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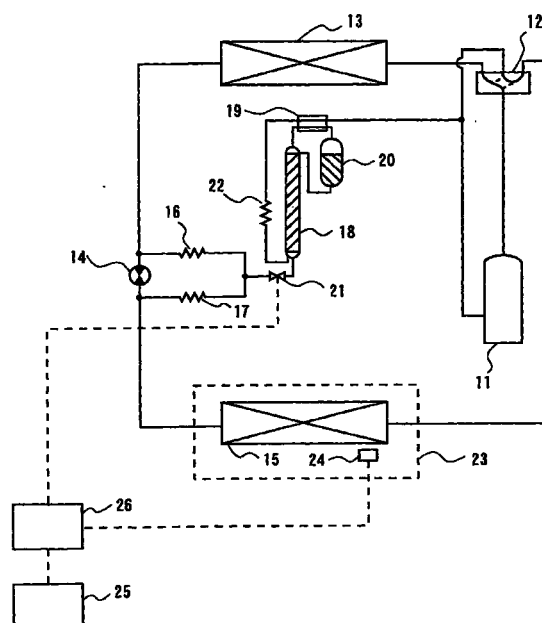
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(54) **HEAT PUMP**

(57) The present invention is a heat pump apparatus, using non-azeotropic refrigerant, which is formed so as to allow control of the performance of the heat pump apparatus through the creation of a closed circuit comprising a rectifying separator, which is connected via a two-way valve to the main circuit of the refrigerant cycle, a cooling unit and a reservoir unit by controlling the two-way valves in opening and closing in response to the size of the detected load and by properly adjusting the refrigerant composition of the main circuit in response to the load condition.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a heat pump apparatus utilizing non-azeotropic refrigerant, in detail, to a heat pump apparatus which can change the performance by changing the component of the refrigerant flowing through the main circuit of the heat pump.

BACKGROUND TECHNOLOGY

[0002] A conventional heat pump apparatus utilizing non-azeotropic refrigerant which changes the component of the refrigerant flowing through the main circuit of the heat pump in order to change the performance is disclosed in the Japanese Patent Publication H5(1993)-44582.

[0003] In the following, the above-mentioned conventional heat pump apparatus is described with reference to the drawing.

[0004] FIG. 44 is a system configuration view showing a refrigeration cycle in the conventional heat pump apparatus disclosed in the above-mentioned gazette.

[0005] As shown in FIG. 44, the conventional heat pump apparatus comprises a compressor 1, a four-way valve 2, an outdoor heat exchanger 3, a main circuit expansion apparatus 4 and an indoor heat exchanger 5, and they are linked in an annular sequence to form the main circuit of the heat pump apparatus.

[0006] In the conventional heat pump apparatus, one end of an expansion unit 6 is connected to a refrigerant pipe joining the outdoor heat exchanger 3 and the main circuit expansion apparatus 4, while the other end is connected to the bottom of a rectifying separator 7. The pipes leading out from both ends of a cooling unit 8 are connected, respectively, to the surface of the ceiling of the top part and the side of the top part of the rectifying separator 7 so as to form an annular structure. The cooling unit 8 also serves as the reservoir unit of the refrigerant. The cooling unit 8 is connected between the compressor 1 and the four-way valve 2, and has an intake pipe to the compressor 1 passing therethrough. The cooling unit 8 is formed so that the refrigerant of the top part of the rectifying separator 7 and the refrigerant moving toward the compressor 1 from the four-way valve 2 exchange heat indirectly.

[0007] In the conventional heat pump apparatus, one end of the expansion unit 9 is connected to the refrigerant pipe joining the main circuit expansion apparatus 4 and the indoor heat exchanger 5, while the other end is connected to the bottom of the rectifying separator 7.

[0008] In the description hereafter the refrigerant flow circuit formed of the expansion unit 6, the rectifying separator 7, the cooling unit 8 and the expansion unit 9 is referred to as a rectifying circuit 10.

[0009] Next, the operation of the conventional heat

pump apparatus which is formed as in the above is described.

[0010] At the time of heating the high temperature refrigerant which has been discharged from the compressor 1, passes through the four-way valve 2 and flows into the indoor heat exchanger 5. In the indoor heat exchanger 5 heat is exchanged with the indoor air so as to heat the indoor space. The refrigerant which has released heat in the indoor heat exchanger 5 is liquefied and discharged from the indoor heat exchanger 5. The refrigerant which has been discharged from the indoor heat exchanger 5 is separated into a flow to the rectifying circuit 10 through the expansion unit 9 and a flow to the main circuit through the main circuit expansion apparatus 4.

[0011] The refrigerant which has passed through the main circuit expansion apparatus 4 is vaporized in the outdoor heat exchanger 3 and passes through the four-way valve 2 so as to be taken into the compressor 1 again.

[0012] On the other hand, the refrigerant which has branched into the rectifying circuit 10 is reduced in pressure by the expansion unit 9 and flows into the bottom of the rectifying separator 7.

[0013] As for the conditions of the refrigerant which has flown into the bottom of the rectifying separator 7, there are cases of a liquid condition and of a gas-liquid two-phase condition according to the performance of the indoor heat exchanger 5 utilized therein.

[0014] In the case that the refrigerant of the gas-liquid two-phase condition flows into the bottom of the rectifying separator 7 from the indoor heat exchanger 5, gas-liquid separation is accelerated within the rectifying separator 7. As for the non-azeotropic refrigerant, the refrigerant of the gas phase (gas condition) which, mainly, contains low boiling point components moves to the top part of the rectifying separator 7 while the refrigerant of the liquid condition which, mainly, contains high boiling point components is collected in the bottom of the rectifying separator 7.

[0015] Then the refrigerant in the gas phase (gas condition) in the top part of the rectifying separator 7 flows into the cooling unit 8 from the refrigerant pipe lead out from the surface of the ceiling of the top part of the rectifying separator 7. In the cooling unit 8, the refrigerant flowing into the cooling unit 8 from the rectifying separator 7 indirectly exchanges heat with the refrigerant of low temperature moving toward the compressor 1 from the four-way valve 2 so as to be liquefied and to be collected. The liquid refrigerant which exceeds the reservoir capacity in the cooling unit 8 flows into the top part of the rectifying separator 7 through the refrigerant pipe joining the cooling unit 8 and the side of the top part of the rectifying separator 7.

[0016] The refrigerant in the liquid condition which mainly contains high boiling point components in the bottom of the rectifying separator 7 is reduced in pressure by the expansion unit 6 and merges together with

the refrigerant flowing through the main circuit which passes through the main circuit expansion apparatus 4. As a result the refrigerant flowing through the main circuit becomes the refrigerant rich in only high boiling point components, which reduces the performance of this heat pump apparatus.

[0017] Next, the case where the refrigerant in the liquid condition flows into the bottom of the rectifying separator 7 from the Indoor heat exchanger 5 is described. In the case that the refrigerant in the liquid condition flows into the bottom of the rectifying separator 7, it is difficult to carry out component separation of the refrigerant in the rectifying circuit 10, and thus, the high boiling point and low boiling point refrigerant moves back to the main circuit through the expansion unit 6, and therefore, the performance of this heat pump apparatus is enhanced.

[0018] In the above-mentioned conventional heat pump apparatus, however, it is necessary to adjust the expansion unit 6 and 9 to the same throttle opening when carrying out a rectifying separation of the low boiling point refrigerant in the case of either cooling or heating. Therefore, the pressure of the rectifying separator 7 becomes the intermediate pressure of the main circuit, and thus, the rectifying separation also operates at this pressure, and therefore, low boiling point components increase in the top part of the rectifying separator 7 so as to lower the saturation temperature for liquefying the refrigerant in the gas phase, which is rising.

[0019] On the other hand, since the intake pipe is utilized between the compressor 1 and the four-way valve 2 as the cooling source of the cooling unit 8, the refrigerant temperature of the cooling source rises in the case that the degree of intake overheating of the compressor 1 is large. Thereby, the temperature is not high enough to liquefy the refrigerant in the gas phase in the top part of the rectifying separator 7 and the cooling heat amount runs short. As a result, in the case that the non-azeotropic refrigerant of which the boiling point gap is relatively large is separated, the separation gap becomes small and the gap of the performance control becomes small in the conventional heat pump apparatus.

[0020] In addition, in the conventional heat pump apparatus, the expansion units 6 and 9 are always in the condition of being open, and the cooling unit 8 is always in the condition that the refrigerant is collected, and therefore, the refrigerant amount of the main circuit cannot be adjusted. Therefore, the conventional heat pump apparatus cannot control the performance through the refrigerant amount of the main circuit.

[0021] The present invention is provided to solve the problem in the conventional heat pump apparatus and the purpose of the invention is to provide a heat pump apparatus which can gain a sufficient component separation gap and makes performance control possible through the adjustment of the refrigerant amount in the main circuit so that the gap in the performance con-

trol can be enlarged in comparison to a prior art.

DISCLOSURE OF THE INVENTION

[0022] To achieve the above-mentioned purpose a heat pump apparatus according to the present invention comprises: a rectifying separator which has the form of a straight pipe substantially long in the vertical direction the bottom of which is connected to an intake pipe of a compressor via a sub-expansion apparatus and which performs rectifying separation of non-azeotropic refrigerant;

a cooling unit which exchanges heat between the refrigerant flowing out from the bottom of said rectifying separator and moving toward said intake pipe of said compressor from said sub-expansion apparatus and the refrigerant in the top part of said rectifying separator;

a reservoir unit collects the refrigerant cooled and liquefied by said cooling unit;

a closed pipe route forming a closed circuit in an annular structure so as to send the refrigerant in the top part of said rectifying separator to said cooling unit and to send the refrigerant from said cooling unit to said reservoir unit and then to return the refrigerant which has been collected in said reservoir unit to the top part of said rectifying separator; a main circuit of a refrigeration cycle which, through pipe, connects said compressor, a four-way valve, an outdoor heat exchanger, an expansion apparatus and an indoor heat exchanger in an annular sequence and which seals in said non-azeotropic refrigerant;

an opening and closing apparatus which makes a connection between said closed circuit and said main circuit so as to be able to open and close the connection; and

a control apparatus which performs opening and closing control of said opening and closing apparatus in accordance with a load condition and makes said non-azeotropic refrigerant within said main circuit flow into said closed circuit.

[0023] Thereby, the cooling unit can be made compact and the refrigerant in the gas phase in the rectifying separator can be liquefied at a sufficiently low temperature and with sufficient cooling heat amount so that the refrigerant which, mainly, contains low boiling point components can be collected and a large separation gap can be created even in the non-azeotropic refrigerant, of which the boiling point gap is large.

[0024] In addition, by controlling opening and closing of the two-way valve, the refrigerant in the reservoir unit can be controlled between full or empty so as to be able to adjust the refrigerant amount in the main circuit, and therefore, a broad range of performance control becomes possible, according to the present invention

through the performance control based on the refrigerant amount in the main circuit and through the performance control based on the refrigerant component.

[0025] Though novel characteristics of the invention are specifically described in the attached claims, the present invention may be better understood and appreciated by reading the following description in conjunction with the drawings with respect to both the configuration and the contents, together with other purposes and characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

FIG. 1 is a system configuration view showing a configuration of a heat pump apparatus of Embodiment 1 according to the present invention;

FIG. 2 is a control flow chart of the heat pump apparatus of Embodiment 1 according to the present invention;

FIG. 3 is a system configuration view of a heat pump apparatus of Embodiment 2 according to the present invention;

FIG. 4 is a control flow chart of the heat pump apparatus of Embodiment 2 according to the present invention;

FIG. 5 is a system configuration view of a heat pump apparatus of Embodiment 3 according to the present invention;

FIG. 6 is a control flow chart of the heat pump apparatus of Embodiment 3 according to the present invention;

FIG. 7 is a system configuration view of a heat pump apparatus of Embodiment 4 according to the present invention;

FIG. 8 is a control flow chart of the heat pump apparatus of Embodiment 4 according to the present invention;

FIG. 9 is a system configuration view of a heat pump apparatus of Embodiment 5 according to the present invention;

FIG. 10 is a control flow chart of the heat pump apparatus of Embodiment 5 according to the present invention;

FIG. 11 is a system configuration view of a heat pump apparatus of Embodiment 6 according to the present invention;

FIG. 12 is a control flow chart of the heat pump apparatus of Embodiment 6 according to the present invention;

FIG. 13 is a system configuration view of a heat pump apparatus of Embodiment 7 according to the present invention;

FIG. 14 is a control flow chart of the heat pump apparatus of Embodiment 7 according to the present invention;

FIG. 15 is a system configuration view of a heat

pump apparatus of Embodiment 8 according to the present invention;

FIG. 16 is a control flow chart of the heat pump apparatus of Embodiment 8 according to the present invention;

FIG. 17 is a system configuration view of a heat pump apparatus of Embodiment 9 according to the present invention;

FIG. 18 is a control flow chart of the heat pump apparatus of Embodiment 9 according to the present invention;

FIG. 19 is a system configuration view of a heat pump apparatus of Embodiment 10 according to the present invention;

FIG. 20 is a control flow chart of the heat pump apparatus of Embodiment 10 according to the present invention;

FIG. 21 is a system configuration view of a heat pump apparatus of Embodiment 11 according to the present invention;

FIG. 22 is a control flow chart of the heat pump apparatus of Embodiment 11 according to the present invention;

FIG. 23 is a system configuration view of a heat pump apparatus of Embodiment 12 according to the present invention;

FIG. 24 is a control flow chart of the heat pump apparatus of Embodiment 12 according to the present invention;

FIG. 25 is a control flow chart of the heat pump apparatus of Embodiment 13 according to the present invention;

FIG. 26 is a system configuration view of a heat pump apparatus of Embodiment 14 according to the present invention;

FIG. 27 is a control flow chart of the heat pump apparatus of Embodiment 14 according to the present invention;

FIG. 28 is a system configuration view of a heat pump apparatus of Embodiment 15 according to the present invention;

FIG. 29 is a control flow chart of the heat pump apparatus of Embodiment 15 according to the present invention;

FIG. 30 is a system configuration view of a heat pump apparatus of Embodiment 16 according to the present invention;

FIG. 31 is a system configuration view of a heat pump apparatus of Embodiment 17 according to the present invention;

FIG. 32 is a control flow chart of the heat pump apparatus of Embodiment 17 according to the present invention;

FIG. 33 is a system configuration view of a heat pump apparatus of Embodiment 18 according to the present invention;

FIG. 34 is a control flow chart of the heat pump apparatus of Embodiment 18 according to the

present invention;

FIG. 35 is a system configuration view of a heat pump apparatus of Embodiment 19 according to the present invention;

FIG. 36 is a control flow chart of the heat pump apparatus of Embodiment 19 according to the present invention;

FIG. 37 is a characteristics chart showing the relationship between the temperature detection value and the pressure detection value of the heat pump apparatus of Embodiment 19 according to the present invention;

FIG. 38 is a system configuration view of a heat pump apparatus of Embodiment 20 according to the present invention;

FIG. 39 is a characteristics chart showing the relationship between the temperature detection value and the pressure detection value of the heat pump apparatus of Embodiment 20 according to the present invention;

FIG. 40 is a schematic configuration view showing one embodiment of a rectifying separator utilized in a heat pump apparatus for Embodiment 21 according to the present invention;

FIG. 41 is a schematic view showing a woven material which is the original form of the filling material inserted inside the container of the rectifying separator in Embodiment 21;

FIG. 42 is a perspective view of the filling material inserted inside the container of the rectifying separator in Embodiment 21;

FIG. 43 is a characteristic chart showing the evaluation result of separation performance of the filling material inserted inside the container of the rectifying separator in Embodiment 21; and

FIG. 44 is a system configuration view showing a refrigeration cycle in a heat pump apparatus according to a prior art.

[0027] It should be noted that all of, or part of, the drawings are created as a schematic expression for the purpose of illustration, and do not necessarily faithfully depict elements shown therein as to the actual relative dimensions and the locations.

BEST MODE FOR CARRYING OUT THE INVENTION

[0028] In the following, preferable embodiments of a heat pump apparatus in accordance with the present invention are described with reference to the attached drawings.

(Embodiment 1)

[0029] FIG. 1 is a system configuration view of a heat pump apparatus of Embodiment 1 in accordance with the present invention. In FIG. 1, a non-azeotropic refrigerant is charged in the heat pump apparatus of

Embodiment 1 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, the main expansion apparatus 14 and an indoor heat exchanger 15 in an annular structure.

[0030] In the heat pump apparatus of Embodiment 1, piping is provided so as to bypass the main expansion apparatus 14, and a sub-expansion apparatus 16 and a sub-expansion apparatus 17 are connected in series through the piping. The bottom of a rectifying separator 18 is connected to the pipe connecting the sub-expansion apparatus 16 and sub-expansion apparatus 17 via a two-way valve 21.

[0031] The rectifying separator 18 has filling material (not shown) filled into the inside and is formed of a straight pipe which is long in the vertical direction. The top part of the rectifying separator 18 is communicated to the top of a reservoir unit 20 via a cooling unit 19. Then the bottom of the reservoir unit 20 is communicated to the top part of the rectifying separator 18. Accordingly, the top part of the rectifying separator 18, the cooling unit 19 and the reservoir unit 20 are connected in an annular structure so as to form a closed circuit.

[0032] Here, in Embodiment 1 the reservoir unit 20 is arranged so that the top part thereof is located higher than the top part of the rectifying separator 18. In addition, the cooling unit 19 is arranged so as to be located higher than the top part of the reservoir unit 20.

[0033] The pipe connecting the top part of the rectifying separator 18 and the cooling unit 19 is connected to the surface of the ceiling of the top part of the rectifying separator 18. The pipe connecting the bottom of the reservoir unit 20 with the top part of the rectifying separator 18 is connected to the side of the top part of the rectifying separator 18. The pipe leading out from the bottom of the rectifying separator 18 is connected to an intake pipe which makes a connection between the compressor 11 and the four-way valve 12 via the sub-expansion apparatus 22 and the cooling unit 19.

[0034] The cooling unit 19 of Embodiment 1 is formed so that the refrigerant moving toward the intake pipe of the compressor 11 from the bottom of the rectifying separator 18 through the sub-expansion apparatus 22 and the refrigerant in the top part of the rectifying separator 18 exchanges heat indirectly. A double piping structure can be adopted for the cooling unit 19 in Embodiment 1.

[0035] In FIG. 1 an indoor unit 23 is formed of the indoor heat exchanger 15, or the like, and is provided with an indoor thermal sensor 24 which detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 23). An operation control apparatus 26 to which data are inputted from the indoor thermal sensor 24 compares a set air temperature "to" stored in a memory apparatus 25 with the temperature "t" of the intake air detected by the indoor thermal sensor 24 and operates so that, in the case that the abso-

lute value of the difference between the temperature "t" of the intake air and the set air temperature "to" is " Δt " or less ($|t - to| \leq \Delta t$), the two-way valve is opened and in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), the two-way valve 21 is closed. The memory apparatus 25 which is electrically connected to the operation control apparatus 26 is an apparatus in which a set air temperature value is stored as a desirable value which the user presets.

[0036] Next, the operation of the heat pump apparatus of Embodiment 1 formed as in the above is described with reference to FIG. 2.

[0037] FIG. 2 is a control flow chart of the heat pump apparatus of Embodiment 1.

[0038] First, the operation at the time of cooling is described.

[0039] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 11, the two-way valve 21 is closed (STEP 1). In this way, under the condition where the two-way valve 21 is closed, the high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the outdoor heat exchanger 13 so as to be condensed and liquefied at the time of cooling. The condensed and liquefied refrigerant is separated into the main circuit which flows into the main expansion apparatus 14 and a circuit which flows into the sub-expansion apparatus 16.

[0040] The refrigerant which has passed through the main expansion apparatus 14 passes through the indoor heat exchanger 15 and flows into the compressor 11 via the four-way valve 12 so as to flow through the main circuit in the refrigeration cycle. On the other hand, the refrigerant which has flown into the sub-expansion apparatus 16 is reduced in pressure so as to be put under a pressure in the vicinity of the intermediate pressure between the highest and the lowest pressure in the main circuit of the refrigeration cycle. At this time, since the two-way valve 21 is closed, the refrigerant from the sub-expansion apparatus is further reduced in pressure by the sub-expansion apparatus 17 and flows into the main circuit.

[0041] Under the above-mentioned conditions, the indoor thermal sensor 24 provided in the indoor unit 23 is used to carry out load determination (STEP 2).

[0042] In STEP 2, in the case that the absolute value of the difference between the temperature (room temperature) "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds a predetermined value " Δt " (in the description hereinafter the predetermined value " Δt " denotes the absolute value of the difference between the preset room temperature and the set temperature) ($|t - to| > \Delta t$), that is to say, in the case that the

cooling load is large, a closing signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. Thereby, the two-way valve 21 maintains the closed condition.

[0043] Accordingly, the refrigerant under intermediate pressure which has been discharged from the sub-expansion unit 16 all passes through the sub-expansion apparatus 17 and is reduced in pressure to be put under low pressure and flows into the main circuit. In this way the refrigerant which has passed through the sub-expansion apparatus 16 maintains the condition of flowing into the main circuit. Thereby, the refrigerant of the main circuit cools the indoor space by the indoor unit 23 and, after that, passes through the four-way valve 12 to be taken into the compressor 11 again.

[0044] Since the two-way valve 21 is closed and the rectifying separator 18 is connected to the intake pipe of the compressor 11 via the cooling unit 19 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the above-mentioned cooling cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to a low pressure condition internally and there is little reservoir of the refrigerant.

[0045] By maintaining the closed condition of the two-way valve 21 as described above, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant as the filled in components have been mixed and the main circuit is operated under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 1 operates with high performance appropriate to the load.

[0046] A load determination is carried out in STEP 2, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. As a result of this the two-way valve 21 converts to the opened condition (STEP 3). Thereby, part of the two-phase refrigerant under the intermediate pressure which has come out from the sub-expansion unit 16 passes through the two-way valve 21 and flow into the bottom of the rectifying separator 18. Since the two-phase refrigerant flows into the rectifying separator 18, part of the refrigerant passes through the sub-expansion apparatus 22 to be reduced in pressure, and then, becomes a two-phase refrigerant of low temperature which flows into the cooling unit 19. In the cooling unit 19 the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 18.

[0047] In the cooling unit 19 of Embodiment 1, since the two-phase refrigerant of low temperature and low pressure, of which the enthalpy is the lowest in the refrigeration cycle, is utilized as a cooling resource of the cooling unit 19, latent heat of the refrigerant can be utilized effectively so that the cooling unit 19 can be compactly formed. In addition, the cooling unit 19 of the heat pump apparatus of Embodiment 1 can, without fail, liquefy the gas in the top part of the rectifying separator 18.

[0048] In this way, the two-phase refrigerant flows into from the bottom of the rectifying separator 18 and the gas refrigerant flows out from the top part of the rectifying separator 18 and this gas refrigerant is cooled by the cooling unit 19. The refrigerant which has been cooled and liquefied in the cooling unit 19 is gradually collected in the reservoir unit 20 and the amount of collection increases. Then part of the refrigerant which has been collected in the reservoir unit 20 returns again to the top part of the rectifying separator 18 and moves downward into the rectifying separator 18. In the case that these conditions occur sequentially, the gas refrigerant which moves upward and the liquid refrigerant which moves downward create the condition of contact between the gas and the liquid in the rectifying separator 18. This condition of contact between the gas and the liquid generates a rectifying effect so that the refrigerant with a large amount of low boiling point refrigerant components is gradually collected in the reservoir unit 20. On the other hand, the refrigerant which moves downward into the rectifying separator 18 and passes through the sub-expansion apparatus 22 gradually increases in high boiling point refrigerant components and passes through the cooling unit 19 to be taken into the compressor 11.

[0049] As described above, because of the structure wherein the refrigerant having a large amount of high boiling point refrigerant components is taken into the compressor 11 of the main circuit via the cooling unit 19, the refrigerant which gradually increases in high boiling point refrigerant components flows through the main circuit.

[0050] As a result of this, the heat pump apparatus of Embodiment 1 can reduce the cooling performance in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant flowing through the main circuit decreases. Thereby, the heat pump apparatus of Embodiment 1 reduces the cooling performance due to the reduction of the refrigerant amount, and in the case that the cooling load is small, the operation with low performance appropriate to this cooling load becomes possible.

[0051] Under the above-mentioned condition of the operation with low performance, a load determination is further carried out (STEP 4). In this STEP 4, in the case that the cooling load becomes large and the absolute value of the difference between the temperature "t" of

the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds the predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valve 21 is transmitted from the operation control apparatus 26 to the two-way valve 21. As a result of this the two-way valve 21 reverts to the closed condition (STEP 5), and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the cooling load can be restarted.

[0052] As described above In the heat pump apparatus of Embodiment 1, the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 and the set air temperature "to" is measured and compared with the predetermined value " Δt " for the judgment of the size of the cooling load. Then, based on the comparison result, the amount of refrigerant and the refrigerant components in the main circuit can be controlled to achieve an appropriate condition in response to the cooling load by carrying out only the opening and closing operation of the two-way valve 21. In this way, the heat pump apparatus of Embodiment 1 can carry out a performance control in response to the detected cooling load by exercising a simple control.

[0053] Next, the operation at the time of heating is described.

[0054] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0055] At the time of the heating operation, in the case that a high heating performance is required, such as immediately after the start-up of the compressor 11, the two-way valve 21 is closed (STEP 1). In this way, under the condition that the two-way valve 21 is closed, high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the indoor heat exchanger 15 so as to be condensed and liquefied at the time of heating. The refrigerant which has been condensed and liquefied is separated into the main circuit which flows into the main expansion apparatus 14 and a circuit which flows into the sub-expansion apparatus 17.

[0056] The refrigerant which has passed through the main expansion apparatus 14 passes through the outdoor heat exchanger 13 and flows into the compressor 11 via the four-way valve 12 so as to flow through the heating cycle of the main circuit. On the other hand, the refrigerant flown into the sub-expansion apparatus 17 is reduced in pressure and put under a pressure in the vicinity of the intermediate pressure between the

highest and the lowest pressure in the main circuit of the heating cycle. At this time, since the two-way valve 21 is closed the refrigerant from the sub-expansion apparatus 17 is further reduced in pressure by the sub-expansion apparatus 16 and flows into the main circuit.

[0057] Under the above-mentioned conditions the indoor thermal sensor 24 provided in the indoor unit 23 is utilized so as to carry out a load determination (STEP 2).

[0058] In STEP 2, in the case that the absolute value of the difference between the set air temperature "to" of the indoor unit 23 stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. Thereby, the two-way valve 21 maintains the closed condition.

[0059] Accordingly, all of the refrigerant under the intermediate pressure which has been discharged from the sub-expansion apparatus 17 passes through the sub-expansion apparatus 16 and is reduced in pressure so as to be put under low pressure and flows into the main circuit. In this way, the refrigerant which has passed through the sub-expansion apparatus 17 maintains the condition of flowing into the main circuit so as to merge together with the refrigerant which has passed through the main expansion apparatus 14. Thereby, the refrigerant in the main circuit evaporates in the outdoor heat exchanger 13, and after that, passes through the four-way valve 12 so as to be absorbed into the compressor 11 again.

[0060] Since the two-way valve 21 is closed and the cooling unit 19 is connected to the intake pipe of the compressor 11, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the above-mentioned heating cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to the low pressure condition internally and there is little reservoir of the refrigerant.

[0061] As described above, by maintaining the closed condition of the two-way valve 21, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 1 can carry out the high performance operation appropriate for the load.

[0062] In STEP 2, a load determination is carried out and in the case that the absolute value of the difference of the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 is the predetermined value " Δt " ($|t - t_o| \leq \Delta t$),

that is to say, in the case that the heating load is small, an opening signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. As a result of this, the two-way valve 21 converts to the opened condition (STEP 3). Thereby, part of the two-phase refrigerant under the intermediate pressure which has been discharged from the sub-expansion apparatus 17 passes through the two-way valve 21 and flows into the bottom of the rectifying separator 18. Since the two-phase refrigerant flows into the rectifying separator 18, part of the refrigerant passes through the sub-expansion apparatus 22 and is reduced in pressure to become a low temperature two-phase refrigerant and flows into the cooling unit 19. In the cooling unit 19, the low temperature two-phase refrigerant exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 18.

[0063] In the cooling unit 19 of Embodiment 1, the two-phase refrigerant of the low temperature and low pressure, of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 19, and therefore, latent heat of the refrigerant can be utilized effectively so that the cooling unit 19 can be compactly formed. In addition, the cooling unit 19 of the heat pump apparatus of Embodiment 1 can, without fail, liquefy the gas in the top part of the rectifying separator 18.

[0064] In this way, since the two-phase refrigerant flows in from the bottom of the rectifying separator 18 the gas refrigerant flows out from the top part of the rectifying separator 18 and this gas refrigerant is cooled by the cooling unit 19. The refrigerant which has been cooled and liquefied by the cooling unit 19 is gradually collected in the reservoir unit 20 so that the amount of collection increases. Then, part of the refrigerant which has been collected in the reservoir unit 20 returns again to the top part of the rectifying separator 18 and moves downward into the rectifying separator 18. In the case that these conditions occur sequentially the gas refrigerant which moves upward and the liquid which moves downward create the condition of contact between the gas and the liquid within the rectifying separator 18. This condition of contact between the gas and the liquid generates a rectifying effect so that the refrigerant which gradually increases in low boiling point refrigerant components is collected in the reservoir unit 20. The refrigerant which moves downward into the rectifying separator 18 and passes through the sub-expansion apparatus 22 gradually increases the amount of high boiling point refrigerant components and passes through the cooling unit 19 so as to be absorbed by the compressor 11.

