for heat exchange between refrigerant and air. In addition, the refrigerant adjustment tank (14) is a tank shaped like a longitudinally elongated cylinder.

[0072] Each of the foregoing two four-way switch valves (21, 22) has four ports. The four-way switch valves (21, 22) are selectively switchable between a first state (indicated by solid line in FIG. 1) in which the first and third ports fluidly communicate with each other and the second and fourth ports fluidly communicate with each other and a second state (indicated by broken line in FIG. 1) in which the first and fourth ports fluidly communicate with each other and the second and third ports fluidly communicate with each other.

[0073] Hereinafter, description will be made in regard to the configuration of the refrigerant circuit (11). The suction and discharge sides of the compressor (15) are connected, respectively, to the second and first ports of the first four-way switch valve (21). The third and fourth ports of the first four-way switch valve (21) are connected, respectively, to one end of the outdoor heat exchanger (12) and to one end of the indoor heat exchanger (13). The inflow and outflow sides of the expander (16) are connected, respectively, to the third port of the second four-way switch valve (22) and to the upper side of the refrigerant adjustment tank (14). The lower side of the refrigerant adjustment tank (14) is connected to the fourth port of the second four-way switch valve (22). The first and second ports of the second four-way switch valve (22) are connected, respectively, to the other end of the outdoor heat exchanger (12) and to the other end of the indoor heat exchanger (13). In the refrigerant circuit (11), the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from the expander (16) to either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator.

[0074] The refrigerant circuit (11) includes a liquid injection line (31) which constitutes a liquid injection passageway and a gas injection line (33) which constitutes a gas injection passageway. One end and the other end of the liquid injection line (31) are connected, respectively, to the bottom side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15). Disposed along the liquid injection line (31) is a liquid side control valve (32) as a liquid side flow rate control mechanism. One end and the other end of the gas injection line (33) are connected, respectively, to the top side

of the refrigerant adjustment tank (14) and to the suction side of the compressor (15). Disposed along the gas injection line (33) is a gas side control valve (34) as a gas side flow rate control mechanism. Both the liquid side control valve (32) and the gas side control valve (34) are implemented by motor-operated valves and the opening of these valves is variable.

[0075] The air conditioner (10) is provided with a controller (90) as a controller means. The controller (90) is configured such that it controls the opening of the liquid and gas side control valves (32, 34). More specifically, the controller (90) sets, as a control target value, a target value of the refrigerant discharge temperature of the compressor (15) and controls the opening of the liquid and gas side control valves (32, 34) so that the actually measured refrigerant discharge temperature of the compressor (15) becomes the control target value. In so doing, the controller (90) sets, as a control target value, a value of the refrigeration cycle high pressure which provides an optimal coefficient of performance (COP) for the refrigeration cycle obtainable in an operational state at the time.

Running Operation

[0076] Hereinafter, description will be made in regard to the operation of the air conditioner (10).

Cooling Operation Mode

[0077] During the cooling operation mode, the first and second four-way switch valves (21, 22) are set to the first state (indicated by solid line in FIG. 1), and refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by solid line arrow in FIG. 1. During the cooling operation mode, the outdoor heat exchanger (12) functions as a gas cooler while on the other hand the indoor heat exchanger (13) functions as an evaporator.

[0078] More specifically, supercritical refrigerant discharged from the compressor (15) flows into the outdoor heat exchanger (12) and dissipates heat to outdoor air. Thereafter, the refrigerant enters the expander (16). In the expander (16), the inflow refrigerant is expanded and resulting power is transmitted to the compressor (15). The outflow of gas-liquid two-phase refrigerant from the expander (16) enters the refrigerant adjustment tank (14) where the refrigerant is separated into a liquid refrigerant and a gas refrigerant. The outflow of liquid refrigerant from the refrigerant adjustment tank (14) enters the indoor heat exchanger (13), absorbs heat from indoor air, and is evaporated. In the indoor heat exchanger (13), indoor air is cooled by the refrigerant. The refrigerant evaporated in the indoor heat exchanger (13) is drawn into the compressor (15) where it is compressed.

Heating Operation Mode

[0079] During the heating operation mode, the first and second four-way switch valves (21, 22) are set to the second state (indicated by broken line in FIG. 1), and refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by broken line arrow in FIG. 1. During the heating operation mode, the indoor heat exchanger (13) functions as a gas cooler while on the other hand the outdoor heat exchanger (12) functions as an evaporator.

[0080] More specifically, supercritical refrigerant discharged from the compressor (15) flows into the indoor heat exchanger (13) and dissipates heat to indoor air. Thereafter, the refrigerant enters the expander (16). In the indoor heat

exchanger (13), indoor air is heated by the refrigerant. In the expander (16), the inflow refrigerant is expanded and resulting power is transmitted to the compressor (15). The outflow of gas-liquid two-phase refrigerant from the expander (16) enters the refrigerant adjustment tank (14) where the refrigerant is separated into a liquid refrigerant and a gas refrigerant. The outflow of liquid refrigerant from the refrigerant adjustment tank (14) enters the outdoor heat exchanger (12), absorbs heat from outdoor air, and is evaporated. The refrigerant evaporated in the outdoor heat exchanger (12) is drawn into the compressor (15) where it is compressed.

Control Operation of the Controller

[0081] How the refrigeration cycle changes its operational state upon the variation in the opening of the liquid and gas side control valves (32, 34) is now explained.

[0082] Referring to FIG. 2 which is a Mollier diagram (pressure-enthalpy diagram), there are represented refrigeration cycles in which the refrigerant evaporating pressure (i.e., the refrigeration cycle low pressure) is P_L and the refrigerant temperature at the outlet of the gas cooler is T_{gc} . It is assumed here that a refrigeration cycle represented by A-B-C-D in FIG. 2 provides an optimal COP in this operational state. In other words, suppose that the COP of the refrigeration cycle is optimized when the refrigerant discharge temperature of the compressor (15) becomes T_d (i.e., when the refrigeration cycle high pressure becomes P_H).

[0083] If, in a so-called supercritical cycle in which the refrigerant cycle high pressure exceeds the refrigerant critical pressure, the refrigerant evaporating pressure (i.e., the refrigeration cycle low pressure), the state of refrigerant drawn into the compressor (more specifically, the degree of superheat or wetness), and the refrigerant temperature at the gas cooler outlet are determined, this accordingly makes it possible to specify a value of the refrigeration cycle high pressure that provides an optimal COP of the refrigeration cycle.

[0084] Now suppose that a refrigeration cycle represented by A'-B'-C'-D' in FIG. 2 is being performed in the refrigerant circuit (11). At this time, the state of refrigerant which is drawn into the compressor (15) is in the state of point A'. The refrigerant in the state of point A' has a lower density than the refrigerant in the state of point A. In this case, if a supply of liquid refrigerant from the liquid injection line (31) is started or the supply amount of liquid refrigerant from the liquid injection line (31) is increased, the refrigerant which is drawn into the compressor (15) approaches the state of point A from the state of point A' and its density becomes higher. In association with the increase in the density of the refrigerant which is drawn into the compressor (15), the density of the refrigerant which flows into the expander (16) likewise becomes higher. Consequently, point C' moves on the isothermal line of the temperature T_{gc} in the direction in which the density increases, and gets closer to point C. The refrigeration cycle high pressure P'_H increases and approaches the pressure P_H , while the refrigerant discharge temperature of the compressor (15) falls and approaches the temperature T_d , whereby the entire refrigeration cycle approaches an ideal refrigeration cycle, i.e., the refrigeration cycle represented by A-B-C-D in FIG. 2.

[0085] In addition, suppose that a refrigeration cycle represented by A''-B''-C''-D'' in FIG. 2 is being performed in the refrigerant circuit (11). At this time, the state of refrigerant which is drawn into the compressor (15) is in the state of point A''. The refrigerant in the state of point A'' has a higher density

than the refrigerant in the state of point A. In this case, if a supply of gas refrigerant from the gas injection line (33) is started or the supply amount of gas refrigerant from the gas injection line (33) is increased, the refrigerant which is drawn into the compressor (15) approaches the state of point A from the state of point A'' and its density becomes lower. In association with the decrease in the density of the refrigerant which is drawn into the compressor (15), the density of the refrigerant which flows into the expander (16) likewise becomes lower. Consequently, point C' moves on the isothermal line of the temperature T_{gc} in the direction in which the density becomes lower, and approaches point C. And, the refrigeration cycle high pressure P''_H decreases and approaches the pressure P_H , while the refrigerant discharge temperature of the compressor (15) increases and approaches the temperature T_d , whereby the entire refrigeration cycle approaches an ideal refrigeration cycle, i.e., the refrigeration cycle represented by A-B-C-D in FIG. 2.