[0065] As described above, because of the structure that the refrigerant having a large amount of high boiling point refrigerant components is absorbed into the compressor 11 of the main circuit via the cooling unit 19 the refrigerant which gradually increases the amount of high boiling point refrigerant components flows

through the main circuit. As a result of this the heat pump apparatus of Embodiment 1 can reduce the heating performance. In addition, since low boiling point refrigerant is collected in the reservoir unit 20, the amount of refrigerant flowing through the main circuit decreases. Thereby, the heat pump apparatus of Embodiment 1 reduces the heating performance due to the decrease of the refrigerant amount, and in the case that the heating load is small, the operation with low performance for that heating load can be carried out.

[0066] As described above, under the condition of the operation with low performance, further load determination is carried out (STEP 4). In this STEP 4, the heating load becomes large, and in the case that the absolute value of the difference between the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds the predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valve 21 is transmitted from the operation control apparatus 26 to the two-way valve 21. As a result of this the two-way valve 21 reverts to the closed condition (STEP 5) and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the heating load becomes possible.

[0067] As described above, in the heat pump apparatus of Embodiment 1, by determining the absolute value of the difference between the set air temperature "to" and the temperature "t" of the intake air of the indoor unit 23 and by comparing that absolute value with the predetermined value " Δt " for the judgment of the size of the load, the two-way valve 21 is controlled in opening and closing so as to be able to adjust the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load. Accordingly, the heat pump apparatus of Embodiment 1 can carry out appropriate performance control in response to the load under the condition of either a cooling or heating operation.

(Embodiment 2)

[0068] Next, a heat pump apparatus of Embodiment 2 in accordance with the present invention is described with reference to FIGS. 3 and 4. FIG. 3 is a system configuration view of the heat pump apparatus of Embodiment 2. FIG. 4 is a control flow chart of a heat pump apparatus in accordance with Embodiment 2. Here, in FIGS. 3 and 4 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of Embodiment 1 in the above are referred to using the same numerals.

[0069] In FIG. 3, a non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 2 which connects, through pipes, a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, an outdoor expansion apparatus 30, an indoor expansion apparatus 32 and an indoor heat exchanger 15 in an annular structure.

[0070] In Embodiment 2 a check-valve 31 is provided in parallel with the outdoor expansion apparatus 30 so as to bypass the outdoor expansion apparatus 30 at the time of the cooling operation while a check-valve 33 is provided in parallel with the indoor expansion apparatus 32 so as to bypass the indoor expansion apparatus at the time of the heating operation. As described above, the compressor 11, the four-way valve 12, the outdoor heat exchanger 13, the outdoor expansion apparatus 30, the check-valve 31, the indoor expansion apparatus 32, the check-valve 33 and the indoor heat exchanger 15 form the main circuit of a refrigeration cycle in the heat pump apparatus of Embodiment 2.

[0071] The bottom of the rectifying separator 18 is connected to a pipe between the outdoor expansion apparatus 30 and the indoor expansion apparatus 32 via the two-way valve 21 and the sub-expansion apparatus 34. The rectifying separator 18 has filling material (not shown) filled into the inside and is formed of a straight pipe which is long in the vertical direction. The top part of the rectifying separator 18 is communicated to the top of a reservoir unit 20 via a cooling unit 19. Then the bottom of the reservoir unit 20 is communicated to the top part of the rectifying separator 18. Accordingly, the top part of the rectifying separator 18, the cooling unit 19 and the reservoir unit 20 are connected in an annular structure so as to form a closed circuit.

[0072] Here, in Embodiment 2 the reservoir unit 20 is arranged so that the top part thereof is located higher than the top part of the rectifying separator 18. In addition, the cooling unit 19 is arranged so as to be located higher than the top part of the reservoir unit 20.

[0073] The pipe connecting the top part of the rectifying separator 18 and the cooling unit 19 is connected to the surface of the ceiling of the top part of the rectifying separator 18. The pipe connecting the bottom of the reservoir unit 20 with the top part of the rectifying separator 18 is connected to the side of the top part of the rectifying separator 18. The pipe leading out from the bottom of the rectifying separator 18 is connected to an intake pipe which makes a connection between the compressor 11 and the four-way valve 12 via the sub-expansion apparatus 22 and the cooling unit 19.

[0074] The cooling unit 19 of Embodiment 2 is formed so that the refrigerant moving toward the intake pipe of the compressor 11 from the bottom of the rectifying separator 18 through the sub-expansion apparatus 22 and the refrigerant in the top part of the rectifying separator 18 exchanges heat indirectly. A double piping

structure can be adopted for the cooling unit 19 in Embodiment 2.

[0075] In FIG. 3 an indoor unit 23 is formed of the indoor heat exchanger 15, or the like, and is provided with an indoor thermal sensor 24 which detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 23). An operation control apparatus 26 to which data are inputted from the indoor thermal sensor 24 compares a set air temperature "to" stored in a memory apparatus 25 with the temperature "t" of the intake air detected by the indoor thermal sensor 24 and operates so that, in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" is " Δt " or less ($|t - to| \leq \Delta t$), the two-way valve 21 is opened and in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), the two-way valve 21 is closed. The memory apparatus 25 which is electrically connected to the operation control apparatus 26 is an apparatus in which a set air temperature value is stored as a desirable value which the user presets.

[0076] Next, the operation of the heat pump apparatus of Embodiment 2 formed as in the above is described with reference to FIG. 4.

[0077] FIG. 4 is a control flow chart of the heat pump apparatus of Embodiment 2.

[0078] First, the operation at the time of cooling is described.

[0079] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 11, the two-way valve 21 is closed (STEP 1). In this way, under the condition where the two-way valve 21 is closed, the high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the outdoor heat exchanger 13 so as to be condensed and liquefied at the time of cooling. The refrigerant which has been condensed and liquefied passes through the check-valve 31 and flows into the indoor expansion apparatus 32 while maintaining high pressure. The refrigerant which has passed through the indoor expansion apparatus 32 passes through the indoor heat exchanger 15 and flows into the compressor 11 via the four-way valve 12 so as to flow through the main circuit in the refrigeration cycle.

[0080] Under the above-mentioned conditions, the indoor thermal sensor 24 provided in the indoor unit 23 is used to carry out load determination (STEP 2). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-

way valve 21. As a result of this, the two-way valve 21 maintains the closed condition.

[0081] Accordingly, the refrigerant which has passed through the check-valve 31 passes through the indoor expansion apparatus 32 so as to be put under low pressure and evaporates in the indoor heat exchanger 15 so as to cool the space provided in the indoor unit 23. After that the refrigerant passes through the four-way valve 12 and is absorbed into the compressor 11.

[0082] Since the two-way valve 21 is closed and the rectifying separator 18 is connected to the intake pipe of the compressor 11 via the cooling unit 19 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the above-mentioned cooling cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to a low pressure condition internally and there is little reservoir of the refrigerant.

[0083] By maintaining the closed condition of the two-way valve 21 as described above, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant as the filled in components have been mixed and the operation is exercised under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 1 operates with high performance appropriate to the load.

[0084] A load determination is carried out in STEP 2, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. As a result of this, the two-way valve 21 converts to the opened condition (STEP 3). Thereby, part of the high pressure refrigerant which has come out of the check-valve 31 passes through the two-way valve 21 and the sub-expansion apparatus 34 and flows into the bottom of the rectifying separator 18. The refrigerant pressure is not reduced to a great extent in the sub-expansion apparatus 34 and the refrigerant flows out to the rectifying separator 18 under a condition of semi-high pressure which is slightly lower than high pressure (semi-high pressure condition). In the rectifying separator 18 the operation of rectifying separation is carried out in the semi-high pressure condition. Here, semi-high pressure indicates the pressure between high pressure and intermediate pressure.

[0085] In addition, part of the refrigerant, which has passed through the rectifying separator 18 from the sub-expansion apparatus 34, is reduced in pressure by the sub-expansion apparatus 22 into low pressure. The

refrigerant of the reduced pressure becomes a two-phase refrigerant at a low temperature and flows into the cooling unit 19. In this cooling unit 19 the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 18.

[0086] Under the above-mentioned condition the pressure within the rectifying separator 18 is semi-high pressure which is slightly lower than high pressure and two-phase refrigerant, of low temperature and low pressure of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 19, and therefore, the difference between the temperature of the top part of the rectifying separator 18 and the temperature of the cooling source of the cooling unit 19 can be made large in Embodiment 2. In addition, since the cooling unit 19 can utilize the latent heat of the cooling source effectively the cooling unit 19 can be made more compact. In addition, since the heat pump apparatus of Embodiment 2 is formed as described above, the gas of the top part of the rectifying separator 18 can, without fail, be liquefied and has the effect of promoting rectifying separation.

[0087] The operation in the rectifying separator 18 of Embodiment 2 is the same as that in the above-mentioned Embodiment 1, of which the detail is omitted. In the rectifying separator 18 of Embodiment 2 the refrigerant, which gradually increases in low boiling point refrigerant components due to the rectifying effect, is collected in the reservoir unit 20. The refrigerant which moves downward into the rectifying separator 18 and passes through the sub-expansion apparatus 22 gradually increases in high boiling point refrigerant components and the refrigerant which passes through the main circuit gradually increases in high boiling point refrigerant components.

[0088] In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant flowing through the main circuit decreases. Thereby, the heat pump apparatus of Embodiment 2 is designed to reduce the cooling performance due to the reduction of the refrigerant amount, and in the case that the cooling load is small, the operation with low performance appropriate to this cooling load becomes possible.

[0089] Under the above-mentioned condition of the operation with low performance, a load determination is further carried out (STEP 4). In this STEP 4, in the case that the cooling load becomes large and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds the predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valve 21 is transmitted from the operation control apparatus 26 to the two-way valve 21. As a result of this the two-way valve 21 reverts to the closed condition (STEP 5), and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the

compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the cooling load can be restarted.

[0090] As described above in the heat pump apparatus of Embodiment 2, the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 and the set air temperature "to" is measured and compared with the predetermined value " Δt " for the judgment of the size of the cooling load. Then, based on the comparison result, the amount of refrigerant and the refrigerant components in the main circuit can be controlled to achieve an appropriate condition in response to the cooling load by carrying out a simple operation of opening and closing the two-way valve 21. In this way, the heat pump apparatus of Embodiment 2 can carry out a performance control in response to the detected cooling load by exercising a simple control. In addition, in Embodiment 2 the pressure of the rectifying separator 18 can be set at semi-high pressure which is slightly lower than high pressure, and therefore, the range of variation of the refrigerant components can be made wider so that it becomes possible to carry out performance control in response to the load, which changes greatly.

[0091] Next, the operation at the time of heating is described.

[0092] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0093] At the time of the heating operation, in the case that a high heating performance is required, such as immediately after the start-up of the compressor 11, the two-way valve 21 is closed (STEP 1). In this way, under the condition that the two-way valve 21 is closed, high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the indoor heat exchanger 15 in the indoor unit 23 so as to be condensed and liquefied at the time of heating. The indoor space is heated due to condensation and liquidation of the refrigerant in the indoor heat exchanger 15. The refrigerant which comes out of the indoor heat exchanger 15 passes through the check-valve 33 and flows into the outdoor expansion apparatus 30 in the high pressure condition.

[0094] Under the above-mentioned conditions the indoor thermal sensor 24 provided in the indoor unit 23 is utilized so as to carry out a load determination (STEP 2).

[0095] In STEP 2, in the case that the absolute value of the difference between the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected

by the indoor thermal sensor 24 exceeds a predetermined value " Δt " ($|t-t_o| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. Thereby, the two-way valve 21 maintains the closed condition. Accordingly, all the refrigerant which comes out of the check-valve 33 passes through the outdoor expansion apparatus 30 so as to be put under low pressure and evaporates in the outdoor heat exchanger 13, and after that, passes through the four-way valve 12 so as to be absorbed again in the compressor 11.

[0096] Since the two-way valve 21 is closed and the cooling unit 19 is connected to the intake pipe of the compressor 11 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the above-mentioned heating cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to the low pressure condition internally and there is little reservoir of the refrigerant.

[0097] As described above, by maintaining the closed condition of the two-way valve 21, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 2 can carry out the high performance operation appropriate for the load.

[0098] In STEP 2, a load determination is carried out and in the case that the absolute value of the difference of the set air temperature " t_o " stored in the memory apparatus 25 and the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 is the predetermined value " Δt " ($|t-t_o| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valve 21 is sent from the operation control apparatus 26 to the two-way valve 21. As a result of this, the two-way valve 21 converts to the opened condition (STEP 3). Thereby, part of the high pressure refrigerant which comes out of the check-valve 33 passes through the two-way valve 21 and the sub-expansion apparatus 34, and flows into the bottom of the rectifying separator 18. Under these conditions, the sub-expansion apparatus 34 is set so that the refrigerant which flows into the rectifying separator 18 is put under intermediate pressure which is slightly lower than high pressure and the rectifying separator 18 is configured so that the operation of rectifying separation is carried out under this intermediate pressure.

[0099] Part of the refrigerant, which has passed through the sub-expansion apparatus 34 and has flown into the rectifying separator 18, passes through the sub-expansion apparatus 22 and is reduced in pressure to become a low temperature two-phase refrigerant and flows into the cooling unit 19. In the cooling unit 19, the

low temperature two-phase refrigerant exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 18.

[0100] The above-mentioned operation at the time of heating is the same operation as at the time of cooling, of which the detailed description is omitted. In Embodiment 2 the difference between the temperature of the top part of the rectifying separator 18 at the time of the heating operation and the temperature of the cooling heat source of the cooling unit 19 can be made larger so that latent heat of the cooling heat source can be utilized effectively. Accordingly, in the heat pump apparatus of Embodiment 2 the cooling unit 19 can be configured more compactly and the gas in the top part of the rectifying separator 18 can, without fail, be liquefied so that it becomes possible to promote rectifying separation.

[0101] In addition, in the same way as at the time of the cooling operation the low boiling point refrigerant is collected in the reservoir unit 20 at the time of the heating operation, and therefore, the amount of the refrigerant flowing through the main circuit is reduced. Thereby, the heat pump apparatus of Embodiment 2 reduces the heating performance due to the decrease of the refrigerant amount, and in the case that the heating load is small, the operation with low performance for that heating load can be carried out.

[0102] As described above, under the condition of the operation with low performance, further load determination is carried out (STEP 4). In this STEP 4, the heating load becomes large, and in the case that the absolute value of the difference between the set air temperature " t_o " stored in the memory apparatus 25 and the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds the predetermined value " Δt " ($|t-t_o| > \Delta t$), a closing signal of the two-way valve 21 is transmitted from the operation control apparatus 26 to the two-way valve 21. As a result of this, the two-way valve 21 reverts to the closed condition (STEP 5) and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the heating load becomes possible.

[0103] As described above, in the heat pump apparatus of Embodiment 2, by determining the absolute value of the difference through the set air temperature " t_o " and the temperature " t " of the intake air of the indoor unit 23 and by comparing that absolute value with the predetermined value " Δt " for the judgment of the size of the load, the two-way valve 21 is controlled in opening and closing so as to be able to adjust the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load. Accord-

ingly, the heat pump apparatus of Embodiment 2 can be set at intermediate pressure which is slightly lower than high pressure in the pressure of the rectifying separator 18 under the operation conditions of either cooling or heating, and therefore, the range of variation of the refrigerant components can be made wider so that it becomes possible to carry out performance control in response to the load, which changes greatly.

(Embodiment 3))

[0104] Next, a heat pump apparatus of Embodiment 3 in accordance with the present invention is described with reference to FIGS. 5 and 6. FIG. 5 is a system configuration view of the heat pump apparatus of Embodiment 3. FIG. 6 is a control flow chart of a heat pump apparatus in accordance with Embodiment 3. Here, in FIGS. 5 and 6 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of Embodiment 1 in the above are referred to using the same numerals.

[0105] In FIG. 5, a non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 3 wherein a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, the main expansion apparatus 14 and an indoor heat exchanger 15 are connected, through pipes, in an annular structure.

[0106] The configuration of the refrigeration cycle of the heat pump apparatus of Embodiment 3 has a connection between the bottom of the rectifying separator 18 and the discharge pipe of the compressor 11, in addition to the configuration of the refrigeration cycle of the heat pump apparatus of the above-mentioned Embodiment 1. A two-way valve 41 and a sub-expansion apparatus 40 make a connection between the bottom of the rectifying separator 18 and the discharge pipe of the compressor 11. The discharge pipe of the compressor 11 is arranged between the compressor 11 and the four-way valve 12.

[0107] In the heat pump apparatus of Embodiment 3, the operation control apparatus 26 operates so as to open the two-way valve 21 and the two-way valve 41 in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$) and to close the two-way valve 21 and the two-way valve 41 in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" exceeds a predetermined value " Δt " ($|t - to| > \Delta t$).

[0108] Next, the operation of the heat pump apparatus of Embodiment 3 formed as in the above is described with reference to FIG. 6.

[0109] FIG. 6 is a control flow chart of the heat pump apparatus of Embodiment 3.

[0110] First, the operation at the time of cooling is described.

[0111] At the time of the cooling operation, in the

case that a cooling performance is required, such as immediately after start-up of the compressor 11, the two-way valves 21 and 41 are closed (STEP 1). In this way, under the condition where the two-way valves 21 and 41 are closed, the high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the outdoor heat exchanger 13 so as to be condensed and liquefied at the time of cooling. The condensed and liquefied refrigerant is separated into the main circuit which flows into the main expansion apparatus 14 and a circuit which flows into the sub-expansion apparatus 16.

[0112] The refrigerant which has flown into the sub-expansion apparatus 16 is reduced in pressure so as to be put under an pressure in the vicinity of the intermediate pressure between the highest and the lowest pressure in the main circuit of the refrigeration cycle.

[0113] Under the above-mentioned conditions, the indoor thermal sensor 24 provided in the indoor unit 23 is used to carry out load determination (STEP 2).

[0114] In STEP 2, in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valves 21 and 41 is sent from the operation control apparatus 26 to each of the two-way valves 21 and 41. Thereby, the two-way valves 21 and 41 maintain the closed condition.

[0115] Accordingly, the refrigerant under intermediate pressure which has been discharged from the sub-expansion unit 16 all passes through the sub-expansion apparatus 17 and is put under low pressure and flows into the main circuit. In this way the refrigerant which has passed through the sub-expansion apparatus 16 merges together with the refrigerant which has passed through the main expansion apparatus 14 and, after that, evaporates in the indoor heat exchanger 15 so as to cool the space provided in the indoor unit 23. Then the refrigerant which comes out of the indoor heat exchanger 15 passes through the four-way valve 12 so as to again be absorbed into the compressor 11.

[0116] Since the two two-way valves 21 and 41 are closed and the rectifying separator 18 is connected to the intake pipe of the compressor 11 via the cooling unit 19 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the above-mentioned cooling cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to a low pressure condition internally and there is little reservoir of the refrigerant.

[0117] By maintaining the closed condition of the two-way valves 21 and 41 as described above, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant as the filled in components

have been mixed and the main circuit is operated under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 3 operates with high performance appropriate to the load.

[0118] A load determination is carried out in STEP 2, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 21 and the two-way valve 41 is sent from the operation control apparatus 26 to each of the two-way valves 21 and 41. As a result of this the two-way valves 21 and 41 convert to the opened condition (STEP 3). Thereby, part of the two-phase refrigerant under the intermediate pressure which has come out from the sub-expansion unit 16 passes through the two-way valve 21 and flow into the bottom of the rectifying separator 18. In addition, part of the discharged gas of the compressor 11 is reduced in pressure into intermediate pressure in the sub-expansion apparatus 40 and passes through the two-way valve 41 so as to flow into the bottom of the rectifying separator 18. Accordingly, at the bottom of the rectifying separator 18 part of the refrigerant which has passed through the sub-expansion apparatus 16 and part of the discharged gas of the compressor 11 merge together. Then part of the refrigerant passes through the sub-expansion apparatus 22 and is reduced in pressure so as to be put under a predetermined pressure and, then, becomes a two-phase refrigerant of low temperature which flows into the cooling unit 19. In the cooling unit 19 the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 18.

[0119] In the cooling unit 19 of Embodiment 3, since the two-phase refrigerant of low temperature and low pressure, of which the enthalpy is the lowest in the refrigeration cycle, is utilized as a cooling resource of the cooling unit 19, latent heat of the refrigerant can be utilized effectively so that the cooling unit 19 can be compactly formed. In addition, the cooling unit 19 of the heat pump apparatus of Embodiment 1 can, without fail, liquefy the gas in the top part of the rectifying separator 18.

[0120] In this way, the two-phase refrigerant flows into from the bottom of the rectifying separator 18 and the gas refrigerant flows out from the top part of the rectifying separator 18 and this gas refrigerant is cooled by the cooling unit 19. The refrigerant which has been cooled and liquefied in the cooling unit 19 is gradually collected in the reservoir unit 20 and the amount of collection increases. Then the refrigerant returns again to the top part of the rectifying separator 18 and moves downward into the rectifying separator 18. In the case

that these conditions occur sequentially, the gas refrigerant which moves upward and the liquid refrigerant which moves downward create the condition of contact between the gas and the liquid in the rectifying separator 18. This condition of contact between the gas and the liquid generates a rectifying effect so that the refrigerant with a large amount of low boiling point refrigerant components is gradually collected in the reservoir unit 20. As a result of this, the refrigerant which moves downward into the rectifying separator 18 and passes through the sub-expansion apparatus 22 gradually increases in high boiling point refrigerant components and passes through the cooling unit 19 to be taken into the compressor 11.

[0121] As described above, in the heat pump apparatus of Embodiment 3, since the discharged gas of the compressor 11 flows directly into the rectifying separator 18, the amount of gas which moves upward increases so as to create an excellent contact between the gas and the liquid, which promotes the rectifying effects. Thereby, in the heat pump apparatus of Embodiment 3, the refrigerant, of which the low boiling point refrigerant components are in great amount, is collected in the reservoir unit 20.

[0122] As a result of this, the refrigerant, of which the high boiling point refrigerant components are large in amount, flows through the main circuit in the refrigeration cycle so as to reduce the cooling performance. In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant flowing through the main circuit decreases. Thereby, the heat pump apparatus of Embodiment 3 reduces the cooling performance due to the reduction of the refrigerant amount, and in the case that the cooling load is small, the operation with low performance appropriate to this cooling load becomes possible.

[0123] Under the above-mentioned condition of the operation with low performance, a load determination is further carried out (STEP 4). In this STEP 4, in the case that the cooling load becomes large and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds the predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valve 21 and the two-way valve 41 is sent from the operation control apparatus 26 to the two-way valves 21 and 41. As a result of this the two-way valves 21 and 41 revert to the closed condition (STEP 5), and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the cooling load can be restarted.

[0124] As described above in the heat pump appa-

ratus of Embodiment 3, the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 and the set air temperature "to" is measured and compared with the predetermined value " Δt " for the judgment of the size of the cooling load. Then, based on the comparison result, the amount of refrigerant and the refrigerant components in the main circuit can be controlled to achieve an appropriate condition in response to the cooling load by carrying out only the simultaneous opening and closing operation of the two-way valves 21 and 41. In this way, the heat pump apparatus of Embodiment 2 can carry out a performance control in response to the detected cooling load by exercising a simple control.

[0125] Next, the operation at the time of heating is described.

[0126] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0127] At the time of the heating operation, in the case that a high heating performance is required, such as immediately after the start-up of the compressor 11, the two two-way valves 21 and 41 are closed (STEP 1). In this way, under the condition that the two-way valves 21 and 41 are closed, high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the indoor heat exchanger 15 so as to be condensed and liquefied at the time of heating. The refrigerant which has been condensed and liquefied is separated into the main circuit which flows into the main expansion apparatus 14 and a circuit which flows into the sub-expansion apparatus 17.

[0128] The refrigerant flown into the sub-expansion apparatus 17 is reduced in pressure and put under a pressure in the vicinity of the intermediate pressure between the highest and the lowest pressure in the main circuit of the refrigeration cycle.

[0129] Under the above-mentioned conditions the indoor thermal sensor 24 provided in the indoor unit 23 is utilized so as to carry out a load determination (STEP 2).

[0130] In STEP 2, in the case that the absolute value of the difference between the set air temperature "to" of the indoor unit 23 stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valves 21 and 41 is sent from the operation control apparatus 26 to the two-way valves 21 and 41.

[0131] As a result of this, the two-way valves 21 and 41 maintain the closed condition.

[0132] Accordingly, all of the refrigerant under the intermediate pressure which has come out from the sub-expansion apparatus 17 passes through the sub-

expansion apparatus 16 and is reduced in pressure so as to be put under low pressure and flows into the main circuit. In this way, the refrigerant which has passed through the sub-expansion apparatus 17 maintains the condition of flowing into the main circuit so as to merge together with the refrigerant which has passed through the main expansion apparatus 14. Thereby, the refrigerant in the main circuit evaporates in the outdoor heat exchanger 13 and, after that, passes through the four-way valve 12 so as to be absorbed into the compressor 11 again.

[0133] Since the two-way valves 21 and 41 are closed and the rectifying separator 18 is connected via the cooling unit 19 to the intake pipe of the compressor 11, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are practically under the condition of being out of the above-mentioned heating cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to the low pressure condition internally and there is little reservoir of the refrigerant.

[0134] As described above, by maintaining the closed condition of the two-way valves 21 and 41, the refrigerant flowing through the main circuit remains the non-azeotropic refrigerant wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 3 can carry out the high performance operation appropriate for the load.

[0135] In STEP 2, a load determination is carried out and in the case that the absolute value of the difference of the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 is the predetermined value " Δt " ($|t - to| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valve 21 and the two-way valve 41 are sent from the operation control apparatus 26 to the two-way valves 21 and 41. As a result of this, the two-way valves 21 and 41 convert to the opened condition (STEP 3). Thereby, part of the two-phase refrigerant under the intermediate pressure which has come out from the sub-expansion apparatus 17 passes through the two-way valve 21 and flows into the bottom of the rectifying separator 18. In addition, part of the discharged gas of the compressor 11 is reduced in pressure into intermediate pressure by the sub-expansion apparatus 40 and passes through the two-way valve 41 so as to flow into the bottom of the rectifying separator 18. Thereby, the refrigerant from the sub-expansion apparatus 17 and part of the discharged gas of the compressor 11 merge together at the bottom of the rectifying separator 18. Then, the refrigerant which comes out of the bottom of the rectifying separator 18 is reduced in pressure, in the sub-expansion apparatus 22, to low pressure and converts to a two-

phase refrigerant of low temperature so as to flow into the cooling unit 19. In this cooling unit 19, the low temperature two-phase refrigerant exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 18.

[0136] In the heat pump apparatus of Embodiment 3, the two-phase refrigerant of the low temperature and low pressure, of which the enthalpy is the lowest in the heating cycle, is utilized as a cooling source of the cooling unit 19, and therefore, latent heat of the refrigerant can be utilized effectively so that the cooling unit 19 can be compactly formed. In addition, the heat pump apparatus of Embodiment 3 can, without fail, liquefy the gas in the top part of the rectifying separator 18.

[0137] In this way, since the two-phase refrigerant flows in from the bottom of the rectifying separator 18 the refrigerant flows out from the top part of the rectifying separator 18 and this refrigerant is cooled by the cooling unit 19. The refrigerant which has been cooled and liquefied by the cooling unit 19 is gradually collected in the reservoir unit 20 so that the amount of collection increases. Then, part of the refrigerant which has been collected in the reservoir unit 20 returns again to the top part of the rectifying separator 18 and moves downward into the rectifying separator 18. In the case that these conditions occur sequentially the gas refrigerant which moves upward into the rectifying separator 18 and the liquid which moves downward create the condition of contact between the gas and the liquid within the rectifying separator 18. This condition of contact between the gas and the liquid generates a rectifying effect so that the refrigerant which gradually increases in low boiling point refrigerant components is collected in the reservoir unit 20. On the other hand, the refrigerant which moves downward into the rectifying separator 18 and passes through the sub-expansion apparatus 22 gradually increases the amount of high boiling point refrigerant components and passes through the cooling unit 19 so as to be absorbed by the compressor 11.

[0138] As described above, in Embodiment 3, the configuration is such that the discharged gas of the compressor 11 directly flows into the rectifying separator 18 at the time of the heating operation in the same way as at the time of the cooling operation. Therefore, in the rectifying separator 18, the amount of the gas which moves upward increases and makes the contact between the gas and the liquid excellent so as to promote the rectifying effects, and the refrigerant of which the low boiling point refrigerant components is very large in amount is collected in the reservoir unit 20.

[0139] As a result, the refrigerant flowing through the main circuit increases greatly in high boiling point refrigerant components so as to be able to control the performance in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit 20, the amount of refrigerant flowing through the main circuit decreases, and therefore, the heating per-

formance can be reduced due to the decrease of the refrigerant amount, and in the case that the heating load is small, the operation with low performance for that heating load can be carried out.

[0140] As described above, under the condition of the operation with low performance, further load determination is carried out (STEP 4). In this STEP 4, the heating load becomes large, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds the predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of 21 and the two-way valve 41 is sent from the operation control apparatus 26 to the two-way valves 21 and 41. As a result of this the two-way valves 21 and 41 revert to the closed condition (STEP 5) and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the heating load can be restarted.

[0141] As described above, in the heat pump apparatus of Embodiment 3, by determining the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 and the set air temperature "to" and by comparing that absolute value with the predetermined value " Δt " for the judgment of the size of the load, the two-way valves 21 and 41 are merely controlled simultaneously in opening and closing so as to enable the adjustment of the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load. Accordingly, the heat pump apparatus of Embodiment 3 can easily carry out performance control. In addition, in Embodiment 3, the discharged gas of the compressor 11 is utilized so as to enable the creation of an excellent contact between the gas and the liquid for rectifying separation, and therefore, reduction in separation time and improvement of the separation performance can be achieved so that refrigerant components can be realized having a broad range of variation which can, without fail, adapt in response to a great change in the load.

(Embodiment 4))

[0142] Next, a heat pump apparatus of Embodiment 4 in accordance with the present invention is described with reference to FIGS. 7 and 8. Here, in FIGS. 7 and 8 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of each of the above-mentioned Embodiments are referred to using the same numerals.

[0143] FIG. 7 is a system configuration view of the

heat pump apparatus of Embodiment 4. In FIG. 7, a non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 4 which connects, through pipes, a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, an outdoor expansion apparatus 30, an indoor expansion apparatus 32 and an indoor heat exchanger 15 in an annular structure.

[0144] In Embodiment 4 a check-valve 31 is provided in parallel with the outdoor expansion apparatus 30 so as to bypass the outdoor expansion apparatus 30 at the time of the cooling operation while a check-valve 33 is provided in parallel with the indoor expansion apparatus 32 so as to bypass the indoor expansion apparatus at the time of the heating operation. As described above, the heat pump apparatus of Embodiment 4 has the same configuration as that of the heat pump apparatus of the above-mentioned Embodiment 2. However, the configuration of the refrigeration cycle of the heat pump apparatus of Embodiment 4 has a connection between the bottom of the rectifying separator 18 and the discharge pipe of the compressor 11 in addition to the configuration of the refrigeration cycle of the heat pump apparatus of Embodiment 2. A two-way valve 51 and a sub-expansion apparatus 50 make a connection between the bottom of the rectifying separator 18 and the discharge pipe of the compressor 11. The discharge pipe of the compressor 11 is arranged between the compressor 11 and the four-way valve 12. In FIG. 8 the elements having the same function and configuration as in Embodiment 2 are denoted by the same numerals.

[0145] An operation control apparatus 26 of Embodiment 4 operates so that, in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" is " Δt " or less ($|t - t_o| \leq \Delta t$), the two-way valve 21 and the two-way valve 51 are opened and in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), the two-way valve 21 and the two-way valve 51 are closed.

[0146] Next, the operation of the heat pump apparatus of Embodiment 4 formed as in the above is described with reference to FIG. 8.

[0147] FIG. 8 is a control flow chart of the heat pump apparatus of Embodiment 4.

[0148] First, the operation at the time of cooling is described.

[0149] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 11, the two two-way valves 21 and 51 are closed (STEP 1). In this way, under the condition where the two-way valves 21 and 51 are closed, the high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the outdoor heat exchanger 13 so as to be condensed and liquefied at the time of cooling. The refrigerant which has been con-

densed and liquefied passes through the check-valve 31 and flows into the indoor expansion apparatus 32 while maintaining high pressure.

[0150] Under the above-mentioned conditions, the indoor thermal sensor 24 is used to carry out load determination (STEP 2). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 21 and the two-way valve 51 is sent from the operation control apparatus 26 to the two-way valves 21 and 51. As a result of this, the two-way valves 21 and 51 maintain the closed condition.

[0151] Accordingly, the refrigerant which has come out of the check-valve 31 passes through the indoor expansion apparatus 32 so as to be put under low pressure and evaporates in the indoor heat exchanger 15 so as to cool the space provided in the indoor unit 23. After that the refrigerant passes through the four-way valve 12 and is absorbed into the compressor 11.

[0152] Since the two-way valves 21 and 51 are closed and the rectifying separator 18 is connected to the intake pipe of the compressor 11 via the cooling unit 19 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert to a low pressure condition and there is little reservoir of the refrigerant.

[0153] By maintaining the closed condition of the two-way valves 21 and 51 as described above, the refrigerant flowing through the main circuit remains the conditions as the filled in components have been mixed and the operation is exercised under the condition with a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 4 operates with high performance appropriate to the load.

[0154] A load determination is carried out in STEP 2, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 is a predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 21 and the two-way valve 51 is sent from the operation control apparatus 26 to each of the two-way valves 21 and 51 so that the two-way valves 21 and 51 are opened (STEP 3).

[0155] In Embodiment 4 the sub-expansion apparatus 34 and the sub-expansion apparatus 50 are set so that the refrigerant flows into the rectifying separator 18 under semi-high pressure, which is slightly lower than high pressure, and the rectifying separation operation in the rectifying separator 18 is carried out under this pressure.

[0156] Part of the high pressure refrigerant which

has come out of the check-valve 31 passes through the two-way valve 21 and the sub-expansion apparatus 34 and flows into the bottom of the rectifying separator 18. In addition, the discharged gas of the compressor 11, which is reduced in pressure to semi-high pressure by the sub-expansion apparatus 50 and which has passed through the two-way valve 51, flows into the bottom of the rectifying separator 18 and merges together with the refrigerant which has passed through the sub-expansion apparatus 34. The resultant merged refrigerant at the bottom of the rectifying separator 18 passes through the sub-expansion apparatus 22 so as to be reduced in pressure and then becomes a two-phase refrigerant of low temperature and flows into the cooling unit 19. In this cooling unit 19 the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 18.

[0157] In Embodiment 4, the configuration allows the discharged gas from the compressor 11 to directly flow into the rectifying separator 18, and therefore, the amount of gas which moves upward increases so as to create an excellent gas-liquid contact for promoting the rectifying effect. In addition, the pressure within the rectifying separator 18 is semi-high pressure which is slightly lower than high pressure and two-phase refrigerant, of low temperature and low pressure of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 19, and therefore, the difference between the temperature of the top part of the rectifying separator 18 and the temperature of the cooling heat source of the cooling unit 19 can be made large in Embodiment 2. As a result of this, in Embodiment 4, not only can the cooling unit 19 be configured compactly but, also, the gas in the top part of the rectifying separator 18 can, without fail, be liquefied and the rectifying separation is promoted so that the refrigerant which contains a significantly large amount of low boiling point refrigerant components is collected in the reservoir unit 20. As a result, since the refrigerant which contains a significantly large amount of high boiling point refrigerant components flows through the main circuit, the heat pump apparatus of Embodiment 4 can control performance in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant flowing through the main circuit decreases and, thereby, the cooling performance is further reduced due to the reduction of the refrigerant amount in the main circuit and the operation with low performance appropriate for this cooling load becomes possible.

[0158] Under the above-mentioned condition of the operation with low performance, a load determination is further carried out (STEP 4). In this STEP 4, in the case that the cooling load becomes large and the absolute value of the difference between the temperature "t" of the intake air of the Indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds the

predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valves 21 and 51 is sent from the operation control apparatus 26 to each of the two-way valves 21 and 51. As a result of this the two-way valves 21 and 51 revert to the closed condition (STEP 5), and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the components wherein the refrigerant of high performance is filled in. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the cooling load becomes possible.

[0159] As described above in the heat pump apparatus of Embodiment 4, the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 and the set air temperature "to" is detected and the amount of refrigerant and the refrigerant components in the main circuit can be controlled to achieve an appropriate condition in response to the cooling load by carrying out a simple operation of simultaneously opening and closing the two-way valves 21 and 51. In this way, in the heat pump apparatus of Embodiment 4, the pressure of the rectifying separator 18 can be set at semi-high pressure, and therefore, the range of variation of the refrigerant components can be made wider so that the apparatus carries out performance control in a wide range in response to the load, which changes greatly.

[0160] Next, the operation at the time of heating is described.

[0161] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0162] At the time of the heating operation, in the case that a high heating performance is required, such as immediately after the start-up of the compressor 11, the two-way valves 21 and 51 are closed (STEP 1). In this way, under the condition that the two-way valves 21 and 51 are closed, high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the indoor heat exchanger 15 so as to be condensed and liquefied at the time of heating. The condensed and liquefied refrigerant contribute to the heating in the indoor unit 23 and passes through the check-valve 33 so as to flow into the outdoor expansion apparatus 30 while being maintained at high pressure.

[0163] Under the above-mentioned conditions the indoor thermal sensor 24 is utilized so as to carry out a load determination (STEP 2).

[0164] In the case that the absolute value of the difference between the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds a predetermined value " Δt "

($|t - t_o| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valves 21 and 51 is sent from the operation control apparatus 26 to each of the two-way valves 21 and 51 so that the two-way valves 21 and 51 are closed. Accordingly, all the refrigerant which comes out of the check-valve 33 passes through the outdoor expansion apparatus 30 so as to be put under low pressure. Then the refrigerant which has passed through the outdoor expansion apparatus 30 evaporates in the outdoor heat exchanger 13 and, after that, passes through the four-way valve 12 so as to be absorbed again in the compressor 11.

[0165] Since the two-way valves 21 and 51 are closed and the rectifying separator 18 is connected to the intake pipe of the compressor 11 via the cooling unit 19 under the above-mentioned conditions, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 are under the condition of being out of the heating cycle. Accordingly, the cooling unit 19, the reservoir unit 20 and the rectifying separator 18 convert, respectively, to the low pressure condition internally and there is little reservoir of the refrigerant.

[0166] As described above, by maintaining the closed condition of the two-way valves 21 and 51, the refrigerant flowing through the main circuit remains the conditions wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 4 can carry out the high performance operation appropriate for the load.

[0167] In STEP 2, a load determination is carried out and in the case that the absolute value of the difference of the set air temperature " t_o " stored in the memory apparatus 25 and the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 is the predetermined value " Δt " ($|t - t_o| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valve 21 and the two-way valve 51 is sent from the operation control apparatus 26 to the two-way valves 21 and 51 so that each of the two-way valves 21 and 51 is opened (STEP 3).

[0168] The sub-expansion apparatus 34 and the sub-expansion apparatus 50 are set so as to reduce the refrigerant in pressure to semi-high pressure so that the refrigerant of semi-high pressure flows into the rectifying separator 18. The rectifying separation operation is carried out under this pressure in the rectifying separator 18.

[0169] Part of the high pressure refrigerant which comes out of the check-valve 33 passes through the two-way valve 21 and the sub-expansion apparatus 34, and flows into the bottom of the rectifying separator 18. In addition, part of the discharged gas of the compressor 11 is reduced in pressure to semi-high pressure in the sub-expansion apparatus 50 and, then, passes through the two-way valve 51 so as to flow into the bottom of the rectifying separator 18. Therefore, the refrigerant

which has passed through the sub-expansion apparatus 34 and part of the discharged gas of the compressor 11 merge together at the bottom of the rectifying separator 18. Then, the refrigerant from the bottom of the rectifying separator 18 passes through the sub-expansion apparatus 22 and is reduced in pressure so as to become a two-phase refrigerant of low temperature and then flows into the cooling unit 19. In this cooling unit 19, the low temperature two-phase refrigerant exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 18.

[0170] In the heat pump apparatus of Embodiment 4, the configuration allows the discharged gas from the compressor 11 to directly flow into the rectifying separator 18, and therefore, the amount of gas which moves upward increases so as to create an excellent gas-liquid contact for promoting the rectifying effect. As a result, since the refrigerant which flows through the main circuit contains a significantly large amount of high boiling point refrigerant components, performance can be controlled in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant flowing through the main circuit decreases and, thereby, performance is further reduced due to this reduction of the refrigerant amount and the operation with low performance appropriate for the load can be easily carried out.

[0171] Under those conditions, load determination is carried out (STEP 4), and in the case that the heating load becomes large, that is to say, in the case that the absolute value of the difference between the set air temperature " t_o " stored in the memory apparatus 25 and the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds the predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valves 21 and 51 is transmitted from the operation control apparatus 26 so as to again close the two-way valves 21 and 51 (STEP 5) and the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit. Thereby, the refrigerant components in the main circuit return to the condition of the filled in components of high performance, and the amount of refrigerant increases so that the high performance operation is carried out in response to the load.

[0172] In this manner, by detecting the absolute value of the difference between the set air temperature " t_o " and the temperature " t " of the intake air of the indoor unit 23, the two-way valves 21 and 51 are merely controlled in simultaneous opening and closing so as to enable the adjustment of the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load. The heat pump apparatus of Embodiment 4 can be set at semi-high pressure in the pressure of the rectifying separator 18, and therefore, the range of variation of the refrigerant components can be made wider so that it becomes possible to carry out performance control in response to the load,

which changes greatly.

(Embodiment 5))

[0173] Next, a heat pump apparatus of Embodiment 5 in accordance with the present invention is described with reference to FIGS. 9 and 10. Here, in FIGS. 9 and 10 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of each of the above-mentioned Embodiments are referred to using the same numerals.

[0174] FIG. 9 is a system configuration view of the heat pump apparatus of Embodiment 5. In FIG. 9, a non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 5 which connects, through pipes, a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, an outdoor expansion apparatus 30, an indoor expansion apparatus 32 and an indoor heat exchanger 15 in an annular structure.

[0175] In Embodiment 5 a check-valve 31 is provided in parallel with the outdoor expansion apparatus 30 so as to bypass the outdoor expansion apparatus 30 at the time of the cooling operation while a check-valve 33 is provided in parallel with the indoor expansion apparatus 32 so as to bypass the indoor expansion apparatus at the time of the heating operation. As described above, the heat pump apparatus of Embodiment 5 has the same configuration as that of the heat pump apparatus of the above-mentioned Embodiment 4. Here, the configuration of the heat pump apparatus of Embodiment 5 has a connection between the cooling unit 19 and the intake pipe of the compressor 11 via the two-way valve 52, in addition to the configuration of the heat pump apparatus of Embodiment 4. In FIG. 9 the elements having the same function and configuration as in Embodiment 4 are denoted by the same numerals.

[0176] The operation control apparatus 26 of the heat pump apparatus of Embodiment 5 converts the two-way valves 21, 51 and 52 to the closed condition in the case that the cooling and heating performance is required such as at the time immediately after the start-up of the compressor 11. Then an operation control apparatus 26 first converts the two-way valves 21, 51 and 52 into the open condition for a predetermined period of time in the case that the absolute value of the difference between the temperature "t" of the intake air and the set air temperature "to" is " Δt " or less ($|t - to| \leq \Delta t$). Next, after a predetermined time has passed since the opening of the two-way valves 21, 51 and 52, the operation control unit 26 converts the two-way valves 21, 51 and 52 into the closed condition. After that, when the absolute value of the difference between the intake air temperature "t" and the set air temperature "to" exceeds a predetermined value " Δt ," only the two-way valve 52 is open while the two-way valve 21 and the two-way valve 51 are maintained in a closed condition.

[0177] Next, the operation of the heat pump appara-

tus of Embodiment 5 formed as in the above is described with reference to FIG. 10.

[0178] FIG. 10 is a control flow chart of the heat pump apparatus of Embodiment 5.

[0179] First, the operation at the time of cooling is described.

[0180] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 11, the three two-way valves 21, 51 and 52 are closed (STEP 1). In this way, under the condition where the two-way valves 21, 51 and 52 are closed, the high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the outdoor heat exchanger 13 so as to be condensed and liquefied. The refrigerant which has been condensed and liquefied passes through the check-valve 31 and flows into the indoor expansion apparatus 32 while maintaining high pressure.

[0181] Under the above-mentioned conditions, the indoor thermal sensor 24 is used to carry out load determination (STEP 2). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 to each of the two-way valves 21, 51 and 52. As a result of this, the two-way valves 21, 51 and 52 maintain the closed condition.

[0182] Accordingly, all the refrigerant which has come out of the check-valve 31 passes through the indoor expansion apparatus 32 so as to be put under low pressure and evaporates in the indoor heat exchanger 15 so as to cool the space provided in the indoor unit 23. After that the refrigerant passes through the four-way valve 12 and is absorbed into the compressor 11.

[0183] Since the two-way valves 21, 51 and 52 are closed under the above-mentioned conditions, there is little reservoir of the refrigerant in the cooling unit 19, the reservoir unit 20 and the rectifying separator 18.

[0184] By maintaining the closed condition of the two-way valves 21, 51 and 52 as described above, the refrigerant flowing through the main circuit remains the conditions as the filled in components have been mixed and the operation is exercised under the condition with a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 5 operates with high performance appropriate to the load.

[0185] A load determination is carried out in STEP 2, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 23 which is detected and measured by the indoor thermal sensor 24 and the set air temperature "to" stored in the memory apparatus 25 is a predeter-

mined value " Δt " or less ($|t-t_0| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 to each of the two-way valves 21, 51 and 2 so that the two-way valves 21, 51 and 52 are opened (STEP 3).

[0186] In Embodiment 5 the sub-expansion apparatus 34 and the sub-expansion apparatus 50 are set so that the refrigerant flows into the rectifying separator 18 under semi-high pressure, which is slightly lower than high pressure, and the rectifying separation operation in the rectifying separator 18 is carried out under this pressure.

[0187] Part of the high pressure refrigerant which has come out of the check-valve 31 passes through the two-way valve 21 and the sub-expansion apparatus 34 and flows into the bottom of the rectifying separator 18. In addition, the discharged gas of the compressor 11, which is reduced in pressure to semi-high pressure by the sub-expansion apparatus 50 and which has passed through the two-way valve 51, flows into the bottom of the rectifying separator 18 and merges together with the refrigerant which has passed through the sub-expansion apparatus 34. The resultant merged refrigerant at the bottom of the rectifying separator 18 passes through the sub-expansion apparatus 22 so as to be reduced in pressure and then becomes a two-phase refrigerant of low temperature and flows into the cooling unit 19. In this cooling unit 19 the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 18.

[0188] In Embodiment 5, the configuration allows the discharged gas from the compressor 11 to directly flow into the rectifying separator 18, and therefore, the amount of gas which moves upward increases so as to create an excellent gas-liquid contact for promoting the rectifying effect. In addition, the pressure within the rectifying separator 18 is semi-high pressure and two-phase refrigerant, of low temperature and low pressure of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 19, and therefore, the difference between the temperature of the top part of the rectifying separator 18 and the temperature of the cooling heat source of the cooling unit 19 can be made large in Embodiment 2. As a result of this, in Embodiment 5, not only can the cooling unit 19 be configured compactly but, also, the gas in the top part of the rectifying separator 18 can, without fail, be liquefied and the rectifying separation is promoted so that the refrigerant which contains a significantly large amount of low boiling point refrigerant components is collected in the reservoir unit 20. As a result, since the refrigerant which contains a significantly large amount of high boiling point refrigerant components flows through the main circuit, the heat pump apparatus of Embodiment 5 can control performance in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit 20 the amount of the refrigerant in the main

circuit decreases and, thereby, the cooling performance is further reduced due to this reduction of the refrigerant amount and the operation with low performance appropriate for this cooling load becomes possible.

[0189] The time determination is carried out whether or not, with respect to time T after the two-way valves 21, 51 and 52 are opened in STEP 3, a preset time T_a has passed (STEP 4). In the case that the predetermined time T_a has passed a closing signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 to the two-way valves 21, 51 and 52 so that the two-way valves 21, 51 and 52 are closed (STEP 5).

[0190] In Embodiment 5 because of the configuration wherein the rectifying separator 18, the cooling unit 19 and the reservoir unit 20 can be separated from the main circuit as described above, it becomes possible to block the circuit which makes the refrigerant flow to the low pressure side. Therefore, the heat pump apparatus of Embodiment 5 can eliminate the loss of the heat amount required for the rectifying separation, which makes possible performance control in response to the load and highly efficient operation can be carried out.

[0191] Under the above-mentioned condition of the operation with low performance, a load determination is further carried out (STEP 6). In this STEP 6, in the case that the cooling load becomes large, that is to say, in the case that the absolute value of the difference between the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 and the set air temperature " t_0 " stored in the memory apparatus 25 exceeds the predetermined value " Δt " ($|t-t_0| > \Delta t$), a closing signal of the two-way valves 21 and 51 and an opening signal of the two-way valve 52 are sent from the operation control apparatus 25. As a result, the two-way valves 21 and 51 are closed and the two-way valve 52 is opened (STEP 7). Accordingly, the refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 so that the refrigerant components in the main circuit revert to the condition of filler components of high performance. In addition, since the amount of refrigerant in the main circuit increases the high performance operation in response to the load becomes possible in the heat pump apparatus of Embodiment 5.

[0192] As described above in the heat pump apparatus of Embodiment 5, the absolute value of the difference between the temperature " t " of the intake air of the indoor unit 23 and the set air temperature " t_0 " is detected and the amount of refrigerant and the refrigerant components in the main circuit can be controlled to achieve an appropriate condition in response to the load by carrying out a simple operation of simultaneously opening and closing the two-way valves 21, 51 and 52. In this way, in the heat pump apparatus of Embodiment 5, the pressure of the rectifying separator 18 can be set at semi-high pressure, and therefore, the range of variation of the refrigerant components can be made wider

so that the apparatus carries out performance control in a wide range in response to the load, which changes greatly.

[0193] Next, the operation at the time of heating is described.

[0194] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0195] At the time of the heating operation, in the case that a high heating performance is required, such as immediately after the start-up of the compressor 11, the two-way valves 21, 51 and 52 are closed (STEP 1). In this way, under the condition that the two-way valves 21, 51 and 52 are closed, high temperature refrigerant which has been discharged from the compressor 11 flows into the four-way valve 12 and the indoor heat exchanger 15 so as to be condensed and liquefied. The condensed and liquefied refrigerant contribute to the heating in the indoor unit 23 and passes through the check-valve 33 so as to flow into the outdoor expansion apparatus 30 while being maintained at high pressure.

[0196] Under the above-mentioned conditions a load determination is carried out (STEP 2). In the case that the absolute value of the difference between the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 to the two-way valves 21, 51 and 52. As a result, the two-way valves 21, 51 and 52 are closed. Accordingly, all the refrigerant which comes out of the check-valve 33 are reduced in pressure in the outdoor expansion apparatus 30 so as to be put under low pressure and evaporates in the outdoor heat exchanger 13 and, after that, passes through the four-way valve 12 so as to be absorbed again into the compressor 11.

[0197] Since the two-way valves 21, 51 and 52 are closed under the above-mentioned conditions, there is little reservoir of the refrigerant in the cooling unit 19, the reservoir unit 20 and the rectifying separator 18.

[0198] As described above, by maintaining the closed condition of the two-way valves 21, 51 and 52, the refrigerant flowing through the main circuit remains the conditions wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, under the above-mentioned condition, the heat pump apparatus of Embodiment 5 can carry out the high performance operation appropriate for the load.

[0199] In STEP 2, a load determination is carried out and in the case that the absolute value of the difference of the set air temperature "to" stored in the memory apparatus 25 and the temperature "t" of the intake

air of the indoor unit 23 detected by the indoor thermal sensor 24 is the predetermined value " Δt " ($|t - t_o| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 so that the two-way valves 21, 51 and 52 are opened (STEP 3).

[0200] The sub-expansion apparatus 34 and the sub-expansion apparatus 50 are set so as to reduce the refrigerant in pressure to semi-high pressure so that the refrigerant of semi-high pressure flows into the rectifying separator 18. The rectifying separation operation is carried out under this pressure in the rectifying separator 18.

[0201] Part of the high pressure refrigerant which comes out of the check-valve 33 passes through the two-way valve 21 and the sub-expansion apparatus 34 so as to be put under semi-high pressure which is slightly lower than high pressure, and flows into the bottom of the rectifying separator 18. In addition, part of the discharged gas of the compressor 11 converts to be in semi-high pressure in the sub-expansion apparatus 50 and, then, passes through the two-way valve 51 so as to flow into the bottom of the rectifying separator 18 and to merge together with the refrigerant which has come out of the sub-expansion apparatus 34. Part of the refrigerant which has flown into the bottom of the rectifying separator 18 passes through the sub-expansion apparatus 22 and is reduced in pressure so as to become a two-phase refrigerant of low temperature and then flows into the cooling unit 19. In this cooling unit 19, the above refrigerant exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 18.

[0202] In the heat pump apparatus of Embodiment 5, the configuration allows the discharged gas from the compressor 11 to directly flow into the rectifying separator 18, and therefore, the amount of gas which moves upward increases so as to create an excellent gas-liquid contact for promoting the rectifying effect. In addition, the pressure within the rectifying separator 18 is semi-high pressure and a two phase refrigerant of low temperature and low pressure, of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 19, and therefore, the difference between the temperature of the top part of the rectifying separator 18 and the temperature of the cooling heat source of the cooling unit 19 can be made large. Thereby in the heat pump apparatus of Embodiment 5, not only can the cooling unit 19 be configured compactly but, also, the gas in the top part of the rectifying separator 18 can, without fail, be liquefied and the rectifying separation is promoted so that the refrigerant which contains a significantly large amount of low boiling point refrigerant components is collected in the reservoir unit 20. As a result, since the refrigerant which flows through the main circuit contains a significantly large amount of high boiling point refrigerant components, performance can be controlled in response to the load. In addition, since low boiling point refrigerant is collected in the reservoir unit

20 the amount of the refrigerant flowing through the main circuit decreases and, thereby, performance can be further reduced due to the reduction of the refrigerant amount and the operation with low performance appropriate for the load becomes possible.

[0203] Time determination whether or not a preset time T_a has passed is carried out after the two-way valves 21, 51 and 52 are opened in STEP 3 (STEP 4). In this STEP 4, in the case a predetermined time T_a has passed a closing signal of the two-way valves 21, 51 and 52 is sent from the operation control apparatus 26 so as to close the two-way valves 21, 51 and 52 (STEP 5).

[0204] In this way, by converting the two-way valves 21, 51 and 52 to the closed condition, the rectifying separator 18, the cooling unit 19 and the reservoir unit 20 can be detached from the main circuit, and therefore, the circuit which makes the refrigerant flow to the low pressure side can be blocked. Therefore, the heat pump apparatus of Embodiment 5 can eliminate the loss of the heat amount required for the rectifying separation and can carry out performance control in response to the load as well as a highly efficient operation.

[0205] Under the above-mentioned conditions, load determination is carried out (STEP 6). In the case that the heating load becomes large in this STEP 6, that is to say, in the case that the absolute value of the difference between the set air temperature " t_o " stored in the memory apparatus 25 and the temperature " t " of the intake air of the indoor unit 23 detected by the indoor thermal sensor 24 exceeds the predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valves 21 and 51 and an opening signal of the two-way valve 52 are sent from the operation control apparatus 25. As a result, the two-way valves 21 and 51 are closed while the two-way valve 52 is opened (STEP 7). The refrigerant which has been collected in the reservoir unit 20 is gradually absorbed into the compressor 11 of the main circuit and, the refrigerant components in the main circuit return to the condition of the filled in components of high performance. In addition the amount of refrigerant increases so that the high performance operation becomes possible in response to the load.

[0206] In this manner, by detecting the absolute value of the difference between the set air temperature " t_o " and the temperature " t " of the intake air of the indoor unit 23, the two-way valves 21, 51 and 52 are merely controlled in simultaneous opening and closing so as to enable the adjustment of the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load. The heat pump apparatus of Embodiment 5 can be set at semi-high pressure in the pressure of the rectifying separator 18, and therefore, the range of variation of the refrigerant components can be made wider so that it becomes possible to carry out performance control in response to the load, which changes greatly.

[0207] Here, in the heat pump apparatus of Embod-

iment 5, in regard to the time when the two-way valves 21, 51 and 52 are all converted to the closed condition so that a closed circuit comprising the rectifying separator 18, the cooling unit 19 and the reservoir unit 20 is detached from the main circuit, the configuration allows the detachment to be carried out when the refrigerant components in the main circuit or the reservoir unit 20 are detected to have become predetermined components.

[0208] Here, in the heat pump apparatus of Embodiment 5, though the description is based on the system configuration shown in the above-mentioned Embodiment 4, it is obvious that the same effects can be gained in the case that the two-way valves 52, as described in Embodiment 5, are provided in any of the system configurations of Embodiments 1, 2 and 3, of which the description is, therefore, omitted.

[0209] In addition, though the compressor is not described in detail in the heat pump apparatus of Embodiments 1, 2, 3, 4 and 5, not only a constant speed compressor but a slightly variable compressor or one having a performance control means such as a cylinder bypass or a variable speed compressor with an inverter can be employed as a compressor and in the case when these are used the same effects as in each of the above-mentioned embodiments can be gained.

[0210] Moreover, as for the two-way valves in each of the above-mentioned embodiments, an electronic-type expansion valve or a manual valve which can block the refrigerant flow can be considered and the cases wherein these are used are also included in the heat pump apparatus of the present invention.

[0211] Additionally, in the heat pump apparatus of the present invention R407C, which is a substitute refrigerant for R22 and which is a mixture of three types of single refrigerants R32, R125 and R134a, can be used as the sealed non-azeotropic refrigerant and, thereby, the difference of boiling points of refrigerants R32 and R125, of which the boiling points are low, and a refrigerant R134a, of which the boiling point is high, can be made large so that not only is the rectifying separation performance advantageous but, also, the ratio of lowering of the performance level can be made large and the most suitable performance control becomes possible for a large load variation.

《Embodiment 6》

[0212] Next, a heat pump apparatus of Embodiment 6 in accordance with the present invention is described with reference to FIGS. 11 and 12.

[0213] FIG. 11 is a system configuration view of the heat pump apparatus of Embodiment 6. FIG. 12 is a control flow chart of the heat pump apparatus of Embodiment 6.

[0214] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 6 which forms the main circuit of a refrigeration cycle by connecting,

through pipes, a compressor 61, a four-way valve 62, an outdoor heat exchanger 63, the main expansion apparatus 64 and an indoor heat exchanger 65 in an annular structure.