[0086] Next, description will be made in regard to the control operation of the controller (90). As described previously, the controller (90) sets a control target value for the refrigerant discharge temperature of the compressor (15). More specifically, the controller (90) gains from sensors et cetera an actual measurement value of the refrigerant cycle low pressure and an actual measurement value of the refrigerant temperature at the gas cooler outlet. In addition, the controller (90) pre-stores, as a function of the refrigerant cycle low pressure and the refrigerant temperature at the gas cooler outlet, a value for the refrigerant discharge temperature of the compressor (15) that provides an optimal COP of the refrigeration cycle. In so doing, the state of the suction refrigerant of the compressor (15) is pre-set as follows: for example, "at a degree of superheat of 5 degrees Centigrade" or "in the saturated state". The controller (90) performs a calculation by substituting a gained actual measurement value in a stored function and sets a result of the calculation as a control target value.

[0087] The controller (90) compares the set control target value with an actual measurement value of the refrigerant discharge temperature of the compressor (15) and, based on the compare result, controls the opening of the liquid and gas side control valves (32, 34).

[0088] For example, suppose that an actual measurement value of the refrigerant discharge temperature of the compressor (15) is higher than the control target value. If, at this time, the gas side control valve (34) is in the open state, the controller (90) gradually reduces the opening of the gas side control valve (34). If, even when the gas side control valve (34) enters the fully closed state, the actually measured refrigerant discharge temperature of the compressor (15) is still higher than the control target value, the controller (90) gradually increases the opening of the liquid side control valve (32). On the contrary, suppose that an actual measurement value of the refrigerant discharge temperature of the compressor (15) is lower than the control target value. If, at this time, the liquid side control valve (32) is in the open state, the controller (90) gradually reduces the opening of the liquid side control valve (32). If, even when the liquid side control valve (32) enters the fully closed state, the actually measured refrigerant discharge temperature of the compressor (15) still falls below the con-

trol target value, the controller (90) gradually increases the opening of the gas side control valve (34).

Advantageous Effects of the First Embodiment

[0089] In the air conditioner (10) of the first embodiment, the liquid injection line (31) is arranged in the refrigerant circuit (11), which arrangement allows liquid refrigerant to be supplied through the liquid injection line (31) to the suction side of the compressor (15). Even in an operational state that will cause an imbalance between the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) unless a certain countermeasure is taken, these amounts are balanced with each other by supplying liquid refrigerant to the suction side of the compressor (15) to thereby control the suction refrigerant density of the compressor (15) whereby the high pressure of the refrigeration cycle can be set to an adequate pressure level value.

[0090] As described above, according to the first embodiment, the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) can be balanced with each other while simultaneously introducing the entire outflow refrigerant from the gas cooler to the expander (16) as it is. Accordingly, according to the first embodiment, it becomes possible to establish a balance between the amount of refrigerant passing through the compressor (15) and the amount of refrigerant passing through the expander (16), regardless of the operational state and without reducing the amount of power recoverable in the expander (16).

[0091] In addition, in the air conditioner (10) of the first embodiment, gas refrigerant in the refrigerant adjustment tank (14) can be supplied to the suction side of the compressor (15) by the gas injection line (33). Therefore, according to the first embodiment, even in an operational state that will cause the amount of refrigerant passable through the compressor (15) to become excessive relative to the amount of refrigerant passable through the expander (16) unless a certain countermeasure is taken, it becomes possible to establish a balance between the amount of refrigerant passable through the compressor (15) and the amount of refrigerant passable through the expander (16) by supplying gas refrigerant to the suction side of the compressor (15) from the gas injection line (33).

Second Embodiment of the Invention

[0092] Hereinafter, description will be made in regard to a second embodiment of the present invention. An air conditioner (10) of the second embodiment is a modification of the air conditioner (10) of the first embodiment (more specifically, the refrigerant circuit (11) and the controller (90) in the first embodiment are modified in configuration in the second embodiment). In the following, the difference from the first embodiment in regard to the air conditioner (10) of the second embodiment is described.

[0093] As shown in FIG. 3, the refrigerant circuit (11) of the second embodiment is provided with a bridge circuit (40) as a substitute for the second four-way switch valve (22). The bridge circuit (40) comprises a bridge connection of four check valves (41, 42, 43, 44). The bridge circuit (40) is configured such that the inflow side of each of the first and fourth check valves (41, 44) is connected to the outflow side of the expander (16); the outflow side of each of the second and third check valves (42, 43) is connected to the inflow side of the

expander (16); the outflow side of the first check valve (41) and the inflow side of the second check valve (42) are connected to the other end of the indoor heat exchanger (13); and the inflow side of the third check valve (43) and the outflow side of the fourth check valve (44) are connected to the other end of the outdoor heat exchanger (12).

[0094] In addition, in the refrigerant circuit (11) of the second embodiment, the refrigerant adjustment tank (14) is arranged differently from the first embodiment. In the refrigerant circuit (11) of the second embodiment, the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator, to the compressor (15). More specifically, the upper and top sides of the refrigerant adjustment tank (14) are connected, respectively, to the second port of the first four-way switch valve (21) and to the suction side of the compressor (15).

[0095] Besides, in the refrigerant circuit (11) of the second embodiment, the liquid injection line (31) and the liquid side control valve (32) are provided, but the gas injection line (33) and the gas side control valve (34) are omitted. In the refrigerant circuit (11), one end and the other end of the liquid injection line (31) are connected, respectively, to the bottom side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15). This arrangement is the same as the first embodiment.

[0096] In addition, with the omission of the gas injection line (33) and the gas side control valve (34), the controller (90) of the second embodiment is configured such that it controls only the opening of the liquid side control valve (32). Stated another way, the controller (90) sets a target value of the refrigerant discharge temperature of the compressor (15) as a control target value and controls the opening of the liquid side control valve (32) so that the actually measured refrigerant discharge temperature of the compressor (15) becomes the control target value.

Running Operation

[0097] Hereinafter, description will be made in regard to the operation of the air conditioner (10).

Cooling Operation Mode

[0098] During the cooling operation mode, the first four-way switch valve (21) is set to the first state (indicated by solid line in FIG. 3) and refrigerant is circuited in the refrigerant circuit (11) in the direction indicated by solid line arrow in FIG. 3. The outdoor heat exchanger (12) functions as a gas cooler while on the other hand the indoor heat exchanger (13) functions as an evaporator.

[0099] More specifically, supercritical refrigerant discharged from the compressor (15) flows into the outdoor heat exchanger (12) and dissipates heat to outdoor air. Thereafter, the refrigerant enters the expander (16). In the expander (16), the inflow refrigerant is expanded and resulting power is transmitted to the compressor (15). The outflow of gas-liquid two-phase refrigerant from the expander (16) enters the indoor heat exchanger (13), absorbs heat from indoor air, and is evaporated. In the indoor heat exchanger (13), indoor air is cooled by the refrigerant. The refrigerant after passage through the indoor heat exchanger (13) flows into the refrigerant adjustment tank (14) and gas refrigerant in the refrigerant adjustment tank (14) is drawn into the compressor (15).

where it is compressed. At that time, since liquid refrigerant is held in the refrigerant adjustment tank (14), gas refrigerant which is drawn into the compressor (15) from the refrigerant adjustment tank (14) enters the saturated state.

Heating Operation Mode

[0100] During the heating operation mode, the first four-way switch valve (21) is set to the second state (indicated by broken line in FIG. 1), and refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by broken line arrow in FIG. 3. The indoor heat exchanger (13) functions as a gas cooler while on the other hand the outdoor heat exchanger (12) functions as an evaporator.

[0101] More specifically, supercritical refrigerant discharged from the compressor (15) flows into the indoor heat exchanger (13) and dissipates heat to indoor air. Thereafter, the refrigerant enters the expander (16). In the indoor heat exchanger (13), indoor air is heated by the refrigerant. In the expander (16), the inflow refrigerant is expanded and resulting power is transmitted to the compressor (15). The outflow of gas-liquid two-phase refrigerant from the expander (16) enters the outdoor heat exchanger (12), absorbs heat from outdoor air, and is evaporated. The refrigerant after passage through the outdoor heat exchanger (12) flows into the refrigerant adjustment tank (14) and gas refrigerant in the refrigerant adjustment tank (14) is drawn into the compressor (15) where it is compressed. At that time, since liquid refrigerant is held in the refrigerant adjustment tank (14), gas refrigerant which is drawn into the compressor (15) from the refrigerant adjustment tank (14) enters the saturated state.

Control Operation of the Controller

[0102] The controller (90) sets a control target value for the refrigerant discharge temperature of the compressor (15). In so doing, the controller (90) sets a control target value in the same way as the first embodiment. In other words, based on an actual measurement value of the refrigeration cycle low pressure and an actual measurement value of the refrigerant temperature at the gas cooler outlet, the controller (90) performs an arithmetic operation to calculate a value of the refrigerant discharge temperature of the compressor (15) that provides an optimal COP of the refrigerant cycle and sets a result of the arithmetic operation as a control target value.