[0215] As shown in FIG. 11, the heat pump apparatus of Embodiment 6 is provided with a pipe which branches from the main circuit, in the middle of the pipe, in the outdoor heat exchanger 63 which forms the main circuit as shown in FIG. 11. The branched pipe is connected to the rectifying separator 70 via the check-valve 66 and the two-way valve 67. The check-valve 66 and the two-way valve 67 are connected in series along the branched pipe. Here, the check-valve 66 is configured so as to have a flow only in the direction from the outdoor heat exchanger 63 to the two-way valve 67.

[0216] The pipe of the main circuit which makes a connection between the main expansion apparatus 64 and the indoor heat exchanger 65 has a branch of pipe connected to the rectifying separator 70. Along this branched pipe the sub-expansion apparatus 68 and the check-valve 69 are connected in series. As shown in FIG. 11, one end of the check-valve 69 is connected to the sub-expansion apparatus 68 and the other end is connected to the pipe between the check-valve 66 and the two-way valve 67. Here, the check-valve 69 has a configuration which allows the flow only in the direction from the sub-expansion apparatus 68 to the two-way valve 67.

[0217] The rectifying separator 70 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The bottom of the rectifying separator 70 is connected to the two-way valve 67. The top part of the rectifying separator 70 is communicated to the top of a reservoir unit 72 via a cooling unit 71, and the bottom of the reservoir unit 72 is communicated to the top part of the rectifying separator 70. Accordingly, the top part of the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 are connected in an annular structure so as to form a closed circuit.

[0218] The reservoir unit 72 is arranged so that the top part thereof is located higher than the top part of the rectifying separator 70. In addition, the cooling unit 71 is arranged so as to be located higher than the top part of the reservoir unit 72.

[0219] The pipe connecting the top part of the rectifying separator 70 and the cooling unit 71 is connected to the surface of the ceiling of the top part of the rectifying separator 70. The pipe connecting the bottom of the reservoir unit 72 with the top part of the rectifying separator 70 is connected to the side of the top part of the rectifying separator 70. The pipe leading out from the bottom of the rectifying separator 70 is connected to an intake pipe of the compressor 61 via the sub-expansion apparatus 73 and the cooling unit 71. The intake pipe to the compressor 61 is a pipe which makes a connection between the compressor 61 and the four-way valve 62.

[0220] The cooling unit 71 is formed so that the

refrigerant moving toward the intake pipe of the compressor 61 from the bottom of the rectifying separator 70 through the sub-expansion apparatus 73 and the refrigerant in the top part of the rectifying separator 70 exchanges heat indirectly. A double piping structure can be adopted for the cooling unit 71 in Embodiment 6.

[0221] An indoor unit 74 of the main circuit is formed of the indoor heat exchanger 65, an indoor thermal sensor 75 or the like. The indoor thermal sensor 75 detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 74). The operation control apparatus 77, to which a signal indicating a measured temperature detected by the indoor thermal sensor 75 is inputted, compares the set air temperature which is stored in the memory apparatus 76 with the air temperature detected by the indoor thermal sensor 75 so as to determine the scale of the difference between the air temperature and the set air temperature, and carries out the opening and closing operation of the two-way valve 67. The memory apparatus 76 stores a set air temperature value which the user pre-sets as a desirable value.

[0222] Next, the operation of the heat pump apparatus of Embodiment 6 formed as in the above is described with reference to FIG. 12.

[0223] FIG. 12 is a control flow chart of the heat pump apparatus of Embodiment 6.

[0224] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 61, the two-way valve 67 is closed (STEP 1). Under these conditions the high temperature refrigerant which has been discharged from the compressor 61 flows into the four-way valve 62 and the outdoor heat exchanger 63 so as to release heat into the outside air and condenses itself to be liquefied. Then the condensed and liquefied refrigerant flows into the main expansion apparatus 64. In the main expansion apparatus 64 the refrigerant is reduced in pressure to low pressure and flows into the indoor heat exchanger 65. In the indoor heat exchanger 65 the refrigerant absorbs heat from the air of the room provided in the indoor unit 74 and evaporates spontaneously into vapor. Refrigerant which has evaporated into vapor passes again through the four-way valve 62 and returns to the compressor 61.

[0225] Under the above-mentioned condition, a load determination is carried out (STEP 2). In the case that the difference between the intake air temperature "t" of the indoor unit 74 detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 76 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result, the two-way valve 67 maintains the closed condition.

[0226] Accordingly, a circuit from a pipe branched from the outdoor heat exchanger 63 to the check-valve

66 does not allow the refrigerant to flow into the rectifying separator 70 since the two-way valve 67 is in the closed condition. Moreover, the provided check-valve 69 prevents the refrigerant from flowing from the check-valve 66 to the sub-expansion apparatus 68.

[0227] The two-way valve 67 is closed and the rectifying separator 70 is connected to the intake pipe of the compressor 61 via the sub-expansion apparatus 73 and the cooling unit 71, and therefore, the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 are in the low pressure condition of the refrigeration cycle. Accordingly, only the overheat gas is collected in the rectifying separator 70, the cooling unit 71 and the reservoir unit 72, and therefore, there remains only a small amount of reservoir refrigerant.

[0228] By maintaining the closed condition of the two-way valve 67 as described above, the refrigerant flowing through the main circuit remains the conditions as the filled in components have been mixed and the operation is exercised under the condition with a large amount of refrigerant in the main circuit. As a result of this, the heat pump apparatus of Embodiment 6 operates with high performance appropriate to the load.

[0229] A load determination is carried out in STEP 2, and in the case that the difference between the temperature "t" of the intake air of the indoor unit 74 which is detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 76 is a predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result of this, the two-way valve 67 is opened (STEP 3).

[0230] In Embodiment 6, the two-phase refrigerant which is in the process of being condensed and liquefied in the outdoor heat exchanger 63 flows into the bottom of the rectifying separator 70 via the check-valve 66 and the two-way valve 67. Part of the refrigerant which has flown into the rectifying separator 70 is reduced in pressure in the sub-expansion apparatus 73. This refrigerant which has been reduced in pressure becomes a two-phase refrigerant of low temperature and flows into the cooling unit 71 and, then, there indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 70.

[0231] In Embodiment 6 a two-phase refrigerant of low temperature and low pressure is utilized as a cooling source of the cooling unit 71, and therefore, the latent heat of the refrigerant can be effectively utilized so that not only the cooling unit 71 can be made compact but also the gas in the top part of the rectifying separator 70 can be liquefied without fail.

[0232] In addition, the refrigerant which has flown in from the bottom of the rectifying separator 70 is cooled in the cooling unit 71 to be liquefied and is collected gradually in the reservoir unit 72. The refrigerant of the reservoir unit 72 gradually increases in reservoir

amount and returns to the top part of the rectifying separator 70 so as to move downward into the rectifying separator 70. In the case that these conditions occur sequentially, the refrigerant gas moving upward into the rectifying separator 70 and the refrigerant liquid moving downward create a contact between the gas and the liquid within the rectifying separator 70. The contact between the gas and liquid allows the rectifying effects to occur and the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 72. Accordingly, the refrigerant which moves downward into the rectifying separator 70 and which passes through the sub-expansion apparatus 73 gradually increases in high boiling point refrigerant components and is absorbed by the compressor 61 via the cooling unit 71.

[0233] As described above, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase so that the heat pump apparatus of Embodiment 6 can lower the performance level. In addition, since the low boiling point refrigerant is collected in the reservoir unit 72 the amount of refrigerant in the main circuit is reduced and lowering of the performance level can be further achieved because of the decrease of the refrigerant amount so that the operation of lowered performance level, which is appropriate for the load, becomes possible.

[0234] In Embodiment 6, the pressure of the rectifying separator 70 is semi-high pressure and the cooling source of the cooling unit 71 utilizes a two-phase refrigerant of low temperature and low pressure, and therefore, the difference between the temperature of the top part of the rectifying separator 70 and the temperature of the cooling heat source of the cooling unit 71 can be made large. Therefore, the heat pump apparatus of Embodiment 6 can make the separation gap in the rectifying separator 70 large enough.

[0235] Here, in the above-mentioned condition, the heat pump apparatus of Embodiment 6 can make the two-phase refrigerant, which is in the process of being condensed, flow into the bottom of the rectifying separator 70, and therefore, can secure a sufficient amount of gas generation so as to be able to shorten the time necessary for the separation. In addition, the heat pump apparatus of Embodiment 6 can make the saturated gas flow in, and therefore, the liquefaction of the gas is made easy in comparison to the case where the over-heated gas, such as discharged gas, is introduced and the separation performance can be further increased.

[0236] Here, even in the case that the two-way valve 67 is in the opened condition as described above, the refrigerant will not flow in the direction from the rectifying separator 70 to the sub-expansion apparatus 68 due to the functioning of the check-valve 69.

[0237] In the above-mentioned condition, the load determination is carried out (STEP 4). In the case that the load becomes large and the difference between the

intake air temperature "t" of the indoor unit 74 which is detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 76 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$) a closing signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result of this the two-way valve 67 is again closed (STEP 5) so that the refrigerant which has been collected in the reservoir unit 72 passes through the sub-expansion apparatus 73 and the cooling unit 71 so as to be gradually absorbed by the compressor 71. Accordingly, the refrigerant components of the main circuit revert to the condition of filler components of high performance and the refrigerant amount in the main circuit increases so as to restart the operation of high performance in response to the load.

[0238] As described above in Embodiment 6, the difference between the temperature "t" of the intake air of the indoor unit 74 and the set air temperature "to" is detected and the amount of refrigerant and the refrigerant components in the main circuit are controlled to achieve an appropriate condition in response to the load by carrying out a simple operation of opening and closing the two-way valve 67. In this way, by controlling the refrigerant components, the heat pump apparatus of Embodiment 6 can carry out performance control in response to the load.

[0239] Next, the operation at the time of heating is described.

[0240] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0241] In the case that a high heating performance is required, such as immediately after the start-up of the compressor 61, the two-way valve 67 is closed (STEP 1). In this way, under the condition that the two-way valve 67 is closed, high temperature refrigerant which has been discharged from the compressor 61 flows into the four-way valve 62 and the indoor heat exchanger 65 so as to be condensed and liquefied. The refrigerant which has been condensed and liquefied branches into a circuit which flows into the main expansion apparatus 64 and a circuit which flows into the sub-expansion apparatus 68.

[0242] The refrigerant which has flown into the sub-expansion apparatus 68 is slightly reduced in pressure so as to be put under semi-high pressure, which is slightly lower than high pressure of the refrigeration cycle main circuit. The refrigerant which has come out of this sub-expansion apparatus 68 is in the two-phase condition of a mixture between the gas and the liquid. In addition, the configuration is such that the check-valve 69 creates the flow only in the direction from the sub-expansion apparatus 68 to the two-way valve 67 and the sub-expansion apparatus 68 is connected to the bottom of the rectifying separator 70 via the two-way valve 67.

Accordingly, the opening and closing operation of the two-way valve 67 allows the refrigerant to flow into the rectifying separator 70. Here, the check-valve 66 which is connected to the exit side of the check-valve 69 is in the backward direction, and therefore, no refrigerant passes through this check-valve 66.

[0243] Under the above-mentioned conditions a load determination is carried out (STEP 2), and then, in the case that the difference between the set air temperature "to" of the indoor unit 74, which is stored in the memory apparatus 76, and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result of this the two-way valve 67 maintains the closed condition. Accordingly, the refrigerant which has come out of the indoor heat exchanger 65 passes through the main expansion apparatus 64 and is forced to be put under low pressure so as to evaporate in the outdoor heat exchanger 63. After that, the refrigerant passes through the four-way valve 62 and is again absorbed into the compressor 61.

[0244] The two-way valve 67 is under the closed condition and the cooling unit 71 is connected to the intake pipe of the compressor 61, and therefore, the inside of the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 become filled with low pressure gas so that there is little reservoir of refrigerant.

[0245] As described above, by maintaining the closed condition of the two-way valve 67, the refrigerant flowing through the main circuit remains the conditions wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant so as to be a high performance operation appropriate for the load.

[0246] In STEP 2, a load determination is carried out and in the case that the difference of the set air temperature "to" stored in the memory apparatus 75 and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 is the predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result of this, the two-way valve 67 is made to open (STEP 3) so that the two-phase refrigerant which has come out of the sub-expansion apparatus 68 passes through the two-way valve 67 and flows into the bottom of the rectifying separator 70. Then part of the refrigerant which has flown into the bottom of the rectifying separator 70 passes through the sub-expansion apparatus 73 and is reduced in pressure so as to become a two-phase refrigerant of low temperature and then flows into the cooling unit 71. In this cooling unit 71, the two phase refrigerant of low temperature exchanges heat indirectly with the gas phase refrigerant of the top part of the rec-

tifying separator 70.

[0247] In Embodiment 6 the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the cycle is utilized as the cooling source of the cooling unit 71, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 71 can be made compact but also the gas in the top part of the rectifying separator 70 can, without fail, be liquefied.

[0248] In this way, the refrigerant which has flown in from the bottom of the rectifying separator 70 is cooled and liquefied in the cooling unit 71 so as to be gradually collected in the reservoir unit 72. Then, the reservoir amount in the reservoir unit 72 gradually increases and the refrigerant which has returned to the top part of the rectifying separator 70 starts moving downward into the rectifying separator 70.

[0249] In the case that these conditions occur sequentially, the gas refrigerant which moves upward in the rectifying separator 70 and the liquid refrigerant which moves downward create a contact between the gas and the liquid in the rectifying separator 70 so as to cause the rectifying effects. As a result of this, the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 72. In addition, the refrigerant which moves downward into the rectifying separator 70 and passes through the sub-expansion apparatus 72 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 61 via the cooling unit 71.

[0250] In this way, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and therefore, the lowering of the performance level is made. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 72, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0251] In Embodiment 6, the pressure within the rectifying separator 70 is semi-high pressure and a two phase refrigerant of low temperature and low pressure, of which the enthalpy is the lowest in the cycle, is utilized as a cooling source of the cooling unit 71. Therefore, in the heat pump apparatus of Embodiment 6, the difference between the temperature of the top part of the rectifying separator 70 and the temperature of the cooling heat source of the cooling unit 71 can be made large so that the cooling unit 71 can be made compact. And in the heat pump apparatus of Embodiment 5, the gas in the top part of the rectifying separator 70 can, without fail, be liquefied.

[0252] Under the above-mentioned conditions, load determination is carried out (STEP 4), and in the case that the heating load becomes large, that is to say, in the case that the difference between the set air temperature

"to" stored in the memory apparatus 76 and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 exceeds the predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valve 67 is sent from the operation control apparatus 77 to the two-way valve 67. As a result of this, the two-way valve 67 is again closed (STEP 5) while the refrigerant which has been collected in the reservoir unit 72 is gradually absorbed into the compressor 61. Thereby the refrigerant components in the main circuit return to the condition of the filled in components of high performance, and the amount of refrigerant increases so that the high performance operation is carried out in response to the load.

[0253] In this manner, the magnitude of the load is detected by the difference between the set air temperature "to" and the temperature "t" of the intake air of the indoor unit 74 so that the two-way valve 67 is merely controlled in opening and closing so as to adjust the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load and, thereby, a performance control can be easily carried out, without fail, in either operational condition of cooling or heating.

[0254] Here, in the heat pump apparatus of the present invention, a configuration wherein a sub-expansion apparatus, or the like, is provided between the outdoor heat exchanger 63 and the check-valve 66 so as to control the flow amount of the refrigerant which flows through may be included in the present invention.

《Embodiment 7》

[0255] Next, a heat pump apparatus of Embodiment 7 in accordance with the present invention is described with reference to FIGS. 13 and 14. FIG. 13 is a system configuration view of the heat pump apparatus of Embodiment 7. FIG. 14 is a control flow chart of the heat pump apparatus of Embodiment 7. Here, in FIGS. 13 and 14 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 6 are referred to using the same numerals.

[0256] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 7 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 61, a four-way valve 62, an outdoor heat exchanger 63, the main expansion apparatus 64 and an indoor heat exchanger 65 in an annular structure.

[0257] As shown in FIG. 13, the heat pump apparatus of Embodiment 7 is provided with a pipe which branches from the main circuit, in the middle of the pipe, in the outdoor heat exchanger 63 which forms the main circuit as shown in FIG. 11. The branched pipe is connected to the rectifying separator 70 via the two-way valve 80.

[0258] The pipe of the main circuit which makes a

connection between the main expansion apparatus 64 and the indoor heat exchanger 65 has a branch of pipe connected to the rectifying separator 70. Along this branched pipe the sub-expansion apparatus 68 and the two-way valve 81 are connected in series.

[0259] The rectifying separator 70 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The top part of the rectifying separator 70 is communicated to the top of a reservoir unit 72 via a cooling unit 71, and the bottom of the reservoir unit 72 is communicated to the top part of the rectifying separator 70. Accordingly, the top part of the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 are connected in an annular structure so as to form a closed circuit.

[0260] The reservoir unit 72 is arranged so that the top part thereof is located higher than the top part of the rectifying separator 70. In addition, the cooling unit 71 is arranged so as to be located higher than the top part of the reservoir unit 72.

[0261] The pipe connecting the top part of the rectifying separator 70 and the cooling unit 71 is connected to the surface of the ceiling of the top part of the rectifying separator 70. The pipe connecting the bottom of the reservoir unit 72 with the top part of the rectifying separator 70 is connected to the side of the top part of the rectifying separator 70. The pipe leading out from the bottom of the rectifying separator 70 is connected to an intake pipe of the compressor 61 via the sub-expansion apparatus 73, the cooling unit 71 and the two-way valve 82. The intake pipe to the compressor 61 is a pipe which makes a connection between the compressor 61 and the four-way valve 62.

[0262] The cooling unit 71 is formed so that the refrigerant moving toward the intake pipe of the compressor 61 from the bottom of the rectifying separator 70 through the sub-expansion apparatus 73 and the gas phase refrigerant in the top part of the rectifying separator 70 exchanges heat indirectly. A double piping structure can be adopted for the cooling unit 71 in Embodiment 7.

[0263] An indoor unit 74 of the main circuit is formed of the indoor heat exchanger 65, an indoor thermal sensor 75 or the like. The indoor thermal sensor 75 detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 74). The operation control apparatus 84, to which a signal indicating a measured temperature detected by the indoor thermal sensor 75 is inputted, compares the set air temperature which is stored in the memory apparatus 83 with the air temperature detected by the indoor thermal sensor 75 so as to determine the scale of the difference between the air temperature and the set air temperature, and carries out the opening and closing operation of the two-way valves 80, 81 and 82. The memory apparatus 83 stores a set air temperature value which the user presets as a desirable value.

[0264] Next, the operation of the heat pump appara-

tus of Embodiment 7 formed as in the above is described with reference to FIG. 14.

[0265] FIG. 14 is a control flow chart of the heat pump apparatus of Embodiment 7.

[0266] First, the operation at the time of cooling is described.

[0267] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 61, the two-way valves 80 and 82 are closed while the two-way valve 81 is opened (STEP 1). Under these conditions the high temperature refrigerant which has been discharged from the compressor 61 flows into the four-way valve 62 and the outdoor heat exchanger 63 so as to be condensed and liquefied. The condensed and liquefied refrigerant releases heat to the outside air and flows into the main expansion apparatus 64. In the main expansion apparatus 64 the refrigerant is reduced in pressure to low pressure and flows into the indoor heat exchanger 65 in the indoor unit 74. The indoor heat exchanger 65 absorbs heat from the air of the installed room for cooling and the refrigerant evaporates spontaneously into vapor. Then the refrigerant passes again through the four-way valve 62 and returns to the compressor 61.

[0268] Under the above-mentioned condition, in the case that the difference between the intake air temperature "t" of the indoor unit 74 detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 83 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 80 and the opening and closing signal 82 as well as an opening signal of the two-way valve 81 are sent from the operation control apparatus 84 to the corresponding two-way valves, respectively. As a result of this, the two-way valve 80 and the two-way valve 82 are closed so that the two-way valve 81 maintains the opened condition.

[0269] Accordingly, in a circuit, which passes through the middle of the pipe in the outdoor heat exchanger 63 and through the two-way valve 80 and, since the two-way valve 80 is closed the refrigerant does not flow into the rectifying separator 70. In addition, in a circuit which passes from the rectifying separator 70 through the sub-expansion apparatus 73, the cooling unit 71 and the two-way valve 82, respectively, to the intake pipe of the compressor 61, since the two-way valve 82 is closed the refrigerant does not flow in the direction from the rectifying separator 70 through the sub-expansion apparatus 73 and the cooling unit 71 to the compressor 61.

[0270] On the other hand, since the two-way valve 81 is opened, the refrigerant within the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 flows out to the main circuit of the refrigeration cycle via the sub-expansion apparatus 68 connected to the low pressure side of the refrigeration cycle. Accordingly, the

refrigerant within the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 is, only, the overheated gas in the reservoir so that there is almost no reservoir of the refrigerant.

[0271] As described above, the two-way valve 80 and the two-way valve 82 are closed and the two-way valve 81 is in the open condition and, thereby, the refrigerant of the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the main circuit is operated in the condition wherein there is a large amount of refrigerant. As a result, the heat pump apparatus of Embodiment 7 operates with high performance appropriate to the load.

[0272] A load determination is carried out in STEP 2, and in the case that the difference between the temperature "t" of the intake air of the indoor unit 74 which is detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 83 is a predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valves 80 and 82 is sent from the operation control apparatus 84 so as to close the two-way valves 80 and 82. At the same time a closing signal of the two-way valve 81 is sent from the operation control apparatus 84 so as to close the two-way valve 81 (STEP 3).

[0273] In STEP 3, the two-phase refrigerant which is in the process of being condensed and liquefied in the outdoor heat exchanger 63 flows into the bottom of the rectifying separator 70 via the two-way valve 80. Then part of the refrigerant of the rectifying separator 70 passes through the sub-expansion apparatus 73 so as to be reduced in pressure, and becomes a two-phase refrigerant of low temperature so as to flow into the cooling unit 71. In the cooling unit 71, the two-phase refrigerant of low temperature indirectly exchanges heat with the gas phase refrigerant in the top part of the rectifying separator 70.

[0274] In Embodiment 7 the pressure within the rectifying separator 70 is semi-high pressure and, as for the cooling source of the cooling unit 71, two-phase refrigerant of low temperature and low pressure is utilized, and therefore, the difference between the temperature of the top part of the rectifying separator 70 and the temperature of the cooling heat source of the cooling unit 71 can be made large. Therefore, not only the cooling unit 71 can be made compact but also the gas in the top part of the rectifying separator 70 can be liquefied without fail in the heat pump apparatus of Embodiment 7.

[0275] In addition, the refrigerant which has flown in from the bottom of the rectifying separator 70 is cooled in the cooling unit 71 to be liquefied and is collected gradually in the reservoir unit 72. As a result, the refrigerant of the reservoir unit 72 gradually increases in reservoir amount and returns to the top part of the rectifying separator 70 so as to move downward into the rectifying separator 70. In the case that these conditions

occur sequentially, the refrigerant gas moving upward into the rectifying separator 70 and the refrigerant liquid moving downward create a contact between the gas and the liquid within the rectifying separator 70, which allows the rectifying effects to occur. As a result, the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 72. Then the refrigerant which moves downward into the rectifying separator 70 and which passes through the sub-expansion apparatus 73 gradually increases in high boiling point refrigerant components and is absorbed by the compressor 61 via the cooling unit 71.

[0276] As a result the refrigerant flowing through the main circuit gradually converts to the refrigerant containing an increasing amount of high boiling point refrigerant components so as to be able to control the performance in response to the load. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 72 the amount of the refrigerant in the main circuit decreases and the decrease of the refrigerant amount in the main circuit further reduces the performance so as to be able to carry out the operation of lower level performance appropriate to the load.

[0277] Here, in the above-mentioned condition, the heat pump apparatus of Embodiment 7 can make the two-phase refrigerant, which is in the process of being condensed, flow into the bottom of the rectifying separator 70, and therefore, can secure a sufficient amount of gas generation so as to be able to shorten the time necessary for the separation. In addition, the heat pump apparatus of Embodiment 7 can make the saturated gas flow into the rectifying separator 70, and therefore, the liquefaction of the gas is made easy in comparison to the case where the overheated gas, such as discharged gas, is introduced and the separation performance can also be increased.

[0278] Here, under the above-mentioned condition, the refrigerant which has passed through the two-way valve 80 will not flow in the direction of the sub-expansion apparatus 68 since the two-way valve 81 is closed.

[0279] In the above-mentioned condition, the load determination is carried out (STEP 4), and in the case that the load becomes large and the difference between the intake air temperature "t" of the indoor unit 74 which is detected by the indoor thermal sensor 75 and the set air temperature "to" stored in the memory apparatus 83 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valve 80 and the two-way valve 82 as well as an opening signal of the two-way valve 81 are sent from the operation control apparatus 84 to the corresponding two-way valves. As a result, the two-way valve 80 and the two-way valve 82 are again closed while the two-way valve 81 is again opened (STEP 5). Accordingly, the refrigerant collected in the reservoir unit 72 passes through the rectifying separator 70, the two-way valve 81 and the sub-expansion apparatus 68, and gradually flows out to the indoor heat exchanger 65

so that the refrigerant components in the main circuit revert to the condition of the filler components with high performance. In addition, the refrigerant amount in the main circuit increases so as to restart the operation with high performance in response to the load.

[0280] In Embodiment 7 as described above, since it is possible to make the liquid refrigerant collected in the reservoir unit 72 flow out into the indoor unit 65 of the main circuit, the latent heat held by the liquid refrigerant can be effectively utilized in the indoor unit 65 so that it becomes possible to immediately switch to the operation with high cooling performance in response to the increase of the load.

[0281] As described above in the heat pump apparatus of Embodiment 7, the difference between the temperature "t" of the intake air of the indoor unit 74 and the set air temperature "to" is detected and the amount of refrigerant and the refrigerant components in the main circuit are varied to achieve an appropriate condition in response to the load by carrying out a simple operation of opening and closing the two-way valves 80, 81 and 82 so as to enable the control of cooling performance.

[0282] Next, the operation at the time of heating is described.

[0283] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0284] In the case that, at the time of heating, a high heating performance is required, such as immediately after the start-up of the compressor 61, the two-way valves 80 and 82 are closed, while the two-way valve 81 is opened (STEP 1). Under these conditions, high temperature refrigerant which has been discharged from the compressor 61 flows into the four-way valve 62 and the indoor heat exchanger 65 so as to be condensed and liquefied. The refrigerant which has been condensed and liquefied heats the indoor space. The refrigerant which has come out of the indoor heat exchanger 65 branches into a circuit which flows into the main expansion apparatus 64 and a circuit which flows into the sub-expansion apparatus 68.

[0285] The refrigerant which has flown into the sub-expansion apparatus 68 is slightly reduced in pressure so as to be put under semi-high pressure, which is slightly lower than high pressure of the refrigeration cycle main circuit. Therefore, the refrigerant which has come out of this sub-expansion apparatus 68 is in the two-phase condition of a mixture between the gas and the liquid. In addition, since the sub-expansion apparatus 68 is connected to the bottom of the rectifying separator 70 via the two-way valve 81, the opening and closing operation of the two-way valve 81 can allow the refrigerant to be controlled in flowing into the rectifying separator 70. Moreover, the two-way valve 80 connected to the bottom of the rectifying separator 70 is connected to the pipe in the outdoor heat exchanger 63

so that the opening and closing operation of the two-way valve 80 allows the refrigerant to flow out.

[0286] In STEP 2 a load determination is carried out, and in the case that the difference between the set air temperature "to" of the indoor unit 74, which is stored in the memory apparatus 83, and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valves 81 and 82 as well as an opening signal of the two-way valve 80 are sent from the operation control apparatus 84 to the corresponding two-way valves. As a result, the two-way valves 81 and 82 are closed while the two-way valve 80 maintains the open condition. Accordingly, the refrigerant which has come out of the indoor heat exchanger 65 passes through the main expansion apparatus 64 and is forced to be put under low pressure so as to evaporate in the outdoor heat exchanger 63. After that, the refrigerant passes through the four-way valve 62 and is again absorbed into the compressor 61.

[0287] At this time, since the two-way valves 81 and 82 are closed while the two-way valve 80 is opened, the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 are connected to the outdoor heat exchanger 63 of low pressure. Accordingly, the inside of the rectifying separator 70, the cooling unit 71 and the reservoir unit 72 become filled with low pressure gas so that there is little reservoir of refrigerant.

[0288] As described above, by closing the two-way valves 81 and 82 and by opening the two-way valve 80, the refrigerant flowing through the main circuit remains the conditions wherein the filler components have been mixed, and the operation is carried out under the condition with a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 7 can carry out the operation with high performance appropriate to the load.

[0289] In STEP 2, a load determination is carried out and in the case that the difference of the set air temperature "to" stored in the memory apparatus 83 and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 is the predetermined value " Δt " or less, that is to say, in the case that the heating load is small, an opening signal of the two-way valves 81 and 82 as well as a closing signal of the two-way valve 80 are sent from the operation control apparatus 84 so that the two-way valves 81 and 82 are opened while the two-way valve 80 is closed (STEP 3). Therefore, the two-phase refrigerant which has been slightly pressurized in the sub-expansion apparatus 68 passes through the two-way valve 81 so as to flow into the bottom of the rectifying separator 70. Then, part of the refrigerant which has flown into the rectifying separator 70 is reduced in pressure in the sub-expansion apparatus 73 and converts to a two-phase refrigerant of low temperature so as to flow into the cooling unit 71. In this cooling unit 71, the two phase refrigerant of low

temperature exchanges heat indirectly with the gas phase refrigerant of the top part of the rectifying separator 70.

[0290] In the heat pump apparatus of Embodiment 7, the pressure within the rectifying separator 70 is semi-high pressure and a cooling source of the cooling unit 71 utilizes a two phase refrigerant of low temperature and low pressure, of which the enthalpy is the lowest in the cycle, and, therefore, the difference between the temperature of the top part of the rectifying separator 70 and the temperature of the cooling heat source of the cooling unit 71 can be made large. Thereby in the heat pump apparatus of Embodiment 7, not only can the cooling unit 71 be configured compactly but, also, the gas in the top part of the rectifying separator 70 can, without fail, be liquefied.

[0291] As described above, the refrigerant which has flown in from the bottom of the rectifying separator 70 is cooled and liquefied in the cooling unit 71 so as to be gradually collected in the reservoir unit 72. Then, the reservoir amount in the reservoir unit 72 gradually increases and the refrigerant which has returned to the top part of the rectifying separator 70 starts moving downward into the rectifying separator 70. In the case that these conditions occur sequentially, the refrigerant gas which moves upward in the rectifying separator 70 and the refrigerant liquid which moves downward create a contact between the gas and the liquid in the rectifying separator 70. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 72. Then the refrigerant which moves downward into the rectifying separator 70 and passes through the sub-expansion apparatus 73 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 61 via the cooling unit 71 and the two-way valve 82.

[0292] As described in the above, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and therefore, the lowering of the performance level can be made. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 72, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0293] The heat pump apparatus of Embodiment 7 has a configuration that allows the two-phase refrigerant in the process of condensing to flow into the bottom of the rectifying separator 70, and therefore, a sufficient amount of generated gas can be secured and the time required for the separation can be shortened. In addition, the heat pump apparatus of Embodiment 7 allows the saturated gas to flow into the rectifying separator 70

so as to facilitate the liquefaction of the gas in comparison to the case where the overheated gas, such as the discharged gas, is introduced and so as to enable the increase of the separation performance. Here, in the case that the saturated gas flows into the rectifying separator 70 as described above, the refrigerant will not flow in the direction of the outdoor heat exchanger 63 since the two-way valve 80 is closed.

[0294] Under the above-mentioned conditions, load determination is carried out (STEP 4), and in the case that the load becomes large, that is to say, in the case that the difference between the set air temperature "to" stored in the memory apparatus 83 and the temperature "t" of the intake air of the indoor unit 74 detected by the indoor thermal sensor 75 exceeds the predetermined value " Δt ", a closing signal of the two-way valves 81 and 82 as well as an opening signal of the two-way valve 80 are sent from the operation control apparatus 84 to the corresponding two-way valves. As a result, the two-way valves 81 and 82 are again closed while the two-way valve 80 is again opened (STEP 5). The refrigerant collected in the reservoir unit 72 flows into the pipe in the outdoor heat exchanger 63 and further passes through the four-way valve 62 so as to be absorbed into the compressor 61. As a result of this, the refrigerant components of the main circuit revert to the condition of filler components with high performance and the refrigerant amount of the main circuit increases, and therefore, the heat pump apparatus of Embodiment 7 allows an operation with high performance in response to the load.

[0295] Here, the heat pump apparatus of Embodiment 7 has a configuration which allows the liquid refrigerant collected in the reservoir unit 72 to flow out to the outdoor heat exchanger 63, and therefore, the latent heat held by the liquid refrigerant allows the outdoor heat exchanger 63 to sufficiently absorb heat from the outdoor air so as to be able to immediately switch to the operation with high heating performance in response to the increase in the load.

[0296] In this manner, the magnitude of the load is detected by the difference between the set air temperature and the temperature of the intake air of the indoor unit 74 so that the two-way valves 80, 81 and 82 are merely controlled in opening and closing so as to adjust the amount of refrigerant and the refrigerant component in the main circuit to the condition appropriate for the load and, thereby, a performance control can be carried out in either operational condition of cooling or heating.

[0297] Here, in the heat pump apparatus of Embodiment 7, it is also possible to control the flow amount of the refrigerant which flows through the circuit providing a flow amount control apparatus such as a sub-expansion apparatus between the outdoor heat exchanger 63 and the two-way valve 80 by means of the flow amount control apparatus and such a configuration is also included in the scope of the present invention.

[0298] In the heat pump apparatus of Embodiment 7, R407C, which is a substitute refrigerant for R22 and

which is a mixture of three types of single refrigerants R32, R125 and R134a, can be used as the sealed non-azeotropic refrigerant and, thereby, the difference of boiling points of refrigerants R32 and R125, of which the boiling points are low, and a refrigerant R134a, of which the boiling point is high, can be made large. By using such a refrigerant, not only is the rectifying separation performance advantageous but, also, the ratio of lowering of the performance level can be made large and the most suitable performance control becomes possible for a large load variation.

(Embodiment 8))

[0299] Next, a heat pump apparatus of Embodiment 8 in accordance with the present invention is described with reference to FIGS. 15 and 16. FIG. 15 is a system configuration view of the heat pump apparatus of Embodiment 8. FIG. 16 is a control flow chart of the heat pump apparatus of Embodiment 8.

[0300] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 8 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 111, a four-way valve 112, an outdoor heat exchanger 113, the outdoor main expansion apparatus 114, the indoor main expansion apparatus 115 and an indoor heat exchanger 116 in an annular structure.

[0301] The rectifying separator 117 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The top part of the rectifying separator 117 is communicated to the top of a reservoir unit 119 via a cooling unit 118, and the bottom of the reservoir unit 119 is communicated to the top part of the rectifying separator 117. Accordingly, the top part of the rectifying separator 117, the cooling unit 118 and the reservoir unit 119 are connected in an annular structure so as to form a closed circuit. In addition, the bottom of the reservoir unit 119 is connected to the pipe for liquid of the main circuit which links the outdoor main expansion apparatus 114 and the indoor main expansion apparatus 115 via the two-way valve 123.

[0302] The reservoir unit 119 is arranged so that the top part thereof is located higher than the top part of the rectifying separator 117. In addition, the cooling unit 118 is arranged so as to be located higher than the top part of the reservoir unit 119.

[0303] The pipe connecting the top part of the rectifying separator 117 and the cooling unit 118 is connected to the aperture of the surface of the ceiling of the top part of the rectifying separator 117. The pipe connecting the bottom of the reservoir unit 119 with the top part of the rectifying separator 117 is connected to the aperture formed on the side of the top part of the rectifying separator 117. The pipe leading out from the bottom of the rectifying separator 117 is connected to an intake pipe of the compressor 111 via the sub-expansion

apparatus 122 and the cooling unit 118. The intake pipe to the compressor 111 is a pipe which makes a connection between the compressor 111 and the four-way valve 112. In addition, the bottom of the rectifying separator 117 is connected to the discharge pipe of the compressor 111 via the sub-expansion apparatus 120 and the two-way valve 121. The discharge pipe of the compressor 111 is a pipe which makes a connection between the compressor 111 and the four-way valve 112.

[0304] The cooling unit 118 is formed so that the refrigerant moving toward the intake pipe of the compressor 111 from the bottom of the rectifying separator 117 through the sub-expansion apparatus 122 and the gas phase refrigerant in the top part of the rectifying separator 117 exchanges heat indirectly. A double piping structure can be adopted for the cooling unit 118 in Embodiment 8.

[0305] An indoor unit 124 of the main circuit has the indoor heat exchanger 116, an indoor main expansion apparatus 115, an indoor thermal sensor 125 and the like. The indoor thermal sensor 125 detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 124). The operation control apparatus 127, to which a signal indicating a measured temperature detected by the indoor thermal sensor 125 is inputted, compares the set air temperature which is stored in the memory apparatus 126 with the air temperature detected by the indoor thermal sensor 125 so as to determine the scale of the difference between the air temperature and the set air temperature, and carries out the opening and closing operation of the two-way valves 121 and 123. The memory apparatus 126 stores a set air temperature value which the user presets as a desirable value.

[0306] Next, the operation of the heat pump apparatus of Embodiment 8 formed as in the above is described with reference to FIG. 16.

[0307] FIG. 16 is a control flow chart of the heat pump apparatus of Embodiment 8.

[0308] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 111, the two-way valves 121 and 123 are closed (STEP 1). Under these conditions the refrigerant which is a high pressure gas discharged from the compressor 111 passes through the four-way valve 112 and flows into the outdoor heat exchanger 113 so as to be condensed to become a high pressure liquid refrigerant. The high pressure liquid refrigerant from the outdoor heat exchanger 113 is reduced in pressure to an intermediate pressure between the discharge pressure and the intake pressure in the outdoor main expansion apparatus 114 and is then further reduced in pressure to become a low pressure two-phase refrigerant, under the pressure in the vicinity of the intake pressure, in the indoor main expansion apparatus 115. After that, the refrigerant is evaporated by the indoor heat exchanger

116 so as to be absorbed to the compressor 111 via the four-way valve 112.

[0309] In the refrigeration cycle operation as described above the load determination is carried out (STEP 2). In the case that the difference between the intake air temperature "t" of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 126 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 121 and the opening and closing signal 123 is sent from the operation control apparatus 127. As a result of this, the two-way valve 121 and the two-way valve 123 maintain the closed condition (STEP 1). That is to say, the refrigerant discharged from the compressor 111 circulates only through the main circuit.

[0310] At this time, the two-way valve 121 and the two-way valve 123 are closed and the rectifying separator 117 is connected to the intake pipe of the compressor 111 via the sub-expansion apparatus 122, and therefore, the inside of the rectifying separator 117, the inside of the cooling unit 118 and the inside of the reservoir unit 119 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0311] As described above, by closing the two-way valve 121 and the two-way valve 123, the refrigerant of the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the operation with high performance appropriate to the load can be carried out in the condition wherein there is a large amount of refrigerant.

[0312] A load determination is carried out in STEP 2, and in the case that the difference between the temperature "t" of the intake air of the indoor unit 124 which is detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 126 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, a signal which closes the two-way valve 121 and which opens the two-way valve 123 is transmitted from the operation control apparatus 127. As a result of this, the two-way valve 121 is closed while the two-way valve 123 is opened (STEP 3). This condition is maintained for a specific period of time (T1) (STEP 4).

[0313] In this way, by controlling the opening and closing of the two-way valves 121 and 123 liquid of high density or two-phase refrigerant can be directly collected in the reservoir unit 119 in the heat pump apparatus of Embodiment 8 so that the main circuit can be operated under the condition of a small amount of refrigerant and the reduction of the cooling performance can be carried out in a short time.

[0314] After that, the two-way valve 121 is opened and a signal for closing the two-way valve 123 is transmitted from the operation control means 127 so that the two-way valve 121 is opened and the two-way valve 123 is closed (STEP 5). Thereby, part of the high pressure gas refrigerant is separated into the discharge pipe of

the compressor 111, which passes through the two-way valve 121 and is reduced in pressure by the sub-expansion apparatus 120. The gas refrigerant which is reduced in pressure by the sub-expansion apparatus 120 flows into the bottom of the rectifying separator 117 and moves upward into the rectifying separator 117.

[0315] Afterwards, the refrigerant which has moved upward into the rectifying separator 117 flows into the cooling unit 118 and is condensed and liquefied in the cooling unit 118. The liquid refrigerant which has come out of the cooling unit 118 is collected in the reservoir unit 119 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant in the top part of the rectifying separator moves downward into the rectifying separator 117 and flows into the sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 and flows into the intake pipe of the compressor 111 between the compressor 111 and the four-way valve 112. At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 122 and the gas refrigerant which has flown into the cooling unit 118 from the top part of the rectifying separator 117 indirectly exchange heat in the cooling unit 118.

[0316] As described above in the heat pump apparatus of Embodiment 8, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 118, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 118 can be made compact but also the gas in the top part of the rectifying separator 117 can, without fail, be liquefied.

[0317] In this way, the gas refrigerant which has flown in from the bottom of the rectifying separator 117 is cooled and liquefied in the cooling unit 118 so as to be collected in the reservoir unit 119. Then, the refrigerant again returns to the top part of the rectifying separator 117 and starts moving downward into the rectifying separator 117. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 117 and the liquid refrigerant which moves downward into the rectifying separator 117 create a contact between the gas and the liquid in the rectifying separator 117 so as to cause the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 119. On the other hand, the refrigerant which moves downward into the rectifying separator 117 and passes through the sub-expansion apparatus 122 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 111 via the cooling unit 118.

[0318] In this way, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase and, then, the lowering of the cooling performance level can be made. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 119, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0319] In the above-mentioned condition, the load determination is carried out (STEP 6). In the case that the cooling load becomes large and the difference between the intake air temperature "t" of the indoor unit 124 which is detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 126 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), an opening signal of the two-way valve 123 is transmitted from the operation control apparatus 127 so that the two-way valve 123 is again opened (STEP 7). The condition where the two-way valve 123 is opened is maintained for a specific period of time (T2) (STEP 8). Thereby, the refrigerant which has been collected in the reservoir unit 119 flows into the main circuit. After that, a closing signal of the two-way valve 121 and the two-way valve 123 is transmitted from the operation control apparatus 127 so that the two-way valve 121 and the two-way valve 123 are closed (STEP 1). Due to the closed condition of the two-way valves 121 and 123, the refrigerant amount of the main circuit increases in a short period of time so as to again contain filler components of high performance. As a result of this, the heat pump apparatus of Embodiment 8 can be restarted for the operation of high performance in response to the load.

[0320] As described above in the heat pump apparatus of Embodiment 8, the difference between the temperature of the intake air of the indoor unit 124 and the set air temperature is detected and the amount of refrigerant and the refrigerant components in the main circuit are varied to achieve an appropriate condition in response to the load by carrying out a simple operation of opening and closing the two-way valve 121 and the two-way valve 123 so as to enable the control of performance.

[0321] Here, in FIG. 16, the indoor temperature (measured value) is denoted as "t", a set temperature set by the user is denoted as "to", the difference (a predetermined value) between the indoor temperature set in advance and the set temperature is denoted as " Δt ", time from the start of the second condition (2) of the two-way valve operation is denoted as T, a set time 1 (maintained period of time of the second condition (2) of the two-way valve operation set in advance) is denoted as T1, and a set time 2 (maintained period of time of the fourth condition (4) of the two-way valve operation set in advance) is denoted as T2.

[0322] And the first condition (1) of the two-way

valve operation is the condition where the two-way valve 121 is closed and the two-way valve 123 is closed. The second condition (2) of the two-way valve operation is the condition where the two-way valve 121 is closed and the two-way valve 123 is opened. The third condition (3) of the two-way valve is the condition where the two-way valve 121 is opened and the two-way valve 123 is closed. The fourth condition (4) of the two-way valve operation is the condition where the two-way valve 123 is opened.

[0323] Next, the operation at the time of heating is described.

[0324] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0325] In the case that, at the time of heating, a high heating performance is required, such as immediately after the start-up of the compressor 111, the two-way valve 121 and the two-way valve 123 are closed (STEP 1). The high pressure gas refrigerant discharged from the compressor 111 in this condition passes through the four-way valve 112 and flows into the indoor heat exchanger 116 so as to be condensed to become a high pressure liquid refrigerant. The refrigerant which has come out of the indoor heat exchanger 116 is reduced in pressure to an intermediate pressure between the discharge pressure and the intake pressure in the main expansion apparatus 115 and, then, is sent to the indoor main expansion apparatus 114. In the indoor main expansion apparatus 114, the refrigerant is further reduced in pressure to a pressure in the vicinity of the intake pressure in the compressor 111 to become a low pressure two-phase refrigerant. The low pressure two-phase refrigerant which has been reduced in pressure is evaporated in the outdoor heat exchanger 113 and is, again, absorbed in the compressor 111 via the four-way valve 112.

[0326] In the refrigeration cycle as described above, a load determination is carried out (STEP 2), and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" which is stored in the memory apparatus 126 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valve 121 and the two-way valve 123 is transmitted from the operation control apparatus 127. As a result, the two-way valve 121 and the two-way valve 123 are closed and, then, that condition is maintained (STEP 1). That is to say, the refrigerant discharged from the compressor 111 circulates only through the main circuit.

[0327] Under the above-mentioned condition, the two-way valve 121 and the two-way valve 123 are closed and the sub-expansion apparatus 122 is connected to the intake pipe of the compressor 111, and

therefore, the inside of the rectifying separator 117, the inside of the cooling unit 118 and the inside of the reservoir unit 119 are filled with a low pressure gas and hold almost no reservoir of the refrigerant.

[0328] The operation is carried out as described above in Embodiment 8, the refrigerant in the main circuit remains the conditions as the filled in components have been mixed and the operation is exercised under the condition with a large amount of refrigerant in the main circuit. As a result of this, the heat pump apparatus of Embodiment 8 operates with high performance appropriate to the load.

[0329] Under the above-mentioned conditions, a load determination is carried out (STEP 2). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 126 is the predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), that is to say, in the case that the heating load is small, a signal which closes the two-way valve 121 and which opens the two-way valve 123 is transmitted from the operation control apparatus 127. As a result, the two-way valve 121 is closed while the two-way valve 123 is opened (STEP 3). The condition where the two-way valve 121 is closed in this way and the two-way valve 123 is opened is maintained for a specific period of time (T1) (STEP 4). By operating in this way, liquid refrigerant of high density or two-phase refrigerant can be collected directly in the reservoir unit 119 in Embodiment 8. Therefore, the heat pump apparatus of Embodiment 8 can be operated under the condition where the main circuit has a small amount of refrigerant and the reduction of the heating performance can be carried out in a short period of time.

[0330] After that, the operation control apparatus 127 transmits a signal, which opens the two-way valve 121 and which closes the two-way valve 123, to the corresponding two-way valves. The two-way valve 121 is opened and the two-way valve 123 is closed (STEP 5) and, thereby, part of the high pressure gas from the discharge pipe of the compressor 111 is separated so as to pass through the two-way valve 121 and to be sent to the sub-expansion apparatus 120. The gas refrigerant which has been reduced in pressure in the sub-expansion apparatus 120 flows into the bottom of the rectifying separator 117 so as to move upward into the rectifying separator 117.

[0331] After that, the refrigerant which has moved upward into the rectifying separator 117 flows into the cooling unit 118 and is condensed and liquefied in the cooling unit 118. This liquid refrigerant is collected in the reservoir unit 119 and, thereby, the liquid refrigerant which has been collected previously is returned to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117 and flows into the

sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 and flows into the intake pipe between the compressor 111 and the four-way valve 112. At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 122 and the gas refrigerant which has flown into the cooling unit 118 from the top part of the rectifying separator 117 indirectly exchange heat in the cooling unit 118.

[0332] In the heat pump apparatus of Embodiment 8, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 118, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 118 can be made compact but also the gas in the top part of the rectifying separator 117 can, without fail, be liquefied.

[0333] As described above, the refrigerant which has flown in from the bottom of the rectifying separator 117 is cooled and liquefied in the cooling unit 118 so as to be gradually collected in the reservoir unit 119. Then, the amount of reservoir in the reservoir unit 119 gradually increases so as to return to the top part of the rectifying separator 117. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 117 and the liquid refrigerant which moves downward into the rectifying separator 117 create a contact between the gas and the liquid in the rectifying separator 117. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 119. Then, the refrigerant which moves downward into the rectifying separator 117 and passes through the sub-expansion apparatus 122 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 111 via the cooling unit 118.

[0334] As described above, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase and, then, the lowering of the cooling performance level can be made. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 119, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0335] Under these conditions, the load determination is carried out (STEP 6). In the case that the heating

load becomes large and the difference between the intake air temperature "t" of the indoor unit 124 which is detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 126 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), an opening signal of the two-way valve 123 is transmitted from the operation control apparatus 127. As a result of this, the two-way valve 123 is, again, opened (STEP 7), and these conditions are maintained for a specific period of time (T2) (STEP 8). Thereby, the refrigerant which has been collected in the reservoir unit 119 flows into the main circuit. After that, the operation control apparatus 127 transmits a closing signal of the two-way valve 121 and the two-way valve 123 to the corresponding two-way valves. As a result of this, the two-way valve 121 and the two-way valve 123 are closed (STEP 1). Thereby, the refrigerant amount of the main circuit increases in a short period of time and the main circuit again contains the filler components of high performance. As a result of this, the heat pump apparatus of Embodiment 8 can restart the operation of high performance in response to the load.

[0336] In this manner, in the heat pump apparatus of Embodiment 8, the magnitude of the load is detected by the difference between the temperature of the intake air of the indoor unit 124 and the set air temperature so that the two-way valve 121 and the two-way valve 123 are simply controlled in opening and closing so as to vary the amount of refrigerant and the refrigerant component in the main circuit in response to the condition appropriate for the load. Thereby, the heat pump apparatus of Embodiment 8 can carry out a proper performance control in response to the load condition.

《Embodiment 9》

[0337] Next, a heat pump apparatus of Embodiment 9 in accordance with the present invention is described with reference to FIGS. 17 and 18. FIG. 17 is a system configuration view of the heat pump apparatus of Embodiment 9. FIG. 18 is a control flow chart of the heat pump apparatus of Embodiment 9. In FIGS. 17 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 8 are referred to using the same numerals.

[0338] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 9 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 111, a four-way valve 112, an outdoor heat exchanger 113, an outdoor main expansion apparatus 128, an indoor main expansion apparatus 129 and an indoor heat exchanger 116 in an annular structure.

[0339] The rectifying separator 117 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The top part of the rectifying separator 117 is communicated to the top

of a reservoir unit 119 via a cooling unit 118, and the bottom of the reservoir unit 119 is communicated to the top part of the rectifying separator 117. Accordingly, the top part of the rectifying separator 117, the cooling unit 118 and the reservoir unit 119 are connected in an annular structure so as to form a closed circuit. In addition, the bottom of the reservoir unit 119 is connected to the pipe for liquid of the main circuit which links the outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 via the two-way valve 123.

[0340] In the heat pump apparatus of Embodiment 9, the outdoor main expansion apparatus 128 has a structure which enables complete closure and the indoor main expansion apparatus 129 also has a structure which enables complete closure. The outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 are formed so as to be controlled in opening and closing by the operation control apparatus 131 to which a memory apparatus 130 is connected.

[0341] The memory apparatus 130 stores a set air temperature value which the user presets as a desirable value. The operation control apparatus 131 determines the operational condition of the compressor 111 and the opening degree of the outdoor main expansion apparatuses 128 and 129. In addition, the operation control apparatus 131 compares the set air temperature which is stored in the memory apparatus 130 with the air temperature detected by the indoor thermal sensor 125 and carries out the opening and closing operation of the two-way valves 121 and 123 based on that comparison result. At this time the operation control apparatus 131 adjusts the opening degree of the indoor and outdoor main expansion apparatuses 128 and 129.

[0342] The heat pump apparatus of Embodiment 9 is formed as described above and other parts of the configuration are the same as that of the heat pump apparatus of the above-mentioned Embodiment 8.

[0343] Next, the operation of the heat pump apparatus of Embodiment 9 formed as in the above is described with reference to FIG. 18.

[0344] FIG. 18 is a control flow chart of the heat pump apparatus of Embodiment 9.

[0345] At the time of the cooling operation, in the case that a high cooling performance is required, such as immediately after start-up of the compressor 111, the two-way valves 121 and 123 are in the closed condition, and the refrigerant which is a high pressure gas discharged from the compressor 111 passes through the four-way valve 112 and flows into the outdoor heat exchanger 113 so as to be condensed to become a high pressure liquid refrigerant. This high pressure liquid refrigerant is reduced in pressure to an intermediate pressure between the discharge pressure and the intake pressure in the outdoor main expansion apparatus 128 and is then further reduced in pressure to become a low pressure two-phase refrigerant, under the pressure in the vicinity of the intake pressure, in the

indoor main expansion apparatus 129. After the reduction of pressure to the low pressure two-phase refrigerant, the refrigerant which has evaporated into the gas in the indoor heat exchanger 116 passes through the four-way valve 112 and is again absorbed into the compressor 111.

[0346] In the refrigeration cycle operation as described above the load determination is carried out (STEP 2), and in the case that the difference between the intake air temperature "t" of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 130 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 121 and the opening and closing signal 123 is transmitted from the operation control apparatus 131. As a result of this, the two-way valve 121 and the two-way valve 123 maintain the closed condition (STEP 1). That is to say, in the above refrigeration cycle, the refrigerant discharged from the compressor 111 circulates only through the main circuit.

[0347] Under the above-mentioned conditions, the two-way valve 121 and the two-way valve 123 are closed and the rectifying separator 117 is connected to the intake pipe of the compressor 111 via the sub-expansion apparatus 122 and the cooling unit 118, and therefore, the inside of the rectifying separator 117, the inside of the cooling unit 118 and the inside of the reservoir unit 119 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0348] As described above, by closing the two-way valve 121 and the two-way valve 123, the refrigerant in the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the operation is carried out in the condition wherein there is a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 9 can carry out the operation with high performance appropriate to the load.

[0349] Next, a load determination is carried out in STEP 2 (STEP 2). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 124 which is detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 130 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, a signal which closes the two-way valve 121 and which opens the two-way valve 123 is transmitted from the operation control apparatus 131. As a result of this, the two-way valve 121 is in the closed condition while the two-way valve 123 is in the open condition (STEP 3). This condition is maintained for a specific period of time (T1) (STEP 4). Through the operation in this manner, liquid of high density or two-phase refrigerant can be directly collected in the reservoir unit 119 so that the main circuit can be operated under the condition of a small amount of refrigerant. Accordingly the heat pump apparatus of Embodiment 9 can carry out the reduction of the cooling performance

in a short period of time.

[0350] After that, the two-way valve 121 is opened and a signal for closing the two-way valve 123 is transmitted from the operation control means 131. Since the two-way valve 121 is opened and the two-way valve 123 is closed (STEP 5), part of the high pressure gas refrigerant is separated into the discharge pipe of the compressor 111, and flows into the two-way valve 121. The refrigerant which has passed through the two-way valve 121 is reduced in pressure by the sub-expansion apparatus 120, and flows into the bottom of the rectifying separator 117 so as to move upward into the rectifying separator 117.

[0351] After that, the refrigerant which has moved upward into the rectifying separator 117 flows into the cooling unit 118. The refrigerant which has been condensed and liquefied in the cooling unit 118 is collected in the reservoir unit 119 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117 and flows into the sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 and flows into the intake pipe of the compressor 111 between the compressor 111 and the four-way valve 112.

[0352] In addition, under the condition where the two-way valve 121 is opened and the two-way valve 123 is closed, that is to say, during the process of rectifying separation, the operation control apparatus 131 detects the stoppage of the compressor 111 (STEP 6) and in the case that the main expansion apparatuses 128 and 129 are detected to not be in the state of complete closure (STEP 7), a signal which completely closes the outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 is transmitted from the operation control apparatus 131. As a result, the outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 follow the operation of the main expansion apparatus under the first condition (1) of complete closure (STEP 8). Thereby, the main circuit is separated into the high pressure side and the low pressure side. At this time, the refrigerant on the high pressure side passes through the two-way valve 121 and is sent from the compressor 111 to the sub-expansion apparatus 120. After that, the refrigerant which has moved upward into the rectifying separator 117 flows into the cooling unit 118 so as to be condensed and liquefied in the cooling unit 118. This liquid refrigerant is collected in the reservoir unit 119 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117 and flows into the

sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 until the pressure on the low pressure side and the pressure on the high pressure side are balanced and flows out into the intake pipe of the compressor 111 between the compressor 111 and the four-way valve 112. At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 122 and the gas refrigerant which has flown into the cooling unit 118 from the top part of the rectifying separator 117 indirectly exchange heat in the cooling unit 118.

[0353] Here the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 118, and therefore, the latent heat of the refrigerant can be utilized effectively so that the cooling unit 118 can be made compact. And in addition, the gas in the top part of the rectifying separator 117 can, without fail, be liquefied.

[0354] As described above, the gas refrigerant which has flown in from the bottom of the rectifying separator 117 is cooled and liquefied in the cooling unit 118 so as to be collected in the reservoir unit 119. Then, the refrigerant which has been collected in the reservoir unit 119 again returns to the top part of the rectifying separator 117 and starts moving downward into the rectifying separator 117. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 117 and the liquid refrigerant which moves downward into the rectifying separator 117 create a contact between the gas and the liquid in the rectifying separator 117. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 119. In addition, the refrigerant which moves downward into the rectifying separator 117 and passes through the sub-expansion apparatus 122 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 111 via the cooling unit 118.

[0355] As described above, since the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, the performance level is lowered. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 119, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out. In addition, in the heat pump apparatus of Embodiment 9, even in the case that the compressor 111 stops during the process of the rectifying separation, the process of the rectifying separation

can be maintained until the pressure within the refrigeration cycle is balanced.

[0356] In the above-mentioned condition, the load determination is carried out (STEP 9). In the case that the cooling load becomes large and the absolute value of the difference between the intake air temperature " t " of the indoor unit 124 which is detected by the indoor thermal sensor 125 and the set air temperature " t_o " stored in the memory apparatus 130 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), when the compressor 111 is operated (STEP 10), an opening signal of the two-way valve 123 is transmitted from the operation control apparatus 131. As a result of this, the two-way valve 123 again becomes in the opened condition (STEP 12). At this time, the operation control apparatus 131 determines the operating condition of the compressor (STEP 10) after the determination of the load (STEP 9). At this time, in the case that the stoppage of the compressor 111 is detected, the main expansion apparatuses 128 and 129 are set in the opening degree (STEP 11). In STEP 11, the operation of the main expansion apparatus follows the second condition (2) wherein the outdoor main expansion apparatus 128 is in the first set opening degree ① while the indoor main expansion apparatus 129 is in the second set opening degree ②. After that, the two-way valve 123 is opened in STEP 12.