[0103] The controller (90) compares the set control target value with an actual measurement value of the refrigerant discharge temperature of the compressor (15) and, based on the compare result, controls the opening of the liquid side control valve (32). That is to say, the controller (90) increases the opening of the liquid side control valve (32) if the actually measured refrigerant discharge temperature of the compressor (15) exceeds the control target value while on the other hand the controller (90) reduces the opening of the liquid side control valve (32) if the actually measured refrigerant discharge temperature of the compressor (15) falls below the control target value.

Third Embodiment of the Invention

[0104] Hereinafter, description will be made in regard to a third embodiment of the present invention. An air conditioner (10) of the third embodiment is a modification of the air conditioner (10) of the second embodiment (more specifically, the refrigerant circuit (11) of the second embodiment is modified in configuration in the third embodiment). In the

following, the difference from the second embodiment in regard to the air conditioner (10) of the third embodiment is described.

[0105] As shown in FIG. 4, the refrigerant circuit (11) of the third embodiment is additionally provided with an internal heat exchanger (50). The internal heat exchanger (50) includes a first flow path (51) and a second flow path (52) and effectuates heat exchange between refrigerant in the first flow path (51) and refrigerant in the second flow path (52). In addition, in the internal heat exchanger (50), the area of heat transfer facing the second flow path (52) is larger than the area of heat transfer facing the first flow path (51). In the internal heat exchanger (50), the first flow path (51) is connected to a line extending between the bridge circuit (40) and the outdoor heat exchanger (12) and the second flow path (52) is connected to a line extending between the bridge circuit (40) and the indoor heat exchanger (13).

Running Operation

[0106] During the cooling operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by solid line arrow in FIG. 4. At that time, in the internal heat exchanger (50), the outflow of liquid refrigerant from the outdoor heat exchanger (12) passes through the first flow path (51), while the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the second flow path (52). In other words, in the internal heat exchanger (50), the gas-liquid two-phase refrigerant flows through the second flow path (52) having a greater heat transfer area. This therefore relatively increases the amount of heat exchange between the refrigerant in the first flow path (51) and the refrigerant in the second flow path (52) and, as a result, the temperature of the liquid refrigerant relatively considerably falls during passage through the first flow path (51). The refrigerant that has undergone a drop in temperature during passage through the first flow path (51) is then delivered to the expander (16). In this way, the refrigerant, cooled in the internal heat exchanger (50) and therefore increased in density, is introduced to the expander (16).

[0107] On the other hand, during the heating operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by broken line arrow in FIG. 4. At that time, in the internal heat exchanger (50), the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the first flow path (51), while the outflow of liquid refrigerant from the indoor heat exchanger (13) passes through the second flow path (52). That is to say, in the internal heat exchanger (50), the gas-liquid two-phase refrigerant flows through the first flow path (51) having a smaller heat transfer area. Therefore, the amount of heat exchange between the refrigerant in the first flow path (51) and the refrigerant in the second flow path (52) becomes relatively small and, as a result, the temperature of the liquid refrigerant does not fall considerably during passage through the first flow path (51). The refrigerant after passage through the first flow path (51) is then delivered to the expander (16). In this way, the refrigerant, not cooled considerably in the internal heat exchanger (50) and hardly changed in density, is introduced to the expander (16).

Fourth Embodiment of the Invention

[0108] Hereinafter, description will be made in regard to a fourth embodiment of the present invention. An air condi-

tioner (10) of the fourth embodiment is a modification of the air conditioner (10) of the third embodiment (more specifically, the refrigerant circuit (11) in the third embodiment is modified in configuration in the fourth embodiment). In the following, the difference from the third embodiment in regard to the air conditioner (10) of the fourth embodiment is described.

[0109] As shown in FIG. 5, in the refrigerant circuit (11) of the fourth embodiment, the refrigerant adjustment tank (14) is arranged differently from the third embodiment. In the refrigerant circuit (11) of the fourth embodiment, the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from the expander (16) to either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator.

[0110] The refrigerant circuit (11) of the fourth embodiment is additionally provided with a fifth check valve (45) and a sixth check valve (46). The fifth check valve (45) is disposed in a line connecting the second flow path (52) of the internal heat exchanger (50) and the indoor heat exchanger (13). The fifth check valve (45) is oriented such that the inflow side is located on the side of the indoor heat exchanger (13) while the outflow side is located on the side of the internal heat exchanger (50). The sixth check valve (46) is disposed in a line connecting the first flow path (51) of the internal heat exchanger (50) and the outdoor heat exchanger (12). The sixth check valve (46) is oriented such that the inflow side is located on the side of the outdoor heat exchanger (12) while the outflow side is located on the side of the internal heat exchanger (50).

[0111] In addition, the refrigerant circuit (11) is additionally provided with a lead-in pipe (60). One end of the lead-in pipe (60) is connected to the top side of the refrigerant adjustment tank (14). The other end of the lead-in pipe (60) is branched off into two branch pipes one of which becomes a first lead-in branch pipe (61) and the other of which becomes a second lead-in branch pipe (62). The first lead-in branch pipe (61) is connected between the fifth check valve (45) and the internal heat exchanger (50). The first lead-in branch pipe (61) is provided with a first solenoid valve (56). The second lead-in branch pipe (62) is connected between the sixth check valve (46) and the internal heat exchanger (50). The second lead-in branch pipe (62) is provided with a second solenoid valve (57).

[0112] In addition, the refrigerant circuit (11) is additionally provided with a first lead-out pipe (68) and a second lead-out pipe (69). One end and the other end of the first lead-out pipe (68) are connected, respectively, to the lower side of the refrigerant adjustment tank (14) and between the indoor heat exchanger (13) and the fifth check valve (45). A seventh check valve (47) is disposed in the first lead-out pipe (68). The seventh check valve (47) allows only refrigerant flow from one end towards the other end of the first lead-out pipe (68). One end and the other end of the second lead-out pipe (69) are connected, respectively, to the lower side of the refrigerant adjustment tank (14) and between the outdoor heat exchanger (12) and the sixth check valve (46). An eighth check valve (48) is disposed in the second lead-out pipe (69). The eighth check valve (48) allows only refrigerant flow from one end towards the other end of the second lead-out pipe (69).

Running Operation

[0113] During the cooling operation mode, the first solenoid valve (56) is placed in the open state and the second

solenoid valve (57) is placed in the closed state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by solid line arrow in FIG. 5. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the second flow path (52) of the internal heat exchanger (50) and then through the first lead-in branch pipe (61) and enters the refrigerant adjustment tank (14). In the refrigerant adjustment tank (14), the inflow refrigerant is separated into a liquid refrigerant and a gas refrigerant. The liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the first lead-out pipe (68) to the indoor heat exchanger (13).

[0114] On the other hand, during the heating operation mode, the first solenoid valve (56) is placed in the closed state and the second solenoid valve (57) is placed in the open state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by broken line arrow in FIG. 5. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the first flow path (51) of the internal heat exchanger (50) and then through the second lead-in branch pipe (62) and enters the refrigerant adjustment tank (14). In the refrigerant adjustment tank (14), the inflow refrigerant is separated into a liquid refrigerant and a gas refrigerant. The liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the second lead-out pipe (69) to the outdoor heat exchanger (12).

First Exemplary Variation of the Fourth Embodiment

[0115] In the fourth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0116] Referring to FIG. 6, there is shown a refrigerant circuit (11) according to a first exemplary variation of the fourth embodiment. The refrigerant circuit (11) of the first exemplary variation is provided with a first three-way valve (26) as a substitute for the first and second solenoid valves (56, 57). The first three-way valve (26) is disposed at where the first and second lead-in branch pipes (61, 62) join together. The first three-way valve (26) has three ports of which the second and third ports are connected to the first lead-in branch pipe (61) and to the second lead-in branch pipe (62), respectively.

[0117] In addition, arranged in the refrigerant circuit (11) is a lead-out pipe (65) as a substitute for the first and second lead-out pipes (68, 69). One end of the lead-out pipe (65) is connected to the lower side of the refrigerant adjustment tank (14). The other end of the lead-out pipe (65) is branched off into two branch pipes one of which becomes a first lead-out branch pipe (66) and the other of which becomes a second lead-out branch pipe (67). The first lead-out branch pipe (66) is connected between the indoor heat exchanger (13) and the fifth check valve (45). The second lead-out pipe (67) is connected between the outdoor heat exchanger (12) and the sixth check valve (46).

[0118] The lead-out pipe (65) is provided with a second three-way valve (27). The second three-way valve (27) is disposed at where the first lead-out branch pipe (66) and the second lead-out branch pipe (67) join together. The second three-way valve (27) has three ports of which the second and third ports are connected to the first lead-out branch pipe (66) and to the second lead-out branch pipe (67), respectively.

[0119] During the cooling operation mode, the first three-way valve (26) and the second three-way valve (27) are set to the state (indicated by solid line in FIG. 6) in which the first and second ports fluidly communicate with each other. And,

in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by solid line arrow in FIG. 6. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the second flow path (52) of the internal heat exchanger (50) and then through the first lead-in branch pipe (61) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the first lead-out branch pipe (66) to the indoor heat exchanger (13).