[0357] Through the opening of the two-way valve 123, the refrigerant which has been collected in the reservoir unit 119 flows into the main circuit. Then, after a predetermined time has elapsed, a closing signal of the two-way valve 121 and the two-way valve 123 is transmitted from the operation control apparatus 131 so that the two-way valve 121 and the two-way valve 123 are closed. Thereby, the refrigerant amount of the main circuit increases in a short period of time so as to again contain filler components of high performance, and the operation of high performance can be restarted in response to the load.

[0358] As described above, in the heat pump apparatus of Embodiment 9, the load magnitude is detected through the difference between the temperature of the intake air of the indoor unit 124 and the set air temperature so as to control the opening and closing of the two-way valve 121 and the two-way valve 123. In this manner, the heat pump apparatus of Embodiment 9 varies the amount of refrigerant and the refrigerant components in the main circuit to achieve an appropriate condition in response to the load by carrying out a simple operation so as to enable the control of performance.

[0359] Here, in FIG. 18, the indoor temperature (measured value) is denoted as " t ", a set temperature set by the user is denoted as " t_o ", the difference (a predetermined value) between the indoor temperature set in advance and the set temperature is denoted as " Δt ", time from the start of the second condition (2) of the two-way valve operation is denoted as T , a set time 1 (maintained period of time of the second condition (2) of the two-way valve operation set in advance) is denoted

as T1, and a set time 2 (maintained period of time of the fourth condition (4) of the two-way valve operation set in advance) is denoted as T2.

[0360] And the first condition (1) of the two-way valve operation is the condition where the two-way valve 121 is closed and the two-way valve 123 is closed. The second condition (2) of the two-way valve operation is the condition where the two-way valve 121 is closed and the two-way valve 123 is opened. The third condition (3) of the two-way valve is the condition where the two-way valve 121 is opened and the two-way valve 123 is closed. The fourth condition (4) of the two-way valve operation is the condition where the two-way valve 123 is opened. The first condition (1) of the operation of the main expansion apparatus means that the outdoor main expansion apparatus 128 is in the complete closure condition while the indoor main expansion apparatus 129 is in the complete closure condition. The second condition (2) of the operation of the main expansion apparatus means that the outdoor main expansion apparatus 128 is in the first set opening degree ① while the indoor main expansion apparatus 129 is in the second set opening degree ②.

[0361] Next, the operation at the time of heating is described.

[0362] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0363] In the case that, at the time of heating, a high heating performance is required, such as immediately after the start-up of the compressor 111, the two-way valve 121 and the two-way valve 123 are closed. The high pressure gas refrigerant discharged from the compressor 111 in this condition passes through the four-way valve 112 and flows into the indoor heat exchanger 116. The refrigerant which has been condensed in the indoor heat exchanger 116 becomes a high pressure liquid refrigerant, and is sent to the indoor main expansion apparatus 129. The refrigerant, which has been reduced in pressure to an intermediate pressure between the discharge pressure and the intake pressure by the indoor main expansion apparatus 129, is further reduced in pressure to a low pressure two-phase refrigerant in the vicinity of the intake pressure in the outdoor main expansion apparatus 128. This low pressure two-phase refrigerant is evaporated in the outdoor heat exchanger 113 and is, again, absorbed in the, compressor 111 via the four-way valve 112.

[0364] In such a refrigeration cycle as described above, a load determination is carried out (STEP 1). In the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" which is stored in the memory apparatus 130 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the

heating load is large, a closing signal of the two-way valve 121 and the two-way valve 123 is transmitted from the operation control apparatus 131. Then, the two-way valve 121 and the two-way valve 123 are maintained in the closed condition (STEP 1). Therefore the refrigerant discharged from the compressor 111 circulates only through the main circuit.

[0365] At this time, the two-way valve 121 and the two-way valve 123 are closed and the rectifying separator 117 is connected to the intake pipe of the compressor 111 via the sub-expansion apparatus 122 and the cooling unit 118, and therefore, the inside of the rectifying separator 117, the inside of the cooling unit 118 and the inside of the reservoir unit 119 are filled with a low pressure gas and hold almost no reservoir of the refrigerant.

[0366] In this manner the two-way valve 121 and the two-way valve 123 are closed and, thereby, the operation is carried out in the heat pump apparatus of Embodiment 9 when the refrigerant in the main circuit remains the conditions as the filled in components have been mixed and the operation of high performance appropriate to the load can be carried out under the condition with a large amount of refrigerant.

[0367] Next a load determination is carried out (STEP 2), and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 124 detected by the indoor thermal sensor 125 and the set air temperature "to" stored in the memory apparatus 130 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the heating load is small, a signal which closes the two-way valve 121 and a signal which opens the two-way valve 123 are transmitted from the operation control apparatus 131. As a result, the two-way valve 121 is in the closed condition while the two-way valve 123 is in the open condition (STEP 3). These conditions are maintained for a specific period of time (T1) (STEP 4). Through the operation as described above in Embodiment 9, liquid refrigerant of high density or two-phase refrigerant can be collected directly in the reservoir unit 119 so that the operation can be carried out under the condition where the main circuit has a small amount of refrigerant and the reduction of the performance can be carried out in a short period of time.

[0368] After that, a signal which opens the two-way valve 121 and a signal which closes the two-way valve 123 are transmitted from the operation control apparatus 131 so that the two-way valve 121 is opened and the two-way valve 123 is closed (STEP 5). Thereby, part of the high pressure gas from the discharge pipe of the compressor 111 is separated so as to be sent to the two-way valve 121. The gas refrigerant which has passed through the two-way valve 121 is reduced in pressure in the sub-expansion apparatus 120. The gas refrigerant which has been reduced in pressure in the sub-expansion apparatus 120 flows into the bottom of the rectifying separator 117 so as to move upward into

the rectifying separator 117.

[0369] After that, the refrigerant flows into the cooling unit 118 and is condensed and liquefied in the cooling unit 118. The liquid refrigerant which has been condensed and liquefied is collected in the reservoir unit 119 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117 and flows into the sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 and flows into the intake pipe of the compressor 111 between the compressor 111 and the four-way valve 112.

[0370] As described above, under the condition where the two-way valve 121 is opened and the two-way valve 123 is closed, that is to say, under the condition of the process of the rectifying separation, in the case that the operation control apparatus detects the stoppage of the compressor 111 (STEP 6) and that the main expansion apparatuses 128 and 129 are not in complete closure (STEP 7) a signal which completely closes the outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 is transmitted from the operation control apparatus 131. As a result of this, the outdoor main expansion apparatus 128 and the indoor main expansion apparatus 129 attain the complete closure condition (STEP 8).

[0371] Thereby, the main circuit is separated into the high pressure side and the low pressure side. The refrigerant of the high pressure side passes through the two-way valve 121 and is reduced in pressure in the sub-expansion apparatus 120. This gas refrigerant which has been reduced in pressure flows into the bottom of the rectifying separator 117 and moves upward into the rectifying separator 117.

[0372] After that, the refrigerant which has moved upward into the rectifying separator 117 flows into the cooling unit 118 and is condensed and liquefied in the cooling unit 118. The liquid refrigerant which has been condensed and liquefied is collected in the reservoir unit 119 so that the liquid refrigerant which has been previously collected returns to the top part of the rectifying separator 117 from the bottom of the reservoir unit 119. The refrigerant which has returned to the rectifying separator 117 moves downward into the rectifying separator 117 and flows into the sub-expansion apparatus 122 from the bottom of the rectifying separator 117. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 122 passes through the cooling unit 118 until the pressure of the low pressure side and the pressure of the high pressure side are balanced and flows out to the intake pipe of the compressor 111 between the compressor 111 and the four-way valve 112. At this time, the two-phase refriger-

ant of low temperature which has been reduced in pressure by the sub-expansion apparatus 122 and the gas refrigerant which has flown into the cooling unit 118 from the top part of the rectifying separator 117 indirectly exchange heat in the cooling unit 118.

[0373] At the time of heat exchange in the above-mentioned cooling unit 118, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 118, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 118 can be made compact but also the gas in the top part of the rectifying separator 117 can, without fail, be liquefied.

[0374] As described above, the refrigerant which has flown in from the bottom of the rectifying separator 117 is cooled and liquefied in the cooling unit 118 so as to be collected in the reservoir unit 119. Thereby, the amount of reservoir in the reservoir unit 119 gradually increases so that the refrigerant returns to the top part of the rectifying separator 117 and moves downward into the rectifying separator 117. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 117 and the liquid refrigerant which moves downward into the rectifying separator 117 create a contact between the gas and the liquid in the rectifying separator 117. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 119. In addition, the refrigerant which moves downward into the rectifying separator 117 and passes through the sub-expansion apparatus 122 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 111 via the cooling unit 118.

[0375] As described above, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase in the heat pump apparatus of Embodiment 9 and the lowering of the cooling performance level can be made. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 119, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out. In addition, in the heat pump apparatus of Embodiment 9, even in the case that the compressor 111 stops during the process of rectifying separation the process of rectifying separation, can be maintained until the pressure within the cycle is balanced.

[0376] Under these conditions, the load determination is carried out (STEP 6), and in the case that the heating load becomes large and the difference between the intake air temperature "t" of the indoor unit 124 which is detected by the indoor thermal sensor 125 and

the set air temperature "to" stored in the memory apparatus 130 exceeds a predetermined value " Δt ", an opening signal of the two-way valve 123 is transmitted from the operation control apparatus 131. As a result of this, the two-way valve 123 is, again, in the open condition (STEP 12). At this time, after load determination (STEP 9), the operation condition of the compressor is determined (STEP 10). In STEP 10, in the case that the stoppage of the compressor 111 is detected, the opening degrees of the main expansion apparatuses 128 and 129 are set (STEP 11). After that, the two-way valve 123 is opened in STEP 12. Due to this opening of the two-way valve 123, the refrigerant which has been collected in the reservoir unit 119 flows into the main circuit. After a predetermined time has elapsed, a closing signal of the two-way valve 121 and the two-way valve 123 is transmitted from the operation control apparatus 131 so that the two-way valve 121 and the two-way valve 123 are closed. In this manner, by controlling the two-way valve 121 and the two-way valve 123 in opening and closing, the refrigerant amount of the main circuit increases in a short period of time and the main circuit again contains the filler components of high performance so that the operation with high performance in response to the load can be restarted.

[0377] As described above, in the heat pump apparatus of Embodiment 9, the magnitude of the load is detected by the difference between the temperature of the intake air of the indoor unit 124 and the set air temperature so that the two-way valve 121 and the two-way valve 123 are simply controlled in opening and closing so as to vary the amount of refrigerant and the refrigerant component in the main circuit in response to the condition appropriate for the load. In this manner, by varying the refrigerant amount and the refrigerant composition of the main circuit, the heat pump apparatus of Embodiment 9 can carry out a proper performance control in response to the load.

[0378] In addition, though the compressor is not described in detail in each of the above-mentioned Embodiments in accordance with the present Invention, not only a constant speed compressor but a slightly variable compressor, a compressor having a performance control means such as a cylinder bypass or a variable speed compressor with an inverter can be employed in each of the above-mentioned Embodiments.

[0379] Moreover, as for the two-way valves in each of the above-mentioned embodiments, an electronic-type expansion valve or a manual valve which can block the refrigerant flow can be considered and the cases wherein these are used are also included in the heat pump apparatus of the present invention.

[0380] In addition, in each of the above-mentioned Embodiments in accordance with the present invention, R407C, which is a substitute refrigerant for R22 and which is a mixture of three types of single refrigerants R32, R125 and R134a, can be used as the sealed non-azeotropic refrigerant and, thereby, the difference of

boiling points of refrigerants R32 and R125, of which the boiling points are low, and a refrigerant R134a, of which the boiling point is high, can be made large. Moreover, by using the above-mentioned refrigerant, not only is the rectifying separation performance advantageous but, also, the ratio of lowering of the performance level can be made large and the most suitable performance control becomes possible for a large load variation.

10 (Embodiment 10)

[0381] Next, a heat pump apparatus of Embodiment 10 in accordance with the present invention is described with reference to FIGS. 19 and 20. FIG. 19 is a system configuration view of the heat pump apparatus of Embodiment 10. FIG. 20 is a control flow chart of the heat pump apparatus of Embodiment 10.

[0382] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 10 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 211, a four-way valve 212, an outdoor heat exchanger 213, an outdoor main expansion apparatus 214, an indoor main expansion apparatus 215 and an indoor heat exchanger 216 in an annular structure.

[0383] The rectifying separator 217 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The top part of the rectifying separator 217 is communicated to the top of a reservoir unit 219 via a cooling unit 218, and the bottom of the reservoir unit 219 is communicated to the top part of the rectifying separator 217. Accordingly, the top part of the rectifying separator 217, the cooling unit 218 and the reservoir unit 219 are connected in an annular structure so as to form a closed circuit. In addition, the bottom of the reservoir unit 219 is connected to the pipe for liquid of the main circuit which links the outdoor main expansion apparatus 214 and the indoor main expansion apparatus 215 via the two-way valve 224.

[0384] In Embodiment 10 the cooling unit 218 is arranged in a position higher than the top part of the rectifying separator 217 and the top part of the reservoir unit 219.

[0385] In addition, the pipe which makes a connection between the top part of the rectifying separator 217 and the cooling unit 218 is connected to the ceiling of the top part of the rectifying separator 217. The pipe which makes a connection between the bottom of the reservoir unit 219 and the top part of the rectifying separator 217 is connected to the side of the top part of the rectifying separator 217.

[0386] In addition, the bottom of the rectifying separator 217 is connected to the discharge pipe of the compressor 211 via the sub-expansion apparatus 220 and the two-way valve 221. The discharge pipe of the compressor 211 is a pipe linking the discharge part of the compressor 211 and the four-way valve 212. Also, the

bottom of the rectifying separator 217 is connected to the intake pipe of the compressor 211 via the sub-expansion apparatus 222, the cooling unit 218 and the two-way valve 223. The intake pipe of the compressor 211 is a pipe linking the intake part of the compressor 211 and the four-way valve 212.

[0387] The cooling unit 218 is formed so that the refrigerant moving from the bottom of the rectifying separator 217 toward the two-way valve 223 via the sub-expansion apparatus 222 and the refrigerant in the top part of the rectifying separator 217 indirectly exchange heat. As for the cooling unit 218, it is possible to adopt a double pipe structure.

[0388] An indoor unit 225 connected to the main circuit has an indoor main expansion apparatus 215, the indoor heat exchanger 216, an indoor thermal sensor 226 and the like. The indoor thermal sensor 226 detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 225). In addition, an outdoor thermal sensor 227 is provided in the vicinity of the outdoor heat exchanger 213. This outdoor thermal sensor 227 is a thermal sensor which detects the outdoor air temperature and is provided in the air intake part of the outdoor heat exchanger 213.

[0389] In the heat pump apparatus of Embodiment 10 a memory apparatus 228 and an operation control apparatus 229 are provided and the memory apparatus 228 stores a set air temperature value which is preset at a desired value by the user. The operation control apparatus 229 is formed so as to determine the operation condition of the compressor 211. The operation control apparatus 229 carries out an operation based on the operation condition of the compressor 211, the set air temperature of the memory apparatus 228, the indoor air temperature detected by the indoor thermal sensor 226 and the outdoor air temperature detected by the outdoor thermal sensor 227 so as to carry out the opening and closing operation of the three two-way valves 221, 223 and 224.

[0390] Next, the operation of the heat pump apparatus of Embodiment 10 formed as in the above is described with reference to FIG. 20.

[0391] FIG. 20 is a control flow chart of the heat pump apparatus of Embodiment 10.

[0392] First, the operation at the time of cooling is described.

[0393] After starting up the cooling operation, the air conditioning load is estimated based on the outdoor temperature detected by the outdoor thermal sensor 227, the indoor temperature detected by the indoor thermal sensor 226 and the set temperature stored in the memory apparatus 228 (STEP 1). At this time, in the case that the estimated load Lo is larger than a preset load standard value Ls ($Lo \geq Ls$), the two-way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is opened (STEP 2). At this time, in the case that the liquid refrigerant is collected in the reservoir unit 219, the liquid refrigerant flows out to the main circuit so

that only gas refrigerant remains.

[0394] Under the first condition (1) of the operation of the two-way valves wherein the two-way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is open, the high pressure gas refrigerant discharged from the compressor 211 passes through the four-way valve 220 and flows into the outdoor heat exchanger 213 so as to be condensed to become a high pressure liquid refrigerant. Then, this high pressure liquid refrigerant is reduced in pressure to the intermediate pressure between the discharge pressure and the intake pressure of the compressor 211 in the outdoor main expansion apparatus 214 and is then further reduced in pressure to become low pressure two-phase refrigerant under the pressure in the vicinity of the intake pressure in the indoor main expansion apparatus 215. After that, the refrigerant evaporated in the indoor heat exchanger 216 is again absorbed into the compressor 211 via the four-way valve 212.

[0395] In the refrigeration cycle operation as described above the load determination is carried out (STEP 3), and in the case that the difference between the intake air temperature " t " of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature " to " stored in the memory apparatus 228 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, the conditions of STEP 2 are maintained. That is to say, the refrigerant discharged from the compressor 211 circulates only through the main circuit. At this time, the two-way valve 221 and the two-way valve 224 are closed while the two-way valve 223 is open and the rectifying separator 217 is connected to the intake pipe of the compressor 211 via the sub-expansion apparatus 222 and the cooling unit 218, and therefore, the inside of the rectifying separator 217, the inside of the cooling unit 218 and the inside of the reservoir unit 219 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0396] By providing a refrigeration cycle as described above, the refrigerant in the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the main circuit is operated in the condition wherein there is a large amount of refrigerant, and therefore, the heat pump apparatus of Embodiment 10 can carry out the operation with high performance appropriate to the load.

[0397] Next, a load determination is carried out in STEP 3. In STEP 3 in the case that the absolute value of the difference between the temperature " t " of the intake air of the indoor unit 225 which is detected by the indoor thermal sensor 226 and the set air temperature " to " stored in the memory apparatus 228 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, a signal which closes the two-way valve 221 and the two-way valve 223 and which opens the two-way valve 224 is transmitted from the operation control apparatus 229. As a

result of this, the two-way valve 221 and the two-way valve 223 are in the closed condition while the two-way valve 224 is in the open condition (STEP 4). This condition is referred to as the second condition (2) of the operation of the two-way valves. This condition is maintained for a specific period of time (T1) (STEP 5). Through the opening and closing operation of the two-way valves 221, 223 and 224 in this manner, liquid of high density or two-phase refrigerant can be directly collected in the reservoir unit 219 so that the main circuit can be operated under the condition of a small amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 10 can carry out the reduction of the cooling performance in a short period of time.

[0398] After that, a signal which opens the two-way valve 221 and the two-way valve 223 and which closes the two-way valve 224 is transmitted from the operation control apparatus 229 so that the two-way valve 221 and the two-way valve 223 are opened while the two-way valve 224 is closed. This condition is referred to as the third condition (3) of the operation of the two-way valves. As a result of this, part of the high pressure gas refrigerant is separated from the discharge pipe of the compressor 211, and passes through the two-way valve 221 so as to be reduced in pressure by the sub-expansion apparatus 220. The gas refrigerant which has reduced in pressure flows into the bottom of the rectifying separator 217 so as to move upward into the rectifying separator 217.

[0399] After that, the refrigerant which has moved upward into the rectifying separator 217 flows into the cooling unit 218. The liquid refrigerant which has been condensed and liquefied in the cooling unit 218 is collected in the reservoir unit 219 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 217 from the bottom of the reservoir unit 219. The refrigerant which has returned to the rectifying separator 217 moves downward into the rectifying separator 217 and flows into the sub-expansion apparatus 222 from the bottom of the rectifying separator 217. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 222 passes through the cooling unit 218 and the two-way valve 223 so as to flow into the intake pipe of the compressor 211 which creates a linkage between the compressor 211 and the four-way valve 212.

[0400] At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 222 and the gas refrigerant which has flown into the cooling unit 218 from the top part of the rectifying separator 217 indirectly exchange heat in the cooling unit 218.

[0401] At the time of heat exchange in the above-mentioned cooling unit 218, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 218, and therefore,

the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 218 can be made compact but also the gas in the top part of the rectifying separator 217 can, without fail, be liquefied.

[0402] As described above, the gas refrigerant which has flown in from the bottom of the rectifying separator 217 is cooled and liquefied in the cooling unit 218 so as to be collected in the reservoir unit 219. Then, the liquid refrigerant in the reservoir unit 219 returns to the top part of the rectifying separator 217 and moves downward into the rectifying separator 217. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 217 and the liquid refrigerant which moves downward into the rectifying separator 217 create a contact between the gas and the liquid in the rectifying separator 217. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 219. As a result of this, the refrigerant which moves downward into the rectifying separator 217 and passes through the sub-expansion apparatus 222 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 211 via the cooling unit 218.

[0403] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 219, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the further lowering of the performance level so that it becomes possible to carry out the operation of low performance appropriate for the load.

[0404] Moreover, under the above-mentioned conditions, the operation determination of the compressor 211 is carried out (STEP 7). In STEP 7, in the case that the compressor 211 is determined to be operating the condition of STEP 6 is maintained and the load determination is carried out (STEP 8). In STEP 8, in the case that the cooling load is determined to be small ($|t-t_o| < \Delta t$) the condition of STEP 6 is maintained.

[0405] On the other hand, in the case that the cooling load is determined to be large ($|t-t_o| \geq \Delta t$) in STEP 8, the process moves to STEP 9. In the case that the cooling load becomes larger and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "t_o" stored in the memory apparatus 228 becomes a predetermined value " Δt " or more ($|t-t_o| \geq \Delta t$), an opening signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 229. As a result, the two-way valve 221 and the two-way valve 224 again become in the open condition (STEP 9). This condition is the fourth condition (4) of the operation of the

two-way valves. These conditions are maintained for a specific time (T2) (STEP 10).

[0406] By opening the two-way valves 221 and 224 in this way, the refrigerant which has collected in the reservoir unit 219 flows out to the main circuit. After that, the closing signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 229 so that the two-way valve 221 and the two-way valve 224 are closed (STEP 2). The two-way valves 221 and 224 are controlled in this way to open and to close and, thereby, the amount of refrigerant in the main circuit increases in a short period of time and, at the same time, the main circuit again contains the filler components of high performance so that the heat pump apparatus of Embodiment 10 can restart the operation of high performance in response to the load.

[0407] On the other hand, in the case that the compressor 211 is determined to have stopped in STEP 7, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 229 so as to close the two-way valve 221, the two-way valve 223 and the two-way valve 224 (STEP 11). This condition is the fifth condition (5) of the operation of the two-way valves. After that, the operation determination of the compressor 211 is carried out (STEP 12). In the case that the compressor 211 is determined to have stopped in STEP 12, the condition of STEP 11 is maintained. On the other hand, in the case that the compressor 211 is determined to be operating, the operation of the two-way valves of STEP 6 is carried out so as to restart the operation of the rectifying separation.

[0408] By operating each of the two-way valves 221, 223 and 224 as described above, even in the case that the compressor 211 has stopped during the operation of the rectifying separation, the refrigerant which has collected in the reservoir unit 219 will not flow out to the main circuit. Thereby, even under the above-mentioned circumstances the refrigerant component ratio immediately before the compressor 211 has stopped is maintained so as to enable the restarting of the separation operation with that refrigerant component ratio, and therefore, the time required for completing the separation operation can be shortened in the heat pump apparatus of Embodiment 10.

[0409] On the other hand, in the load estimation immediately after the start-up (STEP 1), in the case that the estimated load L_o is determined to be smaller than the preset load standard value L_s ($L_o < L_s$), the load condition at the last time of operation stoppage is judged (STEP 13). In the case of the judgment that the operation has stopped under the condition of a large load ($L_h=1$) in STEP 13, the above-mentioned operation of STEP 2 is carried out and, after that, the separation operation of STEP 3, and the following, is carried out.

[0410] On the other hand, in the case of the judgment that the operation has stopped during the previous operation under the condition of a small load ($L_h=0$) in

STEP 13, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 229. As a result of this, the two-way valve 221, the two-way valve 223 and the two-way valve 224 become in the closed condition (STEP 14). This condition is the sixth condition (6) of the operation of the two-way valves. These conditions are maintained for a specific time (T3) (STEP 15).

[0411] After that, the load determination is carried out (STEP 16) and in the case that the load is still at a predetermined value or less ($|t-t_o| \leq \Delta t$), the condition of STEP 14 is maintained and the heat pump apparatus is operated. By implementing the above-mentioned process, under the condition that the refrigerant of low boiling point, which has been separated out at the previous operation, is maintained in the reservoir unit 219, the operation can be restarted in the condition of reduced performance appropriate to the load.

[0412] On the other hand, in the case that the load is determined to be larger than the predetermined value " Δt " ($|t-t_o| > \Delta t$) in STEP 16, the operation moves to the operation of the two-way valves of STEP 2 (first condition (1)) so as to discharge the refrigerant within the reservoir unit 219 into the main circuit. Therefore, mixed non-azeotropic refrigerant of the filler components instantly flows through the main circuit for the operation under the condition wherein there is a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 10 can instantly carry out the operation of high performance appropriate to the load.

[0413] In this way, the heat pump apparatus of Embodiment 10 can change the conditions of the refrigerant amount and the refrigerant components in the main circuit in response to the size of the load through a simple operation of opening and closing the two-way valve 221, the two-way valve 223 and the two-way valve 224 by detecting the difference between the temperature of the intake air of the indoor unit 225 and the set air temperature. Accordingly, the heat pump apparatus of Embodiment 10 can appropriately carry out performance control in response to the load condition.

[0414] Here, in FIG. 20, the indoor temperature (measured value) is denoted as " t ", a set temperature set by the user is denoted as " t_o ", the difference (a predetermined value) between the indoor temperature set in advance and the set temperature is denoted as " Δt ", the measured time is denoted as T , a set time 1 (maintained period of time of the second condition (2) of the two-way valve operation set in advance) is denoted as T_1 , a set time 2 (maintained period of time of the fourth condition (4) of the two-way valve operation set in advance) is denoted as T_2 , a set time 3 (maintenance time of the sixth condition (6)) of the preset operation of the two-way valves is denoted as T_3 , an estimated load standard value measured time is denoted as L_o , a set load standard value is denoted as L_s and a load determination value is denoted as L_h (large load=1 and small

load=0).

[0415] And the first condition (1) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is open and the two-way valve 224 is closed. The second condition (2) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is closed and the two-way valve 224 is open. The third condition (3) of the two-way valve is the condition where the two-way valve 221 is open, the two-way valve 223 is open, and the two-way valve 224 is closed. The fourth condition (4) of the two-way valve operation is the condition where the two-way valve 221 is open, the two-way valve 223 is closed and the two-way valve 224 is open. The fifth condition (5) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is closed and the two-way valve 224 is closed. The sixth condition (6) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is closed and the two-way valve 224 is closed.

[0416] Next, the operation at the time of heating is described.

[0417] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0418] After the start-up of the heating operation, the air conditioning load is estimated based on the outdoor temperature detected by the outdoor thermal sensor 227, the indoor temperature detected by the indoor thermal sensor 226 and the set temperature stored in the memory apparatus 228 (STEP 1).

[0419] In this STEP 1, in the case that the estimated load L_o is determined to be larger than the preset load standard value L_s ($L_o \geq L_s$), the two-way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is opened (STEP 2).

[0420] At this time, in the case that the liquid refrigerant is collected in the reservoir unit 219, the liquid refrigerant in the reservoir unit 219 flows out to the main circuit and only gas refrigerant remains in the reservoir unit 219. The high pressure gas refrigerant discharged from the compressor 211 in this condition passes through the four-way valve 212 and flows into the indoor heat exchanger 216 so as to be condensed. The refrigerant which has been condensed and has become a high pressure liquid refrigerant is reduced in pressure, by the indoor main expansion apparatus 215, to an intermediate pressure between the discharge pressure and the intake pressure. After that the refrigerant of the intermediate pressure is further reduced in pressure to a low pressure two-phase refrigerant in the vicinity of the intake pressure in the outdoor main expansion apparatus 214. This low pressure refrigerant which has reduced in pressure so as to be a two-phase refrigerant is evaporated in the outdoor heat exchanger 213 and is,

again, absorbed in the compressor 211 via the four-way valve 212.

[0421] In such a refrigeration cycle as described above, a load determination is carried out (STEP 3). In this STEP 3, in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "to" which is stored in the memory apparatus 228 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, the conditions of STEP 2 are maintained. That is to say, the refrigerant discharged from the compressor 211 circulates only through the main circuit.

[0422] At this time, the two-way valve 221 and the two-way valve 224 are closed while the two-way valve 223 is open and the rectifying separator 217 is communicated to the intake pipe of the compressor 211, and therefore, the inside of the rectifying separator 217, the inside of the cooling unit 218 and the inside of the reservoir unit 219 are filled with a low pressure gas and hold almost no reservoir of the refrigerant.

[0423] In this manner the two-way valves 221 and 224 are closed while the two-way valve 223 is open, and therefore, the heat pump apparatus is operated where the refrigerant in the main circuit remains the conditions as the filled in components have been mixed and the operation is carried out with a large amount of refrigerant. Thereby, the heat pump apparatus of Embodiment 10 can carry out the operation of high performance appropriate to the load.

[0424] Next a load determination is carried out in STEP 3, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "to" stored in the memory apparatus 228 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the heating load is small, a signal which closes the two-way valve 221 and the two-way valve 223 and which opens the two-way valve 224 is transmitted from the operation control apparatus 229. As a result, the two-way valve 221 and the two-way valve 223 are in the closed condition while the two-way valve 224 is in the open condition (STEP 4). These conditions are maintained for a specific period of time (T_1) (STEP 5).