[0120] On the other hand, during the heating operation mode, the first three-way valve (26) and the second three-way valve (27) are set to the state (indicated by broken line in FIG. 6) in which the first and third ports fluidly communicate with each other. And, in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by broken line arrow in FIG. 6. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the first flow path (51) of the internal heat exchanger (50) and then through the second lead-in branch pipe (62) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the second lead-out branch pipe (67) to the outdoor heat exchanger (12).

Second Exemplary Variation of the Fourth Embodiment

[0121] In the fourth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0122] Referring to FIG. 7, there is shown a refrigerant circuit (11) according to a second exemplary variation of the fourth embodiment. The refrigerant circuit (11) of the second exemplary variation is provided with a second four-way switch valve (22) as a substitute for the bridge circuit (40). The second four-way switch valve (22) has four ports of which: the first port is connected to the first flow path (51) of the internal heat exchanger (50); the second port is connected to the second flow path (52) of the internal heat exchanger (50); the third port is connected to the inflow side of the expander (16); and the fourth port is connected to the outflow side of the expander (16).

[0123] In addition, in the refrigerant circuit (11) of the second exemplary variation, the first and second solenoid valves (56, 57) and the fifth to eighth check valves (45, 46, 47, 48) are omitted and a third four-way switch valve (23) and a fourth four-way switch valve (24) are provided instead. The third four-way switch valve (23) has four ports of which: the first port is connected to the first lead-out pipe (68); the second port is connected to the second flow path (52) of the internal heat exchanger (50); the third port is connected to the other end of the indoor heat exchanger (13); and the fourth port is connected to the first lead-in branch pipe (61). The fourth four-way switch valve (24) has four ports of which: the first port is connected to the other end of the outdoor heat exchanger (12); the second port is connected to the second lead-in branch pipe (62); the third port is connected to the first flow path (51) of the internal heat exchanger (50); and the fourth port is connected to the second lead-out pipe (69).

[0124] During the cooling operation mode, the four-way switch valves (21, 22, 23, 24) are all set to the state indicated by solid line in FIG. 7. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 7. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the second flow path (52) of the internal heat exchanger (50)

and then through the first lead-in branch pipe (61) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the first lead-out branch pipe (66) to the indoor heat exchanger (13).

[0125] On the other hand, during the heating operation mode, the four-way switch valves (21, 22, 23, 24) are all set to the state indicated by broken line in FIG. 7. And, in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by broken line arrow in FIG. 7. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the first flow path (51) of the internal heat exchanger (50) and then through the second lead-in branch pipe (62) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the second lead-out branch pipe (67) to the outdoor heat exchanger (12).

Third Exemplary Variation of the Fourth Embodiment

[0126] In the fourth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0127] Referring to FIG. 8, there is shown a refrigerant circuit (11) according to a third exemplary variation of the fourth embodiment. The refrigerant circuit (11) of the third exemplary variation is provided with a second four-way switch valve (22) as a substitute for the bridge circuit (40). The second four-way switch valve (22) has four ports of which: the first port is connected to a third four-way switch valve (23) which is described later; the second port is connected to the second flow path (52) of the internal heat exchanger (50); the third port is connected to the inflow side of the expander (16); and the fourth port is connected to the outflow side of the expander (16).

[0128] In addition, in the refrigerant circuit (11) of the third exemplary variation, the sixth check valve (46) is omitted and the third four-way switch valve (23) and a third solenoid valve (58) are added instead. The third four-way switch valve (23) has four ports of which: the first port is connected to the other end of the outdoor heat exchanger (12); the second port is connected to the first port of the second four-way switch valve (22); the third port is connected to one end of the first flow path (51) of the internal heat exchanger (50); and the fourth port is connected to the other end of the first flow path (51) of the internal heat exchanger (50). The third solenoid valve (58) is connected between the fourth port of the third four-way switch valve (23) and the first flow path (51) of the internal heat exchanger (50).

[0129] In the refrigerant circuit (11) of the third exemplary variation, the connecting location of each of the second lead-in branch pipe (62) and the second lead-out pipe (69) is changed. More specifically, the second lead-in branch pipe (62) is connected between the first flow path (51) of the internal heat exchanger (50) and the third solenoid valve (58) and the second lead-out pipe (69) is connected between the fourth port of the third four-way switch valve (23) and the third solenoid valve (58).

[0130] During the cooling operation mode, the four-way switch valves (21, 22, 23) are set to the state indicated by solid line in FIG. 8 and the first and third solenoid valves (56, 58) are placed in the open state while the second solenoid valve (57) is placed in the closed state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 8. More specifically, the outflow of

gas-liquid two-phase refrigerant from the expander (16) passes through the second flow path (52) of the internal heat exchanger (50) and then through the first lead-in branch pipe (61) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the first lead-out pipe (68) to the indoor heat exchanger (13).

[0131] On the other hand, during the heating operation mode, the four-way switch valves (21, 22, 23) are set to the state indicated by broken line in FIG. 8 and the first and third solenoid valves (56, 58) are placed in the closed state while the second solenoid valve (57) is placed in the open state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction as indicated by broken line arrow in FIG. 8. More specifically, the outflow of gas-liquid two-phase refrigerant from the expander (16) passes through the first flow path (51) of the internal heat exchanger (50) and then through the second lead-in branch pipe (62) and enters the refrigerant adjustment tank (14). In addition, liquid refrigerant in the refrigerant adjustment tank (14) is delivered through the second lead-out pipe (69) to the outdoor heat exchanger (12).

Fifth Embodiment of the Invention

[0132] Hereinafter, description will be made in regard to a fifth embodiment of the present invention. An air conditioner (10) of the fifth embodiment is a modification of the air conditioner (10) of the first embodiment (more specifically, the refrigerant circuit (11) of the first embodiment is modified in configuration in the fifth embodiment). In the following, the difference from the first embodiment in regard to the air conditioner (10) of the fifth embodiment is described.

[0133] As shown in FIG. 9, in the refrigerant circuit (11) of the fifth embodiment, the first and second four-way switch valves (21, 22) are arranged differently from the first embodiment. Of the four ports of the first four-way switch valve (21), the first port is connected to the discharge side of the compressor (15); the second port is connected to the lower side of the refrigerant adjustment tank (14); the third port is connected to one end of the outdoor heat exchanger (12); and the fourth port is connected to the other end of the indoor heat exchanger (13). Of the four ports of the second four-way switch valve (22), the first port is connected to the other end of the outdoor heat exchanger (12); the second port is connected to one end of the indoor heat exchanger (13); the third port is connected to the inflow side of the expander (16); and the fourth port is connected to the suction side of the compressor (15). And, both the liquid injection line (31) and the gas injection line (33) are connected between the suction side of the compressor (15) and the second four-way switch valve (22).

Running Operation

[0134] During the cooling operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the first state (indicated by solid line in FIG. 9). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 9. In other words, refrigerant discharged from the compressor (15) passes through the outdoor heat exchanger (12), then through the expander (16), then through the refrigerant adjustment tank (14), and then through the indoor heat exchanger (13), in that order and is drawn into the compressor (15) where it is compressed.

[0135] On the other hand, during the heating operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the second state (indicated by broken line in FIG. 9). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 9. In other words, refrigerant discharged from the compressor (15) passes through the indoor heat exchanger (13), then through the expander (16), then through the refrigerant adjustment tank (14), and then through the outdoor heat exchanger (12), in that order and is drawn into the compressor (15) where it is compressed.

Sixth Embodiment of the Invention

[0136] Hereinafter, description will be made in regard to a sixth embodiment of the present invention. An air conditioner (10) of the sixth embodiment is a modification of the air conditioner (10) of the fifth embodiment (more specifically, the refrigerant circuit (11) of the fifth embodiment is modified in configuration in the sixth embodiment). In the following, the difference from the fifth embodiment in regard to the air conditioner (10) of the sixth embodiment is described.

[0137] As shown in FIG. 10, in the refrigerant circuit (11) of the sixth embodiment, the refrigerant adjustment tank (14) is arranged differently from the fifth embodiment. In the refrigerant circuit (11) of the sixth embodiment, the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator, to the compressor (15). More specifically, the upper side of the refrigerant adjustment tank (14) is connected to the fourth port of the second four-way switch valve (22) and the top thereof is connected to the suction side of the compressor (15). With the change in the arrangement of the refrigerant adjustment tank (14), the second port of the first four-way switch valve (21) is connected to the outflow side of the expander (16).

[0138] Besides, in the refrigerant circuit (11) of the sixth embodiment, the liquid injection line (31) and the liquid side control valve (32) are provided, but the gas injection line (33) and the gas side control valve (34) are omitted. In the refrigerant circuit (11), one end and the other end of the liquid injection line (31) are connected to the bottom side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15), respectively. This arrangement is the same as the fifth embodiment.