[0425] By controlling the two-way valves 221, 223 and 224 in opening and closing in this manner, liquid refrigerant of high density or two-phase refrigerant can be collected directly in the reservoir unit 219 so that the operation can be carried out under the condition where the main circuit has a small amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 10 can carry out the reduction of the performance in a short period of time.

[0426] After that, a signal which opens the two-way valve 221 and the two-way valve 223 as well as a signal which closes the two-way valve 224 are transmitted

from the operation control apparatus 229. As a result of this, the two-way valve 221 and the two-way valve 223 are opened while the two-way valve 224 is closed (STEP 6).

[0427] Thereby, part of the high pressure gas from the discharge pipe of the compressor 211 is separated and passes through the two-way valve 221 so as to be reduced in pressure by the sub-expansion apparatus 220. Then the gas refrigerant which has been reduced in pressure flows into the bottom of the rectifying separator 217 so as to move upward into the rectifying separator 217.

[0428] After that, the refrigerant which has moved upward into the rectifying separator 217 flows into the cooling unit 218 and is condensed and liquefied in the cooling unit 218. The liquid refrigerant which has been condensed and liquefied is collected in the reservoir unit 219 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 217 from the bottom of the reservoir unit 219. The refrigerant which has returned to the rectifying separator 217 moves downward into the rectifying separator 217 and flows into the sub-expansion apparatus 222 from the bottom of the rectifying separator 217 so as to be reduced in pressure. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 222 passes through the cooling unit 218 and the two-way valve 223 and flows into the intake pipe of the compressor 211 which creates a linkage between the compressor 211 and the four-way valve 212.

[0429] At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 222 and the gas refrigerant which has flown into the cooling unit 218 from the top part of the rectifying separator 217 indirectly exchange heat in the cooling unit 218.

[0430] At the time of heat exchange in the above-mentioned cooling unit 218, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 218, and therefore, the latent heat can be utilized effectively so that not only the cooling unit 218 can be made compact but also the gas in the top part of the rectifying separator 217 can, without fail, be liquefied.

[0431] In this manner, the gas refrigerant which has flown in from the bottom of the rectifying separator 217 is cooled and liquefied in the cooling unit 218 so as to be collected in the reservoir unit 219. Then, the refrigerant in the reservoir unit 219 returns to the top part of the rectifying separator 217 and moves downward into the rectifying separator 217. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 217 and the liquid refrigerant which moves downward into the rectifying separator 217 create a contact between the gas and the liquid in the rectifying separator 217 causing the rectifying effects. As a result of this, the refrigerant, of

which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 219. On the other hand, the refrigerant which moves downward into the rectifying separator 217 and passes through the sub-expansion apparatus 222 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 211 via the cooling unit 218.

[0432] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase so that the heat pump apparatus of Embodiment 10 can make the cooling performance level to be lower. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 219, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0433] In addition, under the third condition (3) wherein the two-way valves 221 and 223 are open and the two-way valve 224 is closed, the operation determination of the compressor 211 is carried out (STEP 7). In the case that the compressor 211 is determined to be operating in STEP 7, the condition of STEP 6 is maintained and the load determination is carried out (STEP 8). Then, in the case that the heating load is determined to be small ($|t-to| < \Delta t$), the third condition (3) of STEP 6 is maintained.

[0434] On the other hand, in the case that the heating load is determined to have become larger in STEP 8, the process moves to STEP 9. In the case that the heating load becomes larger and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "to" stored in the memory apparatus 228 becomes a predetermined value " Δt " or more ($|t-to| \geq \Delta t$), the opening signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 229. As a result of this, the two-way valve 221 and the two-way valve 224 are reopened (STEP 9) and these conditions are maintained for a specific time (STEP 10).

[0435] By opening the two-way valves 221 and 224 in this way, the refrigerant which has been collected in the reservoir unit 219 flows out to the main circuit. After that, the closing signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 229 so that the two-way valve 221 and the two-way valve 224 become in the closed condition (STEP 2). By controlling the two-way valves 221 and 224 to open and to close in this way, the refrigerant amount in the main circuit increases in a short period of time and the main circuit again contains the filler components of high performance, and therefore, the heat pump apparatus of Embodiment 10 can restart the operation of high performance in response to the load.

[0436] On the other hand, in the case that the com-

pressor 211 is determined to have stopped in STEP 7, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 229. As a result of this, the two-way valve 221, the two-way valve 223 and the two-way valve 224 becomes in the closed condition (STEP 1). After that, the operation determination of the compressor 211 is carried out (STEP 12). In the case that the compressor 211 is determined to have stopped in STEP 12, the fifth condition (5) of STEP 11 is maintained and in the case that the compressor 211 is determined to be operating the operation of STEP 6 is carried out so as to restart the rectifying separation operation.

[0437] Due to such an opening and closing operation of the two-way valves, even in the case that the compressor 211 has stopped during the rectifying separation operation the refrigerant which has been collected in the reservoir unit 219 will not flow out to the main circuit. Therefore, in the heat pump apparatus of Embodiment 10, the separation operation can be restarted with the refrigerant component ratio immediately before the compressor 211 has stopped so that the time required for completing the rectifying separation can be shortened.

[0438] On the other hand, in the case that the estimated load L_o is determined to be smaller than the preset load standard value L_s ($L_o < L_s$) in the load estimation immediately after the start-up (STEP 1), the load condition at the previous operation stoppage is determined (STEP 13). In the case that the operation is determined to have stopped in the condition of a large load in STEP 13, the operation of STEP 2 is carried out and, after that, the separation operation of STEP 3 and the following is carried out.

[0439] On the other hand, in the case that the load condition at the time of previous operation stoppage is determined to be a stoppage of a small load condition in STEP 13, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 229 so that the two-way valve 221, the two-way valve 223 and the two-way valve 224 become in the closed condition (STEP 14). These conditions are maintained for a specific time (T_3) (STEP 15).

[0440] After that the load determination is carried out (STEP 16). In STEP 16, in the case that load is determined to be a predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), the operation is carried out under the sixth condition (6) where the condition of STEP 14 is maintained. Thereby, the refrigerant of low boiling point components separated in the previous operation can be maintained in the reservoir unit 219 so as to be able to restart the operation in the condition of low performance appropriate to the load.

[0441] And in the case that the load is larger than the predetermined value " Δt " ($|t - t_o| > \Delta t$) in STEP 16, the process moves to the operation of STEP 2 so as to release the refrigerant within the reservoir unit 219 into

the main circuit. Since the operation of the two-way valves is carried out in this way, the heat pump apparatus of embodiment 10 is instantly operated with mixed non-azeotropic refrigerant of filler components and under the condition wherein there is a large amount of the refrigerant so that the operation of high performance appropriate to the load becomes possible.

[0442] In this manner, the magnitude of the load is detected by the difference between the temperature of the intake air of the indoor unit 225 and the set air temperature so that the two-way valve 221, the two-way valve 223 and the two-way valve 224 are simply controlled in opening and closing so as to vary the amount of refrigerant and the refrigerant component in the main circuit in response to the condition of the load. Accordingly, the heat pump apparatus of Embodiment 10 can carry out proper performance control in response to the condition of the load.

《Embodiment 11》

[0443] Next, a heat pump apparatus of Embodiment 11 in accordance with the present invention is described with reference to FIGS. 21 and 22. FIG. 21 is a system configuration view of the heat pump apparatus of Embodiment 11. FIG. 22 is a control flow chart of the heat pump apparatus of Embodiment 11.

[0444] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 11 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 211, a four-way valve 212, an outdoor heat exchanger 213, an outdoor main expansion apparatus 230, an indoor main expansion apparatus 231 and an indoor heat exchanger 216 in an annular structure.

[0445] In the heat pump apparatus of Embodiment 11 elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 10 are referred to using the same numerals.

[0446] The heat pump apparatus of Embodiment 11 differs greatly from the heat pump apparatus of Embodiment 10 in the point that an outdoor main expansion apparatus 230 which enables complete closure is used as an outdoor main expansion apparatus while an indoor main expansion apparatus 231 which enables complete closure is used as an indoor main expansion apparatus. In addition, in embodiment 11, an intake pressure sensor 232 and a discharge pressure sensor 233 are provided. The intake pressure sensor 232 is installed in the intake pipe of the compressor 211 while the discharge pressure sensor 233 is installed in the discharge pipe of the compressor 211.

[0447] In the heat pump apparatus of Embodiment 11, the memory apparatus 234 stores a set air temperature value preset by the user at a desired value and a set differential pressure value between the discharge pressure and the intake pressure of the compressor

211. The operation control apparatus 235 determines the operation condition of the compressor 211 and the opening degree of the main expansion apparatuses 230 and 231. By using the determination result the operation control apparatus 235 carries out the opening and closing operation of the two-way valves 221, 223 and 224. The set air temperature of the memory apparatus 234, the indoor air temperature detected by the indoor thermal sensor 226, the outdoor air temperature detected by the outdoor thermal sensor 227, the intake pressure detected by the intake pressure sensor 232 and the discharge pressure detected by the discharge pressure sensor 233 are used for the operation of the operation control apparatus 235. Then, based on the operation result, the operation control apparatus 235 carries out the opening and closing operation of the two-way valves 221, 223 and 224 and, in addition, adjusts the opening degree of the indoor main expansion apparatus 230 and the outdoor main expansion apparatus 231.

[0448] The remaining part of the configuration in Embodiment 11 is the same as in the above-mentioned Embodiment 10, of which the description is omitted.

[0449] Next, the operation of the heat pump apparatus of Embodiment 11 formed as in the above is described with reference to FIG. 22.

[0450] FIG. 22 is a control flow chart of the heat pump apparatus of Embodiment 11.

[0451] First, the operation at the time of cooling is described.

[0452] After starting up the cooling operation, the air conditioning load is estimated based on the outdoor temperature detected by the outdoor thermal sensor 227, the indoor temperature detected by the indoor thermal sensor 226 and the set temperature stored in the memory apparatus 234 (STEP 1). At this time, in the case that the estimated load L_o is larger than a preset load standard value L_s ($L_o \geq L_s$), the two-way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is opened (STEP 2). At this time, in the case that the liquid refrigerant is collected in the reservoir unit 219, the liquid refrigerant flows out to the main circuit so that only gas refrigerant remains in the reservoir unit 219.

[0453] Under the first condition (1) of the operation of the two-way valves in STEP 2, the high pressure gas refrigerant discharged from the compressor 211 passes through the four-way valve 212 and flows into the outdoor heat exchanger 213. The high pressure liquid refrigerant which has been condensed in the outdoor heat exchanger 213 is reduced in pressure to the intermediate pressure between the discharge pressure and the intake pressure by the outdoor main expansion apparatus 230. After that, the refrigerant of the intermediate pressure is further reduced in pressure to a low pressure in the vicinity of the intake pressure in the indoor main expansion apparatus 231. This low pressure two-phase refrigerant is evaporated in the indoor

heat exchanger 216 and is again absorbed into the compressor 211 via the four-way valve 212.

[0454] In the refrigeration cycle operation as described above the load determination is carried out (STEP 3). In STEP 3, in the case that the difference between the intake air temperature "t" of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "to" stored in the memory apparatus 234 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, the first condition (1) of STEP 2 is maintained. That is to say, the refrigerant discharged from the compressor 211 circulates only through the main circuit.

[0455] At this time, the two-way valve 221 and the two-way valve 224 are closed while the two-way valve 223 is open and the rectifying separator 217 is communicated to the intake pipe of the compressor 211, and therefore, the inside of the rectifying separator 217, the inside of the cooling unit 218 and the inside of the reservoir unit 219 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0456] By closing the two-way valve 221 and the two-way valve 224 and opening the two-way valve 223 as described above, the heat pump apparatus has the refrigerant in the main circuit which is non-azeotropic refrigerant where the filler components have been mixed in, and the main circuit is operated in the condition wherein there is a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 11 can carry out the operation with high performance appropriate to the load.

[0457] Next, a load determination is carried out (STEP 3). In STEP 3 in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 which is detected by the indoor thermal sensor 226 and the set air temperature "to" stored in the memory apparatus 234 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, a signal which closes the two-way valve 221 and the two-way valve 223 and which opens the two-way valve 224 is transmitted from the operation control apparatus 235. As a result of this, the two-way valve 221 and the two-way valve 223 are in the closed condition while the two-way valve 224 is in the open condition (STEP 4). This condition is referred to as the second condition (2) of the operation of the two-way valves. This second condition (2) is maintained for a specific period of time (T1) (STEP 5).

[0458] As described above, the two-way valve 221 and the two-way valve 223 are in the closed condition while the two-way valve 224 is in the open condition and, thereby, the heat pump apparatus of Embodiment 11 can directly collect liquid of high density or two-phase refrigerant in the reservoir unit 219 so that the main circuit can be operated under the condition of a small amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 11 can carry out the

reduction of the cooling performance in response to the load in a short period of time.

[0459] After that, a signal which opens the two-way valve 221 and the two-way valve 223 and a signal which closes the two-way valve 224 are transmitted from the operation control apparatus 235 so that the two-way valve 221 and the two-way valve 223 are opened while the two-way valve 224 is closed (STEP 6). This condition is referred to as the third condition (3) of the operation of the two-way valves.

[0460] Thereby, part of the high pressure gas refrigerant is separated from the discharge pipe of the compressor 211, and passes through the two-way valve 221 so as to flow into the sub-expansion apparatus 220. And then, the gas refrigerant which has reduced in pressure in the sub-expansion apparatus 220 flows into the bottom of the rectifying separator 217 so as to move upward into the rectifying separator 217.

[0461] After that, the refrigerant which has moved upward into the rectifying separator 217 flows into the cooling unit 218. The liquid refrigerant which has been condensed and liquefied in the cooling unit 218 is collected in the reservoir unit 219 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 217 from the bottom of the reservoir unit 219. The refrigerant which has returned to the rectifying separator 217 moves downward into the rectifying separator 217 and flows into the sub-expansion apparatus 222 from the bottom of the rectifying separator 217. The two-phase refrigerant which has been reduced in pressure in the sub-expansion apparatus 222 passes through the cooling unit 218 and the two-way valve 223 so as to flow into the intake pipe of the compressor 211 which creates a linkage between the compressor 211 and the four-way valve 212. At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 222 and the gas refrigerant which has flown into the cooling unit 218 from the top part of the rectifying separator 217 indirectly exchange heat in the cooling unit 218.

[0462] At the time of heat exchange in the cooling unit 218, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 218, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 218 can be made compact but also the gas in the top part of the rectifying separator 217 can, without fail, be liquefied.

[0463] As described above, the gas refrigerant which has flown in from the bottom of the rectifying separator 217 is cooled and liquefied in the cooling unit 218 so as to be collected in the reservoir unit 219. Then, the liquid refrigerant in the reservoir unit 219 returns to the top part of the rectifying separator 217 and moves downward into the rectifying separator 217. In the case that these conditions occur sequentially, the gas refrigerant

erant which moves upward into the rectifying separator 217 and the liquid refrigerant which moves downward into the rectifying separator 217 create a contact between the gas and the liquid in the rectifying separator 217. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 219. In addition, the refrigerant which moves downward into the rectifying separator 217 and passes through the sub-expansion apparatus 222 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 211 via the cooling unit 218 and the two-way valve 223.

[0464] As described in the above, in the heat pump apparatus of Embodiment 11, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 219, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the further lowering of the performance level. Accordingly the heat pump apparatus of Embodiment 11 can carry out the operation of low performance appropriate for the load.

[0465] Next, under the condition of STEP 6 wherein the two-way valve 221 and the two-way valve 223 are open and the two-way valve 224 is closed, the operation determination of the compressor 211 is carried out (STEP 7). In this STEP 7, in the case that the compressor 211 is determined to be operating the condition of STEP 6 is maintained and the load determination is carried out (STEP 8). In STEP 8, in the case that the cooling load is determined to be small ($|t-t_o| < \Delta t$) the condition of STEP 6 is maintained.

[0466] On the other hand, in the case that the cooling load is determined to be large ($|t-t_o| \geq \Delta t$) in STEP 8, the process moves to STEP 9. In the case that the cooling load becomes larger and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "t_o" stored in the memory apparatus 234 becomes a predetermined value " Δt " or more, an opening signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 235 so that the two-way valve 221 and the two-way valve 224 are again in the open condition (STEP 9). This condition is the fourth condition (4) of the operation of the two-way valves. This fourth condition (4) is maintained for a specific time (T₂) (STEP 10).

[0467] Through the open condition of the two-way valve 221 and the two-way valve 224, the refrigerant which has collected in the reservoir unit 219 flows out to the main circuit. After that, a closing signal of the two-way valve 221 and the two-way valve 224 is transmitted

from the operation control apparatus 235 so that the two-way valve 221 and the two-way valve 224 are closed (STEP 2). Thereby, the amount of refrigerant in the main circuit increases in a short period of time and, at the same time, the main circuit again contains the filler components of high performance so that the heat pump apparatus can restart the operation of high performance in response to the load.

[0468] On the other hand, in the case that the compressor 211 is determined to have stopped in STEP 7, a complete closure signal of the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 is transmitted from the operation control apparatus 235. As a result of this, the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 become in the complete closure condition (STEP 11). This condition is the first condition (1) of the operation of the main expansion apparatus.

[0469] After that, the operation control apparatus 235 uses the measurement values from the intake pressure sensor 232 and the discharge pressure sensor 233 so as to calculate out the difference ΔP between the discharge pressure and the intake pressure, which is compared with the value of pressure difference P_s which is preset and stored in the memory apparatus 234 (STEP 12). In the case that the pressure difference ΔP is the set value of pressure difference P_s or more ($\Delta P \geq P_s$) in STEP 12 this operation of pressure difference is carried out repeatedly. On the other hand, in the case that the pressure difference ΔP becomes less than the value of the pressure difference P_s ($\Delta P < P_s$), a closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 235 so that the two-way valve 221, the two-way valve 223 and the two-way valve 224 are closed (STEP 13).

[0470] After that, the operation determination of the compressor 211 is carried out (STEP 14), and in the case that the compressor 211 is determined to have stopped, the fifth condition (5) of the operation of the two-way valves of STEP 13 is maintained. And in the case that the compressor 211 is determined to be operating, a signal which opens the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 to a preset and predetermined opening degree is transmitted from the operation control apparatus 235. As a result of this, the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 are opened to a predetermined opening degree (STEP 15). In STEP 15 the outdoor main expansion apparatus 230 is in the first set opening degree ① and the indoor main expansion apparatus 231 is in the second set opening degree ②. After becoming in this condition, the operation of STEP 6 is carried out so as to restart the separation operation.

[0471] Due to the above-mentioned operation of the main expansion apparatuses, the refrigerant which has been collected in the reservoir unit 219 will not flow out

to the main circuit even under the condition where the compressor 211 has stopped during the separation operation. Therefore, the compressor 211 can restart the separation operation, with the component ratio immediately before the stoppage, so that the time required for completing the separation can be further shortened.

[0472] On the other hand, in the load estimation immediately after the start-up (STEP 1), in the case that the estimated load L_o is determined to be smaller than the preset load standard value L_s ($L_o < L_s$), the load condition at the last time of operation stoppage is judged (STEP 16). In the case of the judgment that the operation has stopped under the condition of a large load ($L_h = 1$) in STEP 16, the above-mentioned operation of STEP 2 is carried out and, after that, the separation operation of STEP 3, and the following, is carried out.

[0473] On the other hand, in the case of the judgment that the operation has stopped during the previous operation under the condition of a small load ($L_h = 0$) in STEP 16, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 235. As a result of this, the two-way valve 221, the two-way valve 223 and the two-way valve 224 become in the closed condition (STEP 17). These conditions are maintained for a specific time (T_3) (STEP 18). After that, the load determination is carried out (STEP 19) and in the case that the load is still at a predetermined value or less ($|t - t_o| \leq \Delta t$), the condition of STEP 17 is maintained while the operation is carried out. By converting the two-way valves 221, 223 and 224 into the closed condition, the refrigerant of low boiling point, which has been separated out at the previous operation, is maintained in the reservoir unit 219 so that the operation can be restarted in the condition of reduced performance appropriate to the load.

[0474] On the other hand, in the case that the load is determined to be large in STEP 19, the operation moves to the operation in STEP 2 and the refrigerant within the reservoir unit 219 is discharged into the main circuit. Thereby, the main circuit is instantly operated under the condition wherein there is a large amount of refrigerant, which is mixed non-azeotropic refrigerant of the filler components so that the heat pump apparatus can carry out the operation of high performance appropriate to the load.

[0475] In this way, the refrigerant amount and the refrigerant components in the main circuit can be changed into the conditions in response to the load through a simple operation of opening and closing the two-way valve 221, the two-way valve 223 and the two-way valve 224 by detecting the size of the load through the difference between the temperature of the intake air of the indoor unit 225 and the set air temperature. Accordingly, the heat pump apparatus of Embodiment 11 can appropriately carry out performance control in response to the load in further shorter period of time.

[0476] Here, in FIG. 22, the indoor temperature (measured value) is denoted as "t", a set temperature set by the user is denoted as "to", the difference (a pre-determined value) between the indoor temperature set in advance and the set temperature is denoted as " Δt ", the measured time is denoted as T, a set time 1 (main-
 5 maintained period of time of the second condition (2) of the two-way valve operation set in advance) is denoted as T1, a set time 2 (maintained period of time of the fourth condition (4) of the two-way valve operation set in
 10 advance) is denoted as T2, a set time 3 (maintenance time of the sixth condition (6)) of the preset operation of the two-way valves) is denoted as T3, an estimated load standard value measured time is denoted as Lo, a set
 15 load standard value is denoted as Ls, a load determination value is denoted as Lh (large load=1 and small load=0), a measured pressure difference (measurement value) is denoted as ΔP and a preset pressure difference is denoted as Ps.

[0477] And the first condition (1) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is open and the two-way valve 224 is closed. The second condition (2) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223
 25 is closed and the two-way valve 224 is open. The third condition (3) of the two-way valve is the condition where the two-way valve 221 is open, the two-way valve 223 is open, and the two-way valve 224 is closed. The fourth condition (4) of the two-way valve operation is the condition where the two-way valve 221 is open, the two-way valve 223 is closed and the two-way valve 224 is open. The fifth condition (5) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is closed and the two-way valve 224
 35 is closed. The sixth condition (6) of the two-way valve operation is the condition where the two-way valve 221 is closed, the two-way valve 223 is closed and the two-way valve 224 is closed.

[0478] Next, the operation at the time of heating is described.

[0479] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0480] After the start-up at the time of the heating operation, the air conditioning load is estimated based on the outdoor temperature detected by the outdoor thermal sensor 227, the indoor temperature detected by the indoor thermal sensor 226 and the set temperature stored in the memory apparatus 234 (STEP 1).

[0481] In STEP 1, in the case that the estimated load Lo is determined to be larger than the preset load standard value Ls ($Lo \geq Ls$), the two-way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is opened (STEP 2).

[0482] Under the first condition (1) wherein the two-

way valve 221 and the two-way valve 224 are closed and the two-way valve 223 is open, in the case that liquid refrigerant is collected in the reservoir unit 219, this liquid refrigerant passes through the two-way valve 223 and flows out to the main circuit. Thereby, only gas refrigerant remains in the reservoir unit 219. The high pressure gas refrigerant discharged from the compressor 211 in this first condition (1) passes through the four-way valve 212 and flows into the indoor heat exchanger 216 so as to be condensed. The high pressure liquid refrigerant which has been condensed is reduced in pressure, by the indoor main expansion apparatus 231, to an intermediate pressure between the discharge pressure and the intake pressure, and then, is further reduced in pressure to a low pressure in the vicinity of the intake pressure in the outdoor main expansion apparatus 230. This low pressure refrigerant which has reduced in pressure so as to be a two-phase refrigerant is evaporated in the outdoor heat exchanger 213 and is, again, absorbed in the compressor 211 via the four-way valve 212.

[0483] In such a refrigeration cycle as described above, a load determination is carried out (STEP 3). In STEP 3, in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "to" which is stored in the memory apparatus 234 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, the conditions of STEP 2 are maintained. That is to say, the refrigerant discharged from the compressor 211 circulates only through the main circuit.

[0484] The two-way valve 221 and the two-way valve 224 are closed while the two-way valve 223 is open and the rectifying separator 217 is communicated to the intake pipe of the compressor 211, and therefore, the inside of the rectifying separator 217, the inside of the cooling unit 218 and the inside of the reservoir unit 219 are filled with a low pressure gas and hold almost no reservoir of the refrigerant.

[0485] Through the above-mentioned operation in the heat pump apparatus of Embodiment 11, the refrigerant in the main circuit becomes the conditions as the filled in components have been mixed and the main circuit is operated with a large amount of refrigerant. Accordingly, the heat pump apparatus can carry out the operation of high performance appropriate to the load.

[0486] Next a load determination is carried out in STEP 3, and in the case that the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 (room temperature) detected by the indoor thermal sensor 226 and the set air temperature "to" stored in the memory apparatus 234 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, a signal which closes the two-way valve 221 and the two-way valve 223 and which opens the two-way valve 224 is transmit-

ted from the operation control apparatus 235. As a result of this, the two-way valve 221 and the two-way valve 223 are in the closed condition while the two-way valve 224 is in the open condition (STEP 4). These conditions are maintained for a specific period of time (T1) (STEP 5). By operating the two-way valves in opening and closing as described above, liquid refrigerant of high density or two-phase refrigerant can be collected directly in the reservoir unit 219 so that the operation can be carried out under the condition where the main circuit has a small amount of refrigerant. Accordingly, the heat pump apparatus of Embodiment 11 can carry out the reduction of the performance in a short period of time.

[0487] After that, in STEP 6, a signal which opens the two-way valve 221 and the two-way valve 223 and which closes the two-way valve 224 is transmitted from the operation control apparatus 235 so that the two-way valve 221 and the two-way valve 223 are opened while the two-way valve 224 is closed.

[0488] By opening the two-way valves 221 and 223 and by closing the two-way valve 224 as described above, part of the high pressure gas from the discharge pipe of the compressor 211 is separated and passes through the two-way valve 221 so as to be reduced in pressure by the sub-expansion apparatus 220. This gas refrigerant which has been reduced in pressure flows into the bottom of the rectifying separator 217 so as to move upward into the rectifying separator 217.

[0489] After that, the refrigerant which has moved upward into the rectifying separator 217 flows into the cooling unit 218. The liquid refrigerant which has been condensed and liquefied in the cooling unit 218 is collected in the reservoir unit 219 and the liquid refrigerant which has been collected previously returns to the top part of the rectifying separator 217 from the bottom of the reservoir unit 219. The refrigerant which has returned to the rectifying separator 217 moves downward into the rectifying separator 217 and flows into the sub-expansion apparatus 222 from the bottom of the rectifying separator 217, and then, the two-phase refrigerant which has been reduced in pressure passes through the cooling unit 218 and the two-way valve 223 so as to flow into the intake pipe of the compressor 211 which creates a linkage between the compressor 211 and the four-way valve 212.

[0490] At this time, the two-phase refrigerant of low temperature which has been reduced in pressure by the sub-expansion apparatus 222 and the gas refrigerant which has flown into the cooling unit 218 from the top part of the rectifying separator 217 indirectly exchange heat in the cooling unit 218.

[0491] At the time of heat exchange in the above-mentioned cooling unit 218, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 218, and therefore, the latent heat of the refrigerant can be utilized effec-

tively so that not only the cooling unit 218 can be made compact but also the gas in the top part of the rectifying separator 217 can, without fail, be liquefied.

[0492] In this manner, the gas refrigerant which has flown in from the bottom of the rectifying separator 217 is cooled and liquefied in the cooling unit 218 so as to be collected in the reservoir unit 219. Then, the refrigerant in the reservoir unit 219 returns to the top part of the rectifying separator 217 and moves downward into the rectifying separator 217. In the case that these conditions occur sequentially, the gas refrigerant which moves upward into the rectifying separator 217 and the liquid refrigerant which moves downward into the rectifying separator 217 create a contact between the gas and the liquid in the rectifying separator 217. This contact between the gas and the liquid causes the rectifying effects so that the refrigerant, of which the low boiling point refrigerant components gradually increase, is collected in the reservoir unit 219. In addition, the refrigerant which moves downward into the rectifying separator 217 and passes through the sub-expansion apparatus 22 gradually converts to the refrigerant which contains a large amount of high boiling point refrigerant components and is absorbed into the compressor 211 via the cooling unit 218.

[0493] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase so that the performance level can be made low. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 219, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount in the main circuit contributes to the lowering of the performance level. Accordingly, the heat pump apparatus of Embodiment 11 can carry out the operation of low performance appropriate for the load.

[0494] As described above, under the condition wherein the two-way valve 221 and the two-way valve 223 are open while the two-way valve 224 is closed, the operation determination of the compressor 211 is carried out (STEP 7). In the case that the compressor 211 is determined to be operating in STEP 7, the condition of STEP 6 is maintained and the load determination is carried out (STEP 8). In the case that the cooling load is determined to be small ($|t-t_0| < \Delta t$), the condition of STEP 6 is maintained.

[0495] On the other hand, in the case that the cooling load becomes larger in STEP 8 and the absolute value of the difference between the temperature "t" of the intake air of the indoor unit 225 detected by the indoor thermal sensor 226 and the set air temperature "t₀" calculated out in the operation apparatus 234 becomes a predetermined value " Δt " or more ($|t-t_0| \geq \Delta t$), an opening signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 235. As a result of this, the two-way valve 221 and the two-way valve 224 are reopened (STEP 9). These conditions are maintained for a spe-

cific time (STEP 10).