[0139] In addition, with the omission of the gas injection line (33) and the gas side control valve (34), the controller (90) of the sixth embodiment is configured such that it controls only the opening of the liquid side control valve (32). The controller (90) sets a target value of the refrigerant discharge temperature of the compressor (15) as a control target value and controls the opening of the liquid side control valve (32) so that the actually measured refrigerant discharge temperature of the compressor (15) becomes the control target value. In other words, the controller (90) of the sixth embodiment is configured in the same way that the controller (90) of the second embodiment is configured.

Running Operation

[0140] During the cooling operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the first state (indicated by solid line in FIG. 10). And, in the refrigerant circuit (11), refrigerant is

circulated in the direction indicated by solid line arrow in FIG. 10. In other words, refrigerant discharged from the compressor (15) passes through the outdoor heat exchanger (12), then through the expander (16), then through the indoor heat exchanger (13), and then through the refrigerant adjustment tank (14), in that order and is drawn into the compressor (15) where it is compressed.

[0141] On the other hand, during the heating operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the second state (indicated by broken line in FIG. 10). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 10. In other words, refrigerant discharged from the compressor (15) passes through the indoor heat exchanger (13), then through the expander (16), then through the outdoor heat exchanger (12), and then through the refrigerant adjustment tank (14), in that order and is drawn into the compressor (15) where it is compressed.

Seventh Embodiment of the Invention

[0142] Hereinafter, description will be made in regard to a seventh embodiment of the present invention. An air conditioner (10) of the seventh embodiment is a modification of the air conditioner (10) of the fifth embodiment (more specifically, the refrigerant circuit (11) in the fifth embodiment is modified in configuration in the seventh embodiment). In the following, the difference from the fifth embodiment in regard to the air conditioner (10) of the seventh embodiment is described.

[0143] As shown in FIG. 11, the refrigerant circuit (11) of the seventh embodiment is additionally provided with an internal heat exchanger (50). The internal heat exchanger (50) of the seventh embodiment has the same configuration as the internal heat exchanger (50) of the third embodiment. In other words, the internal heat exchanger (50) of the seventh embodiment is provided with a first flow path (51) and a second flow path (52) and the area of heat transfer facing the first flow path (51) is larger than the area of heat transfer facing the second flow path (52). In the internal heat exchanger (50), the first flow path (51) is connected between the first port of the second four-way switch valve (22) and the outdoor heat exchanger (12) and the second flow path (52) is connected between the second port of the second four-way switch valve (22) and the indoor heat exchanger (13).

Running Operation

[0144] During the cooling operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the first state (indicated by solid line in FIG. 11). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 11. In other words, refrigerant discharged from the outdoor heat exchanger (12) functioning as a gas cooler passes through the first flow path (51) of the internal heat exchanger (50) and then flows into the expander (16). In addition, refrigerant discharged from the indoor heat exchanger (13) functioning as an evaporator passes through the second flow path (52) of the internal heat exchanger (50) and is then drawn into the compressor (15).

[0145] On the other hand, during the heating operation mode, both the first four-way switch valve (21) and the second four-way switch valve (22) are set to the second state (indicated by broken line in FIG. 11). And, in the refrigerant

circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 11. In other words, refrigerant discharged from the indoor heat exchanger (13) functioning as a gas cooler passes through the second flow path (52) of the internal heat exchanger (50) and then flows into the expander (16). In addition, refrigerant discharged from the outdoor heat exchanger (12) functioning as an evaporator passes through the first flow path (51) of the internal heat exchanger (50) and is then drawn into the compressor (15).

Eighth Embodiment of the Invention

[0146] Hereinafter, description will be made in regard to an eighth embodiment of the present invention. An air conditioner (10) of the eighth embodiment is a modification of the air conditioner (10) of the seventh embodiment (more specifically, the refrigerant circuit (11) and the controller (90) in the seventh embodiment are modified in configuration in the eighth embodiment). In the following, the difference from the seventh embodiment in regard to the air conditioner (10) of the eighth embodiment is described.

[0147] As shown in FIG. 12, the refrigerant circuit (11) of the eighth embodiment is additionally provided with a first solenoid valve (71) and a second solenoid valve (72). The first solenoid valve (71) is disposed between the second flow path (52) of the internal heat exchanger (50) and the outdoor heat exchanger (12). The second solenoid valve (72) is disposed between the first flow path (51) of the internal heat exchanger (50) and the outdoor heat exchanger (12).

[0148] In the refrigerant circuit (11) of the eighth embodiment, the refrigerant adjustment tank (14) is arranged differently from the seventh embodiment. In the refrigerant circuit (11) of the eighth embodiment, the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator, to the compressor (15).

[0149] With the change in the arrangement of the refrigerant adjustment tank (14), the second port of the first four-way switch valve (21) is connected to the outflow side of the expander (16) in the refrigerant circuit (11). In addition, the refrigerant circuit (11) of the eighth embodiment is additionally provided with a first lead-in pipe (63), a second lead-in pipe (64), and a lead-out pipe (65).

[0150] One end and the other end of the first lead-in pipe (63) are connected to the upper side of the refrigerant adjustment tank (14) and between the indoor heat exchanger (13) and the first solenoid valve (71), respectively. The first lead-in pipe (63) is provided with a third solenoid valve (73). One end and the other end of the second lead-in pipe (64) are connected to the upper side of the refrigerant adjustment tank (14) and between the outdoor heat exchanger (12) and the second solenoid valve (72), respectively. The second lead-in pipe (64) is provided with a fourth solenoid valve (74).

[0151] One end of the lead-out pipe (65) is connected to the top side of the refrigerant adjustment tank (14). The other end of the lead-out pipe (65) is branched off into two branch pipes one of which becomes a first lead-out branch pipe (66) and the other of which becomes a second lead-out branch pipe (67). The first lead-out branch pipe (66) is connected between the second flow path (52) of the internal heat exchanger (50) and the first solenoid valve (71). The first lead-out branch pipe (66) is provided with a first check valve (76). The first check valve (76) permits only refrigerant flow in the direction in which refrigerant flows out from the refrigerant adjustment

tank (14). The second lead-out branch pipe (67) is connected between the first flow path (51) of the internal heat exchanger (50) and the second solenoid valve (72). The second lead-out branch pipe (67) is provided with a second check valve (77). The second check valve (77) permits only refrigerant flow in the direction in which refrigerant flows out from the refrigerant adjustment tank (14).

[0152] Besides, in the refrigerant circuit (11) of the present embodiment, the liquid injection line (31) and the liquid side control valve (32) are provided, but the gas injection line (33) and the gas side control valve (34) are omitted. In the refrigerant circuit (11), one end and the other end of the liquid injection line (31) are connected to the bottom side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15), respectively. This arrangement is the same as the seventh embodiment.

[0153] In addition, with the omission of the gas injection line (33) and the gas side control valve (34), the controller (90) of the second embodiment is configured such that it controls only the opening of the liquid side control valve (32). The controller (90) sets a target value of the refrigerant discharge temperature of the compressor (15) as a control target value and controls the opening of the liquid side control valve (32) so that the actually measured refrigerant discharge temperature of the compressor (15) becomes the control target value. Stated another way, the controller (90) of the present embodiment is configured in the same way as the controller (90) of the second embodiment.

[0154] During the cooling operation mode, the second and third solenoid valves (72, 73) are placed in the open state while on the other hand the first and fourth solenoid valves (71, 74) are placed in the closed state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 12. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) flows through the first lead-in pipe (63) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the first lead-out branch pipe (66) into the internal heat exchanger (50) and is drawn, after passage through the second flow path (52) of the internal heat exchanger (50), into the compressor (15).

[0155] On the other hand, during the heating operation mode, the second and third solenoid valves (72, 73) are placed in the closed state while on the other hand the first and fourth solenoid valves (71, 74) are placed in the open state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 12. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) flows through the second lead-in pipe (64) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the second lead-out branch pipe (67) into the internal heat exchanger (50) and is drawn, after passage through the first flow path (51) of the internal heat exchanger (50), into the compressor (15).

First Exemplary Variation of the Eighth Embodiment

[0156] In the eighth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0157] Referring to FIG. 13, there is shown a refrigerant circuit (11) according to a first exemplary variation of the eighth embodiment. The refrigerant circuit (11) of the first exemplary variation is provided with a first three-way valve (26) and a second three-way valve (27) instead of the first to fourth solenoid valves (71, 72, 73, 74).

[0158] The first three-way valve (26) is disposed along a line connecting the indoor heat exchanger (13) and the second flow path (52) of the internal heat exchanger (50). The first three-way valve (26) has three ports of which the first port is connected to the indoor heat exchanger (13) and the third port is connected to the second flow path (52) of the internal heat exchanger (50). In addition, connected to the second port of the first three-way valve (26) is the first lead-in pipe (63).

[0159] The second three-way valve (27) is disposed along a line connecting the outdoor heat exchanger (12) and the first flow path (51) of the internal heat exchanger (50). The second three-way valve (27) has three ports of which the first port is connected to the outdoor heat exchanger (12) and the second port is connected to the first flow path (51) of the internal heat exchanger (50). In addition, connected to the third port of the second three-way valve (27) is the second lead-in pipe (64).

[0160] During the cooling operation mode, the first three-way valve (26) and the second three-way valve (27) are set to the state (indicated by solid line in FIG. 13) in which the first and second ports fluidly communicate with each other. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 13. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) flows through the first lead-in pipe (63) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the first lead-out branch pipe (66) into the internal heat exchanger (50) and is drawn, after passage through the second flow path (52) of the internal heat exchanger (50), into the compressor (15).

[0161] On the other hand, during the heating operation mode, the first three-way valve (26) and the second three-way valve (27) are set to the state (indicated by broken line in FIG. 13) in which the first and third ports fluidly communicate with each other. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 13. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) flows through the second lead-in pipe (64) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the second lead-out branch pipe (67) into the internal heat exchanger (50) and is drawn, after passage through the first flow path (51) of the internal heat exchanger (50), into the compressor (15).

Second Exemplary Variation of the Eighth Embodiment

[0162] In the eighth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0163] Referring to FIG. 14, there is shown a refrigerant circuit (11) according to a second exemplary variation of the eighth embodiment. In the refrigerant circuit (11) of the second exemplary variation, the first to fourth solenoid valves (71, 72, 73, 74) and the first and second check valves (76, 77) are omitted and a third four-way switch valve (23) and a fourth four-way switch valve (24) are provided instead.

[0164] The third four-way switch valve (23) is disposed along a line connecting the indoor heat exchanger (13) and the second flow path (52) of the internal heat exchanger (50). The third four-way switch valve (23) has four ports of which the first port is connected to the indoor heat exchanger (13); the fourth port is connected to the second flow path (52) of the internal heat exchanger (50); the second port is connected to the first lead-out branch pipe (66); and the third port is connected to the first lead-in pipe (63).

[0165] The fourth four-way switch valve (24) is disposed along a line connecting the outdoor heat exchanger (12) and the first flow path (51) of the internal heat exchanger (50). The fourth four-way switch valve (24) has four ports of which the first port is connected to the outdoor heat exchanger (12); the third port is connected to the first flow path (51) of the internal heat exchanger (50); the second port is connected to the second lead-out branch pipe (67); and the fourth port is connected to the second lead-in pipe (64).

[0166] During the cooling operation mode, not only the first and second four-way switch valves (21, 22) but also the third and fourth four-way switch valves (23, 24) are set to the state (indicated by solid line in FIG. 14). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 14. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) flows through the first lead-in pipe (63) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the first lead-out branch pipe (66) into the internal heat exchanger (50) and is drawn, after passage through the second flow path (52) of the internal heat exchanger (50), into the compressor (15).

[0167] On the other hand, during the heating operation mode, not only the first and second four-way switch valves (21, 22) but also the third and fourth four-way switch valves (23, 24) are set to the state (indicated by broken line in FIG. 14). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 14. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) flows through the second lead-in pipe (64) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the second lead-out branch pipe (67) into the internal heat exchanger (50) and is drawn, after passage through the first flow path (51) of the internal heat exchanger (50), into the compressor (15).

Third Exemplary Variation of the Eighth Embodiment

[0168] In the eighth embodiment, the refrigerant circuit (11) may be arranged as follows.

[0169] Referring to FIG. 15, there is shown a refrigerant circuit (11) according to a third exemplary variation of the eighth embodiment. The refrigerant circuit (11) of the third exemplary variation is additionally provided with a third four-way switch valve (23). In addition, the refrigerant circuit (11) is provided with a lead-in pipe (60) as a substitute for the first and second lead-in pipes (63, 64).

[0170] In the refrigerant circuit (11) of the third exemplary variation of the eighth embodiment, the third four-way switch valve (23) is disposed in a line extending from the outdoor heat exchanger (12) to the second four-way switch valve (22) by way of the first flow path (51) of the internal heat exchanger (50). More specifically, of the four ports of the third four-way switch valve (23), the first port is connected to the other end of the outdoor heat exchanger (12); the second port is connected to the first port of the second four-way switch valve (22); the third port is connected to one end of the first flow path (51) of the internal heat exchanger (50); and the fourth port is connected to the other end of the first flow path (51) of the internal heat exchanger (50). In addition, in the refrigerant circuit (11), the second solenoid valve (72) is disposed between the fourth port of the third four-way switch valve (23) and the internal heat exchanger (50). Also in the

refrigerant circuit (11), the second lead-out branch pipe (67) is connected between the first flow path (51) of the internal heat exchanger (50) and the second solenoid valve (72).

[0171] One end of the lead-in pipe (60) is connected to the upper side of the refrigerant adjustment tank (14). The other end of the lead-in pipe (60) is branched off into two branch pipes one of which becomes a first lead-in branch pipe (61) and the other of which becomes a second lead-in branch pipe (62). The first lead-in branch pipe (61) is connected between the internal heat exchanger (13) and the first solenoid valve (71). The first lead-in branch pipe (61) is provided with a third solenoid valve (73). The second lead-in branch pipe (62) is connected between the fourth port of the third four-way switch valve (23) and the second solenoid valve (72). The second lead-in branch pipe (62) is provided with a fourth solenoid valve (74).

[0172] During the cooling operation mode, not only the first and second four-way switch valves (21, 22) but also the third four-way switch valve (23) is set to the state (indicated by solid line in FIG. 15) and the second and third solenoid valves (72, 73) are placed in the open state while on the other hand the first and fourth solenoid valves (71, 74) are placed in the closed state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 15. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) flows through the first lead-in branch pipe (61) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the first lead-out branch pipe (66) into the internal heat exchanger (50) and is drawn, after passage through the second flow path (52) of the internal heat exchanger (50), into the compressor (15).

[0173] On the other hand, during the heating operation mode, not only the first and second four-way switch valves (21, 22) but also the third four-way switch valve (23) is set to the state (indicated by broken line in FIG. 15) and the second and third solenoid valves (72, 73) are placed in the closed state while on the other hand the first and fourth solenoid valves (71, 74) are placed in the open state. And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 15. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) flows through the second lead-in branch pipe (62) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the second lead-out branch pipe (67) into the internal heat exchanger (50) and is drawn, after passage through the first flow path (51) of the internal heat exchanger (50), into the compressor (15).

Fourth Exemplary Variation of the Eighth Embodiment

[0174] In the eighth embodiment, the refrigerant circuit (11) may be arranged as follows. A fourth exemplary variation of the eighth embodiment is a modification of the second exemplary variation (see FIG. 14) (more specifically, the internal heat exchanger (50) in the second exemplary variation is modified in configuration in the fourth exemplary variation).

[0175] As shown in FIG. 16, the internal heat exchanger (50) of the fourth exemplary variation of the eighth embodiment is provided with a third flow path (53) in addition to the first and second flow paths (51, 52). The internal heat exchanger (50) is configured such that it effectuates heat

exchange between refrigerant in the first flow path (51) and refrigerant in the second flow path (52) and heat exchange between refrigerant in the first flow path (51) and refrigerant in the third flow path (53). In addition, in the internal heat exchanger (50), neither the area of heat transfer facing the first flow path (51) nor the area of heat transfer facing the third flow path (53) is greater than the area of heat transfer facing the second flow path (52).

[0176] One end and the other end of the first flow path (51) of the internal heat exchanger (50) are connected to the third port of the fourth four-way switch valve (24) and to the first port of the second four-way switch valve (22), respectively. In addition, one end and the other end of the second flow path (52) of the internal heat exchanger (50) are connected to the fourth port of the second four-way switch valve (22) and to the suction side of the compressor (15), respectively. In addition, one end and the other end of the third flow path (53) of the internal heat exchanger (50) are connected to the fourth port of the third four-way switch valve (23) and to the second port of the second four-way switch valve (22), respectively.

[0177] During the cooling operation mode, not only the first and second four-way switch valves (21, 22) but also the third and fourth four-way switch valves (23, 24) are set to the state (indicated by solid line in FIG. 16). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 16. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) flows through the first lead-in pipe (63) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the first lead-out branch pipe (66) into the internal heat exchanger (50) and then passes through the third flow path (53) of the internal heat exchanger (50). After passage through the third flow path (53), the refrigerant flows into the second flow path (52) of the internal heat exchanger (50) and is drawn, after passage through the second flow path (52), into the compressor (15). In addition, the outflow of refrigerant from the outdoor heat exchanger (12) flows into the first flow path (51) of the internal heat exchanger (50) and flows, after passage through the first flow path (51), into the expander (16).

[0178] On the other hand, during the heating operation mode, not only the first and second four-way switch valves (21, 22) but also the third and fourth four-way switch valves (23, 24) are set to the state (indicated by broken line in FIG. 16). And, in the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 16. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) flows through the second lead-in pipe (64) into the refrigerant adjustment tank (14). Gas refrigerant in the refrigerant adjustment tank (14) flows through the second lead-out branch pipe (67) into the internal heat exchanger (50) and then passes through the first flow path (51) of the internal heat exchanger (50). After passage through the first flow path (51), the refrigerant flows into the second flow path (52) of the internal heat exchanger (50) and is drawn, after passage through the second flow path (52), into the compressor (15). In addition, the outflow of refrigerant from the indoor heat exchanger (13) flows into the third flow path (53) of the internal heat exchanger (50) and flows, after passage through the third flow path (53), into the expander (16).

Ninth Embodiment of the Invention

[0179] Hereinafter, description will be made in regard to a ninth embodiment of the present invention. An air conditioner

(10) of the ninth embodiment is a modification of the air conditioner (10) of the first embodiment (more specifically, the refrigerant circuit (11) of the first embodiment is modified in configuration in the ninth embodiment). In the following, the difference from the first embodiment in regard to the air conditioner (10) of the ninth embodiment is described.

[0180] As shown in FIG. 17, the refrigerant circuit (11) of the ninth embodiment is additionally provided with an internal heat exchanger (50). The internal heat exchanger (50) has a first flow path (51) and a second flow path (52) and effectuates heat exchange between refrigerant in the first flow path (51) and refrigerant in the second flow path (52). The first flow path (51) of the internal heat exchanger (50) is disposed along a line connecting the second port of the second four-way switch valve (22) and the indoor heat exchanger (13). On the other hand, the second flow path (52) of the internal heat exchanger (50) is disposed along a line connecting the third port of the second four-way switch valve (22) and the expander (16).

Running Operation

[0181] During the cooling operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by solid line arrow in FIG. 17. At that time, the outflow of refrigerant from the refrigerant adjustment tank (14) enters the first flow path (51) of the internal heat exchanger (50). In addition, the outflow of refrigerant from the outdoor heat exchanger (12) enters the second flow path (52) of the internal heat exchanger (50). In the internal heat exchanger (50), the refrigerant flowing through the second flow path (52) is cooled by the refrigerant flowing through the first flow path (51). And, the refrigerant cooled during passage through the second flow path (52) of the internal heat exchanger (50) is introduced into the expander (16).

[0182] On the other hand, during the heating operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by broken line arrow in FIG. 17. At that time, the outflow of refrigerant from the refrigerant adjustment tank (14) enters the outdoor heat exchanger (12) without passing through the internal heat exchanger (50). In addition, the outflow of refrigerant from the indoor heat exchanger (13) passes through the first flow path (51) of the internal heat exchanger (50) and then enters the second flow path (52) of the internal heat exchanger (50). Consequently, in the internal heat exchanger (50), heat exchange hardly takes place between the refrigerant in the first flow path (51) and the refrigerant in the second flow path (52). And, the refrigerant after passage through the second flow path (52) of the internal heat exchanger (50) flows into the expander (16) in largely the same state as when it exited the indoor heat exchanger (13).

Tenth Embodiment of the Invention

[0183] Hereinafter, description will be made in regard to a tenth embodiment of the present invention. An air conditioner (10) of the tenth embodiment is a modification of the air conditioner (10) of the ninth embodiment (more specifically, the refrigerant circuit (11) and the controller (90) in the ninth embodiment are modified in configuration in the tenth embodiment). In the following, the difference from the ninth embodiment in regard to the air conditioner (10) of the tenth embodiment is described.

[0184] As shown in FIG. 18, in the refrigerant circuit (11) of the tenth embodiment, the refrigerant adjustment tank (14)

is arranged differently from the ninth embodiment. In the refrigerant circuit (11) of the tenth embodiment, the refrigerant adjustment tank (14) is disposed along a refrigerant circulation pathway extending from either the outdoor heat exchanger (12) or the indoor heat exchanger (13), whichever functions as an evaporator, to the compressor (15). With the change in the arrangement of the refrigerant adjustment tank (14), the outflow side of the expander (16) is connected to the fourth port of the second four-way switch valve (22) in the refrigerant circuit (11). In addition, in the refrigerant circuit (11) of the tenth embodiment, the internal heat exchanger (50) is arranged differently from the ninth embodiment.

[0185] More specifically, the refrigerant adjustment tank (14) is connected, at its lower side, to the second port of the first four-way switch valve (21). On the other hand, one end and the other end of the first flow path (51) of the internal heat exchanger (50) are connected, respectively, to the top side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15). The second flow path (52) of the internal heat exchanger (50) is arranged along a line connecting the third port of the second four-way switch valve (22) and the expander (16), which arrangement is the same as the ninth embodiment.

[0186] In addition, the refrigerant circuit (11) of the tenth embodiment is provided with a first solenoid valve (81) and a bypass line (80). The first solenoid valve (81) is disposed between the third port of the second four-way switch valve (22) and the second flow path (52) of the internal heat exchanger (50). One end and the other end of the bypass line (80) are connected, respectively, between the second four-way switch valve (22) and the first solenoid valve (81) and between the second flow path (52) of the internal heat exchanger (50) and the expander (16). The bypass line (80) is provided with a second solenoid valve (82).

[0187] In addition, in the refrigerant circuit (11) of the tenth embodiment, the liquid injection line (31) and the liquid side control valve (32) are provided, but the gas injection line (33) and the gas side control valve (34) are omitted. In the refrigerant circuit (11) of the tenth embodiment, one end and the other end of the liquid injection line (31) are connected, respectively, to the bottom side of the refrigerant adjustment tank (14) and to the suction side of the compressor (15). This arrangement is the same as the first embodiment.

[0188] In addition, with the omission of the gas injection line (33) and the gas side control valve (34), the controller (90) of the tenth embodiment is configured such that it controls only the opening of the liquid side control valve (32). The controller (90) sets a target value of the refrigerant discharge temperature of the compressor (15) as a control target value and controls the opening of the liquid side control valve (32) so that the actually measured refrigerant discharge temperature of the compressor (15) becomes the control target value. In other words, the controller (90) is configured in the same way as the controller (90) of the second embodiment.

Running Operation

[0189] During the cooling operation mode, the first solenoid valve (81) is placed in the open state and the second solenoid valve (82) is placed in the closed state. In the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 18. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) enters the second flow path (52) of the internal heat exchanger (50). In addition, the outflow of gas refrigerant from the

refrigerant adjustment tank (14) enters the first flow path (51) of the internal heat exchanger (50). In the internal heat exchanger (50), the refrigerant flowing through the second flow path (52) is cooled by the refrigerant flowing through the first flow path (51). And, the refrigerant cooled during passage through the second flow path (52) of the internal heat exchanger (50) is introduced into the expander (16).

[0190] On the other hand, during the heating operation mode, the first solenoid valve (81) is placed in the closed state and the second solenoid valve (82) is placed in the open state. In the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 18. More specifically, the outflow of refrigerant from the indoor heat exchanger (13) enters the bypass line (80) and flows into the expander (16) without passing through the internal heat exchanger (50). In other words, the refrigerant flowing into the expander (16) remains in largely the same state as when it exited the indoor heat exchanger (13). In addition, the outflow of gas refrigerant from the refrigerant adjustment tank (14) is drawn through the first flow path (51) of the internal heat exchanger (50) into the compressor (15).

Exemplary Variation of the Tenth Embodiment

[0191] In the tenth embodiment, the refrigerant circuit (11) may be configured as follows.

[0192] Referring to FIG. 19, there is shown a refrigerant circuit (11) of an exemplary variation of the tenth embodiment, the indoor heat exchanger (50) and the bypass line (80) are arranged differently.

[0193] One end and the other end of the first flow path (51) of the internal heat exchanger (50) are connected, respectively, to the fourth port of the second four-way switch valve (22) and to the upper side of the refrigerant adjustment tank (14). The second flow path (52) of the internal heat exchanger (50) is likewise arranged along a line connecting the third port of the second four-way switch valve (22) and the expander (16).

[0194] In the refrigerant circuit (11) of the exemplary variation of the tenth embodiment, the first solenoid valve (81) is disposed between the first flow path (51) of the internal heat exchanger (50) and the refrigerant adjustment tank (14). In addition, in the refrigerant circuit (11), one end and the other end of the bypass line (80) are connected, respectively, between the first flow path (51) of the internal heat exchanger (50) and the second four-way switch valve (22) and between the first solenoid valve (81) and the refrigerant adjustment tank (14). The bypass line (80) is likewise provided with a second solenoid valve (82).

[0195] During the cooling operation mode, the first solenoid valve (81) is placed in the open state and the second solenoid valve (82) is placed in the closed state. In the refrigerant circuit (11), refrigerant is circulated in the direction indicated by solid line arrow in FIG. 19. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) enters the second flow path (52) of the internal heat exchanger (50). In addition, the outflow of refrigerant from the indoor heat exchanger (13) enters the first flow path (51) of the internal heat exchanger (50). In the internal heat exchanger (50), the refrigerant flowing through the second flow path (52) is cooled by the refrigerant flowing through the first flow path (51). And, the refrigerant cooled during passage through the second flow path (52) of the internal heat exchanger (50) is introduced into the expander (16).

[0196] On the other hand, during the heating operation mode, the first solenoid valve (81) is placed in the closed state and the second solenoid valve (82) is placed in the open state. In the refrigerant circuit (11), refrigerant is circulated in the direction indicated by broken line arrow in FIG. 19. More specifically, the outflow of refrigerant from the outdoor heat exchanger (12) enters the bypass line (80) and is drawn into the compressor (15) without passing through the internal heat exchanger (50). In addition, after its passage through the second flow path (52) of the internal heat exchanger (50), the outflow of refrigerant from the indoor heat exchanger (13) enters the expander (16). And, the refrigerant flowing into the expander (16) remains in largely the same state as when it exited the indoor heat exchanger (13).

Eleventh Embodiment of the Invention

[0197] Hereinafter, description will be made in regard to an eleventh embodiment of the present invention. An air conditioner (10) of the eleventh embodiment is a modification of the air conditioner (10) of the first embodiment (more specifically, the refrigerant circuit (11) in the first embodiment is modified in configuration in the eleventh embodiment). In the following, the difference from the first embodiment in regard to the air conditioner (10) of the eleventh embodiment is described.

[0198] As shown in FIG. 20, the refrigerant circuit (11) of the eleventh embodiment is provided with a heat exchange section (85). In the refrigerant circuit (11), the heat exchange section (85) is disposed along a line connecting the first port of the second four-way switch valve (22) and the outdoor heat exchanger (12). In addition, the heat exchange section (85) is housed within the refrigerant adjustment tank (14) and is placed under liquid refrigerant.

Running Operation

[0199] During the cooling operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by solid line arrow in FIG. 20. At that time, the outflow of gas-liquid two-phase refrigerant from the expander (16) enters the refrigerant adjustment tank (14) where the inflow refrigerant is separated into a liquid refrigerant and a gas refrigerant, and the liquid refrigerant within the refrigerant adjustment tank (14) is delivered to the indoor heat exchanger (13). In addition, the outflow of refrigerant from the outdoor heat exchanger (12) enters the heat exchange section (85) and is cooled by the liquid refrigerant in the refrigerant adjustment tank (14). Then, the refrigerant cooled in the heat exchange section (85) flows into the expander (16).

[0200] On the other hand, during the heating operation mode, refrigerant is circulated in the refrigerant circuit (11) in the direction indicated by broken line arrow in FIG. 20. At that time, the outflow of gas-liquid two-phase refrigerant from the expander (16) enters the refrigerant adjustment tank (14) where the inflow refrigerant is separated into a liquid refrigerant and a gas refrigerant, and the liquid refrigerant within the refrigerant adjustment tank (14) is delivered, after passage through the heat exchange section (85), to the outdoor heat exchanger (12). In addition, the outflow of refrigerant from the indoor heat exchanger (13) flows into the expander (16).

Other Embodiments

[0201] In each of the foregoing embodiments, the controller (90) may be configured such that it controls the opening of

the liquid side control valve (32) and the opening of the gas side control valve (34) so that the high pressure of the refrigeration cycle has a predetermined target value.

[0202] In this case, the controller (90) sets a control target value for the refrigeration cycle high pressure. More specifically, the controller (90) gains, from sensors et cetera, an actual measurement value of the refrigerant cycle low pressure and an actual measurement value of the refrigerant temperature at the gas cooler outlet. In addition, the controller (90) pre-stores, as a function of the refrigerant cycle low pressure and the refrigerant temperature at the gas cooler outlet, a value for the refrigerant cycle high pressure that provides an optimal COP of the refrigeration cycle. In so doing, the state of the suction refrigerant of the compressor (15) is pre-set as follows: for example, "at a degree of superheat of 5 degrees Centigrade" or "in the saturated state". The controller (90) performs a calculation by substituting a gained actual measurement value in a stored function and sets a result of the calculation as a control target value.

[0203] Like the controller (90) of each of the foregoing first, fifth, seventh, ninth, and eleventh embodiments, the controller (90) configured to control the opening of the liquid and gas side control valves (32, 34) compares a set control target value with an actual measurement value of the refrigeration cycle high pressure and, based on the compare result, controls the opening of the liquid and gas side control valves (32, 34).

[0204] For example, suppose that an actual measurement value of the refrigeration cycle high pressure is lower than the control target value. If, at this time, the gas side control valve (34) is in the open state, the controller (90) gradually reduces the opening of the gas side control valve (34). If, even when the gas side control valve (34) enters the fully closed state, the actually measured refrigerant discharge temperature of the compressor (15) is still higher than the control target value, the controller (90) gradually increases the opening of the liquid side control valve (32). On the contrary, suppose that an actual measurement value of the refrigerant discharge temperature of the compressor (15) is higher than the control target value. If, at this time, the liquid side control valve (32) is in the open state, the controller (90) gradually reduces the opening of the liquid side control valve (32). If, even when the liquid side control valve (32) enters the fully closed state, the actually measured refrigerant discharge temperature of the compressor (15) still falls below the control target value, the controller (90) gradually increases the opening of the gas side control valve (34).

[0205] In addition, like the controller (90) of each of the second to fourth, sixth, eighth, and tenth embodiments, the controller (90) configured to control the opening of the liquid side control valve (32) compares a set control target value with an actual measurement value of the refrigeration cycle high pressure and, based on the compare result, controls the opening of the liquid side control valve (32).

[0206] For example, if an actual measurement value of the refrigeration cycle high pressure is lower than the control target value, then the controller (90) gradually increases the opening of the liquid side control valve (32). On the contrary, if an actual measurement value of the refrigerant discharge temperature of the compressor (15) is higher than the control

target value, then the controller (90) gradually increases the opening of the gas side control valve (34).

INDUSTRIAL APPLICABILITY

[0207] As has been described above, the present invention finds utility in connection with a refrigeration apparatus having a refrigerant circuit (11) in which is connected an expander (16) for the recovery of power.

What is claimed is:

1. A refrigeration apparatus, equipped with a refrigerant circuit (11) in which an expander (16) for the recovery of power is connected, for performing a refrigeration cycle by causing refrigerant to circulate within the refrigerant circuit (11), the refrigeration apparatus comprising:

- (a) a refrigerant adjustment tank (14), disposed along a refrigerant circulation pathway extending from the expander (16) to a compressor (15) in the refrigerant circuit (11), for controlling the amount of refrigerant circulating in the refrigerant circuit (11);
- (b) a liquid injection passageway (31) for supplying liquid refrigerant in the refrigerant adjustment tank (14) to the suction side of the compressor (15); and
- (c) a liquid flow rate control mechanism (32) for controlling the flow rate of refrigerant in the liquid injection passageway (31).

2. The refrigeration apparatus of claim 1, wherein the refrigerant adjustment tank (14) is disposed downstream of an evaporator in a refrigerant circulation pathway extending from the expander (16) to the compressor (15).

3. The refrigeration apparatus of claim 1, wherein the refrigerant adjustment tank (14) is disposed upstream of an evaporator in a refrigerant circulation pathway extending from the expander (16) to the compressor (15).

4. The refrigeration apparatus of claim 3 comprising:

- (a) a gas injection passageway (33) for supplying gas refrigerant in the refrigerant adjustment tank (14) to the suction side of the compressor (15); and
- (b) a gas flow rate control mechanism (34) for controlling the flow rate of refrigerant in the gas injection passageway (33).

5. The refrigeration apparatus of any one of claims 1 to 4, wherein the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant.

6. The refrigeration apparatus of any one of claims 1 to 3, wherein:

- (a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and
- (b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) so that the temperature of refrigerant discharged from the compressor (15) has a predetermined control target value.

7. The refrigeration apparatus of claim 4, wherein:

- (a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and
- (b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34) so that the temperature of refrigerant discharged from the compressor (15) has a predetermined control target value.

8. The refrigeration apparatus of any one of claims 1 to 3, wherein:

- (a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and
- (b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) so that the high pressure of the refrigeration cycle performed in the refrigerant circuit (11) has a predetermined control target value.

9. The refrigeration apparatus of claim 4, wherein:

- (a) the high pressure of the refrigeration cycle performed by causing refrigerant to circulate in the refrigerant circuit (11) is set to a higher pressure level value than the critical pressure of the refrigerant; and
- (b) the refrigeration apparatus includes controller means (90) for controlling the liquid flow rate control mechanism (32) and the gas flow rate control mechanism (34) so that the high pressure of the refrigeration cycle performed in the refrigerant circuit (11) has a predetermined control target value.

10. The refrigeration apparatus of claim 6, wherein the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

11. The refrigeration apparatus of claim 7 or claim 9, wherein the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

12. The refrigeration apparatus of claim 8, wherein the controller means (90) sets, based on the refrigeration cycle operational state, a control target value so that the coefficient of performance of the refrigeration cycle performed in the refrigerant circuit (11) has an optimal value obtainable in an operational state at the time.

13. The refrigeration apparatus of claim 5, wherein the refrigerant circuit (11) is charged with carbon dioxide as a refrigerant.

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