[0496] Thereby, the refrigerant which has been collected in the reservoir unit 219 flows out to the main circuit, and after that, the closing signal of the two-way valve 221 and the two-way valve 224 is transmitted from the operation control apparatus 235 so that the two-way valve 221 and the two-way valve 224 are closed (STEP 2). As a result of this, the refrigerant amount in the main circuit increases in a short period of time and the main circuit again contains the filler components of high performance, and therefore, the heat pump apparatus of Embodiment 11 can restart the operation of high performance in response to the load.

[0497] On the other hand, in the case that the compressor 211 is determined to have stopped in STEP 7, the complete closure signal of the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 is transmitted from the operation control apparatus 235 so that the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 are completely closed (STEP 11).

[0498] After that, the operation apparatus 234 calculates out the pressure difference ΔP between the discharge pressure and the intake pressure. Then, the operation apparatus 234 compares the calculated pressure difference ΔP with the value of pressure difference P_s which is preset and stored in the memory apparatus 234 (STEP 12). In the case that the pressure difference ΔP is the set value of pressure difference P_s or more ($\Delta P \geq P_s$) in STEP 12 this operation of pressure difference is carried out repeatedly. On the other hand, in the case that the pressure difference ΔP becomes lower than the set value of pressure difference P_s in STEP 12 ($\Delta P < P_s$), a closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 235. As a result of this, the two-way valve 221, the two-way valve 223 and the two-way valve 224 become in the closed condition (STEP 13).

[0499] After that, the operation determination of the compressor 211 is carried out (STEP 14), and in the case the compressor 211 is determined to have stopped, the condition of STEP 13 is maintained. On the other hand, in the case that the compressor 211 is determined to be operating in STEP 14, the operation control apparatus 235 transmits a signal which opens the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 to a preset and predetermined opening degree. As a result of this the outdoor main expansion apparatus 230 and the indoor main expansion apparatus 231 are opened to a predetermined opening degree (STEP 15). After that, the operation of STEP 6 is carried out so as to restart the separation operation.

[0500] Due to such an opening and closing operation of the two-way valves as described above, even in the case that the compressor 211 has stopped during the separation operation the refrigerant which has been

collected in the reservoir unit 219 will not flow out to the main circuit. Therefore, in the heat pump apparatus of Embodiment 11, the separation operation can be restarted with the refrigerant component ratio immediately before the compressor 211 has stopped so that the time required for completing the separation can be shortened further more.

[0501] In the case that the estimated load Lo is determined to be smaller than the preset load standard value Ls ($Lo < Ls$) in the load estimation immediately after the start-up (STEP 1), the load condition at the previous operation stoppage is determined (STEP 16). In the case that the operation is determined to have stopped in the condition of a large load in STEP 16, the operation of the two-way valves in STEP 2 (the first condition (1)) is carried out and, after that, the separation operation of STEP 3 and the following is carried out.

[0502] On the other hand, in the case that the load condition at the time of previous operation stoppage is determined to be a stoppage of a small load condition in STEP 16, the closing signal of the two-way valve 221, the two-way valve 223 and the two-way valve 224 is transmitted from the operation control apparatus 235. As a result of this, the two-way valve 221, the two-way valve 223 and the two-way valve 224 are in the closed condition (STEP 17), so that these conditions are maintained for a specific time (T_3) (STEP 18). After that, the load determination is carried out (STEP 19), and in the case that load is determined to be small, the operation is carried out under the condition where the condition of STEP 17 is maintained.

[0503] By operating the two-way valves as described above, the heat pump apparatus of embodiment 11 can maintain the refrigerant of low boiling point separated out by the previous operation in the reservoir unit 219 and can restart the operation under a condition of low performance appropriate to the load.

[0504] On the other hand, in the case that the load is determined to be large in STEP 19, the process moves to the operation of STEP 2 so as to release the refrigerant within the reservoir unit 219 into the main circuit. Thereby, the main circuit is instantly operated with mixed non-azeotropic refrigerant of filler components and under the condition wherein there is a large amount of the refrigerant. As a result of this, the heat pump apparatus of Embodiment 1 can carry out the operation of high performance appropriate to the load.

[0505] As described above, the magnitude of the load is detected by the difference between the temperature of the intake air of the indoor unit 225 and the set air temperature so that the two-way valve 221, the two-way valve 223 and the two-way valve 224 are simply controlled in opening and closing so as to vary the amount of refrigerant and the refrigerant component in the main circuit in response to the condition of the load. Accordingly, the heat pump apparatus of Embodiment 11 can carry out proper performance control in response to the load for a shorter period of time.

[0506] In the heat pump apparatus of Embodiment 11, in the case that R407C, which is a substitute refrigerant for R22 and which is a mixture of three types of single refrigerants R32, R125 and R134a, is used as the sealed non-azeotropic refrigerant, the difference of boiling points of refrigerants R32 and R125, of which the boiling points are low, and a refrigerant R134a, of which the boiling point is high, can be made large, which is advantageous for the rectifying separation performance. Moreover, by using R407C as non-azeotropic refrigerant, the heat pump apparatus of Embodiment 11 can make the ratio of lowering of the performance large so that the most suitable performance control becomes possible for a large load variation.

《Embodiment 12》

[0507] Next, a heat pump apparatus of Embodiment 12 in accordance with the present invention is described with reference to FIGS. 23 and 24. FIG. 23 is a system configuration view of the heat pump apparatus of Embodiment 12. FIG. 24 is a control flow chart of the heat pump apparatus of Embodiment 12.

[0508] A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 12 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 311, a four-way valve 312, an outdoor heat exchanger 313, an outdoor main expansion apparatus 314, an indoor main expansion apparatus 315 and an indoor heat exchanger 316 in an annular structure.

[0509] The rectifying separator 317 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. The top part of the rectifying separator 317 is communicated to the top of a reservoir unit 319 via a cooling unit 318, and the bottom of the reservoir unit 319 is communicated to the top part of the rectifying separator 317. Accordingly, the top part of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 are connected in an annular structure so as to form a closed circuit.

[0510] The top part of the reservoir unit 319 is arranged to be in a higher position than the top part of the rectifying separator 317. In addition, the cooling unit 318 is arranged in a position higher than the top part of the reservoir unit 319.

[0511] In addition, the pipe which makes a connection between the top part of the rectifying separator 317 and the cooling unit 318 is connected to the ceiling of the top part of the rectifying separator 317. The pipe which makes a connection between the bottom of the reservoir unit 319 and the top part of the rectifying separator 317 is connected to the side of the top part of the rectifying separator 317.

[0512] In addition, the pipe leading out from the bottom of the rectifying separator 317 is connected, via the sub-expansion apparatus 321 and the two-way valve 320, to the pipe which links the outdoor main expansion

apparatus 314 and the indoor main expansion apparatus 315. The bottom of the rectifying separator 317 is connected to the intake pipe of the compressor 311 via the sub-expansion apparatus 322, the cooling unit 318 and the two-way valve 323. This intake pipe is a pipe linking the compressor 311 and the four-way valve 312.

[0513] The cooling unit 318 is formed so that the refrigerant moving from the bottom of the rectifying separator 317 toward the two-way valve 323 via the sub-expansion apparatus 322 and the refrigerant in the top part of the rectifying separator 317 indirectly exchange heat. As for the cooling unit 318 in Embodiment 12, it is possible to adopt a double pipe structure.

[0514] In addition, the bottom of the reservoir unit 319 is connected, via the two-way valve 324, to the intake pipe of the compressor 311 which links the compressor 311 and the four-way valve 312.

[0515] An indoor unit 325 of the main circuit has an indoor main expansion apparatus 315, the indoor heat exchanger 316, an indoor thermal sensor 326 and the like, and the indoor thermal sensor 326 detects the indoor air temperature (that is to say the temperature of the intake air of the indoor unit 325). In addition, the memory apparatus 327 stores the set air temperature value preset by the user at a desired value. The operation control apparatus 328 compares the absolute value of the difference between the intake air temperature "t" detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 with a predetermined value "Δt" so as to control the two-way valves 320, 323 and 324 for opening and closing based on the comparison result.

[0516] Next, the operation of the heat pump apparatus of Embodiment 12 formed as in the above is described with reference to FIG. 24.

[0517] FIG. 24 is a control flow chart of the heat pump apparatus of Embodiment 12.

[0518] In the following description the case where high performance is required, such as immediately after the start-up of the compressor 311, is assumed to be the start of the process.

[0519] First, immediately after the start-up of the cooling operation, the two-way valve 320 is closed while the two-way valves 323 and 324 are open (STEP 1). At this time, the refrigerant of high temperature and high pressure which has been discharged from the compressor 311 passes through the four-way valve 312 and flows into the outdoor heat exchanger 313 so as to be condensed and liquefied in the outdoor heat exchanger 313. This refrigerant, which has been condensed and liquefied, flows into the outdoor main expansion apparatus 314 so as to be reduced in pressure to the intermediate pressure.

[0520] Under the above-mentioned conditions, the load determination is carried out (STEP 2), and in the case that the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to"

stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - t_0| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. That is to say, the two-way valve 320 is kept closed and the two-way valves 323 and 324 become in the open condition.

[0521] Accordingly, all of the refrigerant of the intermediate pressure which has come out of the outdoor main expansion apparatus 314 flows into the indoor main expansion apparatus 315 so as to be put under low pressure. Then, the refrigerant which has flown into the indoor heat exchanger 316 evaporates so as to cool the space where the indoor unit 325 is provided. After that, the refrigerant passes through the four-way valve 312 so as to be again absorbed into the compressor 311.

[0522] In the above-mentioned refrigeration cycle, the two-way valve 320 is closed while the two-way valves 323 and 324 are open and the rectifying separator 317 is connected to the intake pipe of the compressor 311 via the two-way valves 323 and 324, and therefore, the inside of the rectifying separator 317, the inside of the cooling unit 318 and the inside of the reservoir unit 319 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0523] The two-way valve 320 is closed while the two-way valves 323 and 324 are open in this manner, the refrigerant in the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the operation is carried out in the condition wherein there is a large amount of refrigerant. As a result of this, the heat pump apparatus of Embodiment 12 can carry out the operation with high performance appropriate to the load.

[0524] Next, a load determination is carried out (STEP 2), and in the case that the difference between the temperature " t " of the intake air of the indoor unit 325 which is detected by the indoor thermal sensor 326 and the set air temperature " t_0 " stored in the memory apparatus 327 is a predetermined value " Δt " or less ($|t - t_0| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valves 320 and 323 and a closing signal of the two-way valve 324 are sent from the operation control apparatus 328. As a result of this, the two-way valves 320 and 323 become in the opened condition while the two-way valve 324 becomes in the closed condition (STEP 3). Under these conditions part of the two-phase refrigerant of intermediate pressure which has come out of the outdoor main expansion apparatus 314 passes through the two-way valve 320 and the sub-expansion apparatus 321, and flows into the bottom of the rectifying separator 317.

[0525] At an initial stage of this condition, the insides of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 contain little refrigerant,

and are in an almost empty condition. Therefore, part of the refrigerant which has passed through the two-way valve 320 and the sub-expansion apparatus 321 and has flown into the bottom of the rectifying separator 317 passes through the rectifying separator 317 so as to be collected in the reservoir unit 319. In addition, part of the refrigerant of the rectifying separator 317 passes through the sub-expansion apparatus 322 so as to be reduced in pressure and becomes a two-phase refrigerant of low temperature and, then, flows into the cooling unit 318. In the cooling unit 318 the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 317.

[0526] When the refrigerant of the reservoir unit 319 gradually increases, the front part of the liquid refrigerant within the reservoir unit 319 flows into the rectifying separator 317 which moves downward into the rectifying separator 317. Under these conditions a small, and diminishing, amount of liquid refrigerant moves upward into the rectifying separator 317 and mainly gas refrigerant starts moving upward into the rectifying separator 317 from the bottom of the rectifying separator 317. Then, the liquid refrigerant which has been cooled and liquefied in the cooling unit 318 returns to the top part of the rectifying separator 317 while being collected in the reservoir unit 319 and moves downward into the rectifying separator 317.

[0527] When these conditions occur in sequence the refrigerant gas which moves upward into the rectifying separator 317 and the refrigerant liquid which moves downward into the rectifying separator 317 make a contact between the gas and the liquid within the rectifying separator 317. This contact between the gas and the liquid causes rectifying effects so that refrigerant which gradually increases in refrigerant components of low boiling point is collected in the reservoir unit 319. On the other hand, the refrigerant, which moves downward into the rectifying separator 317, gradually increases in refrigerant components of high boiling point. Therefore, the refrigerant which moves downward in the rectifying separator 317 merges together with the two-phase refrigerant which has passed through the two-way valve 320 and the sub-expansion apparatus 321 and which has flown into the bottom of the rectifying separator 317 and, then, passes through the sub-expansion apparatus 322, the cooling unit 318 and, in addition, through the opened two-way valve 323 so as to be absorbed into the compressor 311.

[0528] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered in response to the load, in the case that the load is small. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 319, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the further lowering of the performance level.

Accordingly, the heat pump apparatus of Embodiment 12 can carry out the operation of low performance appropriate for the load.

[0529] At the time of heat exchange in the above-mentioned cooling unit 18, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 318. Therefore, the heat pump apparatus of Embodiment 12 can utilize the latent heat of the refrigerant effectively so that not only the cooling unit 318 can be made compact but also the gas in the top part of the rectifying separator 317 can, without fail, be liquefied.

[0530] Next, under the conditions where the two-way valves 320 and 323 are open while the two-way valve 324 is closed, the load determination is carried out (STEP 4). In STEP 4, when the load becomes large and in the case that the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is again closed while the two-way valves 323 and 324 are opened (STEP 1).

[0531] By closing the two-way valve 320 and by opening the two-way valves 323 and 324, the refrigerant of low boiling point which has been collected in the reservoir unit 319 is absorbed into the compressor 311 via the two-way valves 323 and 324. As a result of this, the refrigerant components of the main circuit return to the condition of the filler components of high performance and the refrigerant amount in the main circuit increases. Accordingly, the heat pump apparatus of Embodiment 12 can restart the operation of high performance in response to the load.

[0532] In the heat pump apparatus of Embodiment 12 the two-way valve 324 is provided between the reservoir unit 319 and the intake pipe of the compressor 311, and therefore, the refrigerant within the reservoir unit 319 can be made to flow into the main circuit in a short period of time, which allows for excellent control in response to the load change.

[0533] In this way, the conditions of the refrigerant amount and the refrigerant components in the main circuit can be changed in response to the size of the load through a simple operation of opening and closing the two-way valves 320, 323 and 324 by detecting the difference between the temperature of the intake air of the indoor unit 325 and the set air temperature. Accordingly, the heat pump apparatus of Embodiment 12 can appropriately carry out performance control in response to the load.

[0534] Next, the operation at the time of heating is described.

[0535] The flow of the refrigerant at the time of the

heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0536] In the case that, at the time of heating, a high heating performance is required, such as immediately after the start-up of the compressor 311, the two-way valve 320 is closed while the two-way valves 323 and 324 are open (STEP 1). The refrigerant of high temperature and high pressure discharged from the compressor 311 in this condition passes through the four-way valve 312 and flows into the indoor heat exchanger 316. In the indoor heat exchanger 316, the refrigerant contributes to the heating and is condensed and liquefied and, then, flows into the indoor main expansion apparatus 315. In the indoor main expansion apparatus 315 the refrigerant is reduced in pressure to the intermediate pressure.

[0537] In the above-mentioned refrigeration cycle, a load determination is carried out (STEP 2). In STEP 2, in the case that the difference between the temperature "t" of the intake air of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" which is stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the heating load is large, a closing signal of the two-way valve 320 and an opening signal of two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is kept closed while the two-way valves 323 and 324 are kept open.

[0538] Accordingly, all of the refrigerant of intermediate pressure which has come out of the indoor main expansion apparatus 315 passes through the outdoor expansion apparatus 314 to be put under low pressure and, then, evaporates by absorbing heat from the outside air in the outdoor heat exchanger 313. After that the refrigerant passes through the four-way valve 312 and is absorbed again into the compressor 311.

[0539] As described above, the two-way valve 320 is closed, the two-way valves 323 and 324 are open, the cooling unit 318 and the reservoir unit 319 are connected to the intake pipe of the compressor 311 via the two-way valve 323 and the two-way valve 324, and therefore, the inside of the rectifying separator 317, the inside of the cooling unit 318 and the inside of the reservoir unit 319 are filled with low pressure gas with little reservoir of the refrigerant remaining.

[0540] In this manner, by operating the two-way valves, the operation is carried out under the conditions where the refrigerant in the main circuit is non-azeotropic refrigerant as the filled in components have been mixed and where the main circuit has a large amount of refrigerant. Accordingly, the heat pump apparatus of Embodiment 12 can carry out the operation of high performance appropriate to the load.

[0541] Next a load determination is carried out (STEP 2), and in the case that the difference between

the temperature "t" of the intake air of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valves 320 and 323 and a closing signal of the two-way valve 324 are sent from the operation control apparatus 328. As a result of this, the two-way valves 320 and 323 are opened (STEP 3), and therefore, part of the two-phase refrigerant of intermediate pressure which has come out of the indoor main expansion apparatus 315 passes through the two-way valve 320 and the sub-expansion apparatus 321 and flows into the bottom of the rectifying separator 317.

[0542] Under the above-mentioned initial conditions, the inside of the rectifying separator 317, the inside of the cooling unit 318 and the inside of the reservoir unit 319 contain little refrigerant and are in the empty condition. Under these conditions the refrigerant flows into the bottom of the rectifying separator 317. The refrigerant which has flown into the bottom of the rectifying separator 317 passes through the rectifying separator 317 and the cooling unit 318 and is collected in the reservoir unit 319. In addition, part of the refrigerant passes through the sub-expansion apparatus 322 so as to be reduced in pressure and becomes a two-phase refrigerant of low temperature and, then, flows into the cooling unit 318, where the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 317.

[0543] When the refrigerant of the reservoir unit 319 gradually increases, the front part of the liquid refrigerant within the reservoir unit 319 allows the liquid refrigerant to move downward into the rectifying separator 317. Under these conditions, almost no liquid refrigerant moves upward into the rectifying separator 317. The main gas refrigerant starts moving upward into the rectifying separator 317 from the bottom of the rectifying separator 317 and is cooled and liquefied in the cooling unit 319 so as to be collected in the reservoir unit 319. Then, the refrigerant returns to the top part of the rectifying separator 317 and moves downward into the rectifying separator 317.

[0544] When these conditions occur in sequence the refrigerant gas which moves upward into the rectifying separator 317 and the refrigerant liquid which moves downward into the rectifying separator 317 make a contact between the gas and the liquid within the rectifying separator 317. This contact between the gas and the liquid causes rectifying effects so that refrigerant which gradually increases in refrigerant components of low boiling point is collected in the reservoir unit 319. On the other hand, the refrigerant, which moves downward into the rectifying separator 317, gradually increases in refrigerant components of high boiling point. This refrigerant which is rich in the components of high boiling point passes through the two-way valve 320 and the

sub-expansion apparatus 321 and merges together with the two-phase refrigerant which has flown into the bottom of the rectifying separator 317 and, then, passes through the sub-expansion apparatus 322 and the cooling unit 318 and, in addition, through the opened two-way valve 323 so as to be absorbed into the compressor 311.

[0545] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered in response to the load, in the case that the load is small. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 319, the main circuit contains a decreasing amount of refrigerant and this decrease of the refrigerant amount contributes to the further lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0546] At the time of heat exchange in the cooling unit 318, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 318, and therefore, the latent heat of the refrigerant can be utilized effectively. Accordingly, in the heat pump apparatus of Embodiment 12, not only the cooling unit 318 can be made compact but also the gas in the top part of the rectifying separator 317 can, without fail, be liquefied.

[0547] Next, under the above-mentioned conditions the load determination is carried out (STEP 4). In the case that the load becomes large and the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is again closed and the two-way valves 323 and 324 are opened (STEP 1). Thereby, the reservoir which has been collected in the reservoir unit 319 is absorbed into the compressor 311 via the two-way valves 323 and 324 so that the refrigerant composition of the main circuit returns to the condition of the filler components of high performance and the refrigerant amount of the main circuit increases. As a result of this, the heat pump apparatus of Embodiment 12 can restart the operation of high performance in response to the load.

[0548] In the heat pump apparatus of Embodiment 12 the two-way valve 324, in particular, makes a direct connection between the reservoir unit 319 and the intake pipe of the compressor 311, and therefore, the refrigerant within the reservoir unit 319 can be made to flow out to the main circuit in a short period of time. As a result of this, the heat pump apparatus of Embodiment 12 allows for excellent control in response to the load.

[0549] In this manner, the refrigerant amount of the

main circuit and the refrigerant composition are changed by a simple operation of opening and closing the two-way valves 320, 323 and 324, by detecting the size of the load, by using the difference between the intake air temperature of the indoor unit 325 and the set air temperature. Therefore, the heat pump apparatus of Embodiment 12 can carry out proper performance control in response to the load.

[0550] Here, in the heat pump apparatus of Embodiment 12 under either of the operation conditions of cooling or heating, in the case that the load becomes large and the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt_1 ", only one of either the two-way valve 323 or the two-way valve 324 may be opened and, even in this case, the same effects as in the above-mentioned Embodiment 12 are gained.

[0551] Here, the configuration may be such that when a small load is detected, or after the operation of collecting the refrigerant of low boiling point in the reservoir unit 319 is carried out for a predetermined time, or when the refrigerant composition of the main circuit or the reservoir unit 319 is detected to have become a predetermined refrigerant composition, the two-way valves 320, 323 and 324 are all closed and the closed circuit formed by the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 is detached from the main circuit.

(Embodiment 13))

[0552] Next, a heat pump apparatus of Embodiment 13 in accordance with the present invention is described with reference to FIG. 25.

[0553] The heat pump apparatus of Embodiment 13 has the same structure as the heat pump apparatus of Embodiment 12 as shown in FIG. 23, as described above, except for the control operation of the operation control apparatus 328 which is different. Therefore, in the following description, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the Embodiment 12 are referred to using the same numerals.

[0554] Next, the operation of the heat pump apparatus of Embodiment 13 formed as in the above is described with reference to FIG. 25.

[0555] FIG. 25 is a control flow chart of the heat pump apparatus of Embodiment 13. In FIG. 25 the conditions where high performance is required, such as immediately after the start-up of the compressor 311, are assumed to be the start of the process.

[0556] First, the operation at the time of cooling is described.

[0557] At the time of the cooling operation, the two-way valve 320 is closed while the two-way valves 323

and 324 are open (STEP 1). At this time, the refrigerant of high temperature and high pressure which has been discharged from the compressor 311 passes through the four-way valve 312 and flows into the outdoor heat exchanger 313 so as to be condensed and liquefied in the outdoor heat exchanger 313. The liquid refrigerant, which has been condensed and liquefied, flows into the outdoor main expansion apparatus 314 so as to be reduced in pressure to the intermediate pressure.

[0558] Under the above-mentioned conditions, the load determination is carried out (STEP 2), and in the case that the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a first predetermined value " Δt_1 " ($|t - to| > \Delta t_1$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is kept closed and the two-way valves 323 and 324 become in the open condition.

[0559] Accordingly, all of the refrigerant of the intermediate pressure which has come out of the outdoor main expansion apparatus 314 passes through the indoor main expansion apparatus 315 so as to be put under low pressure, and then, evaporates so as to cool the space provided in the indoor unit. 325. After that, the refrigerant passes through the four-way valve 312 so as to be again absorbed into the compressor 311.

[0560] In the above-mentioned conditions, the two-way valve 320 is closed while the two-way valves 323 and 324 are open and the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 are connected to the intake pipe of the compressor 311 via the two-way valve 323 and the two-way valve 324, and therefore, the inside of the rectifying separator 317, the inside of the cooling unit 318 and the inside of the reservoir unit 319 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0561] By controlling the two-way valves 320, 323 and 324 as described above, the refrigerant in the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the operation is carried out in the condition wherein the main circuit has a large amount of refrigerant. As a result of this, the heat pump apparatus can carry out the operation with high performance appropriate to the load.

[0562] Next, a load determination is carried out (STEP 2). In STEP 2, in the case that the difference between the temperature "t" of the intake air of the indoor unit 325 which is detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 is a first predetermined value " Δt_1 " or less ($|t - to| \leq \Delta t_1$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valve 320 as well as a closing signal of the two-way valves 323 and 324 are sent from the operation control

apparatus 328. As a result of this, the two-way valve 320 is opened (STEP 3).

[0563] At this time, part of the two-phase refrigerant of intermediate pressure which has come out of the outdoor main expansion apparatus 314 passes through the two-way valve 320 and the sub-expansion apparatus 321, and flows into the bottom of the rectifying separator 317.

[0564] Under the above-mentioned initial condition little refrigerant exists inside the rectifying separator 317, the cooling unit 318 and the reservoir unit 319, which is in a substantially empty condition. Under these conditions, the refrigerant flows into the bottom of the rectifying separator 317. The refrigerant which has flown into the bottoms of the rectifying separator 317 passes through the rectifying separator 317 and the cooling unit 318 and is rapidly collected in the reservoir unit 319.

[0565] Therefore, the refrigerant amount in the main circuit is reduced and the heat pump apparatus is instantly reduced in performance so that the operation quickly corresponding to the reduction of the cooling load becomes possible.

[0566] Next, the load determination is carried out in STEP 4. In the case that the difference between the intake air temperature "t" of the indoor unit 325, which is detected by the indoor thermal sensor 326, and the set air temperature "to", which is stored in the memory apparatus 327, exceeds the second predetermined value " Δt_2 ", which is smaller than the first predetermined value " Δt_1 " ($\Delta t_1 > \Delta t_2$) ($|t - t_o| > \Delta t_2$), the process returns to STEP 2.

[0567] On the other hand, in STEP 4 in the case that the difference between the intake air temperature "t" of the indoor unit 325, which is detected by the indoor thermal sensor 326, and the set air temperature "to", which is stored in the memory apparatus 327, is the second predetermined value " Δt_2 " or less ($|t - t_o| \leq \Delta t_2$), that is to say, in the case that the cooling load is even smaller, the outputting signal of the two-way valves 320 and 323 and the closing signal of the two-way valve 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 and 323 are opened (STEP 5).

[0568] At this time, part of the two-phase refrigerant of intermediate pressure which has come out of the outdoor main expansion apparatus 314 passes through the two-way valve 320 and the sub-expansion apparatus 321, and flows into the bottom of the rectifying separator 317. Then, part of the refrigerant of the rectifying separator 317 passes through the sub-expansion apparatus 322 so as to be reduced in pressure and becomes a two-phase refrigerant of low temperature and, then, flows into the cooling unit 318. In the cooling unit 318 the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 317.

[0569] Under the above-mentioned condition, the

rectifying separator 317, the cooling unit 318 and the reservoir unit 319 are filled with the liquid refrigerant. Therefore, mainly gas refrigerant starts moving upward into the rectifying separator 317 from the bottom of the rectifying separator 317, and is cooled and liquefied in the cooling unit 318. This liquefied refrigerant returns to the top part of the rectifying separator 317 while being collected in the reservoir unit 319 and moves downward into the rectifying separator 317.

[0570] When these conditions occur in sequence the refrigerant gas which moves upward into the rectifying separator 317 and the refrigerant liquid which moves downward into the rectifying separator 317 make a contact between the gas and the liquid within the rectifying separator 317. This contact between the gas and the liquid causes rectifying effects so that refrigerant which gradually increases in refrigerant components of low boiling point is collected in the reservoir unit 319. On the other hand, the refrigerant, which moves downward into the rectifying separator 317, gradually increases in refrigerant components of high boiling point. The refrigerant which contains a large amount of refrigerant components of high boiling point merges together with the two-phase refrigerant which has passed through the two-way valve 320 and the sub-expansion apparatus 321 and which has flown into the bottom of the rectifying separator 317 and, then, passes through the sub-expansion apparatus 322, the cooling unit 318 and, in addition, through the opened two-way valve 323 so as to be absorbed into the compressor 311.

[0571] In this manner, in the heat pump apparatus of Embodiment 13, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered in response to the load, in the case that the load is yet smaller. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 319, the main circuit contains a decreasing amount of refrigerant and the effects of the decrease of the refrigerant amount additionally contributes to the lowering of the performance level, and therefore, the heat pump apparatus of Embodiment 13 can carry out the operation of low performance appropriate for the load.

[0572] In the heat pump apparatus of Embodiment 13, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 318, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 318 can be made compact but also the gas in the top part of the rectifying separator 317 can, without fail, be liquefied.

[0573] Under the above-mentioned condition, the time determination is carried out next (STEP 6). When a preset time T_a has elapsed the two-way valve 320, 323 and 324 are closed (STEP 7). In this way, by closing the two-way valves 320, 323 and 324, the condition remains such that the refrigerant of low boiling point is collected

in the reservoir unit 319 so that the main circuit can be operated with the refrigerant which contains a large amount of cooling components of high boiling point. Thereby, the closed circuit formed of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 can be detached from the main circuit. As a result of this, the circuit which makes the two-phase refrigerant flow into the low pressure side can be blocked so that loss of heat amount required for rectifying separation can be eliminated. Accordingly, the heat pump apparatus of Embodiment 13 can reduce performance in response to the load and carry out a highly efficient operation.

[0574] Next, the load determination is carried out in STEP 8. In the case that the difference between the intake air temperature "t" of the indoor unit 325, which is detected by the indoor thermal sensor 326, and the set air temperature "to", which is stored in the memory apparatus 327, is the second predetermined value " Δt_2 " or less ($|t - t_o| \leq \Delta t_2$), that is to say, in the case that the cooling load is even smaller, the conditions in STEP 7 are maintained so that the main circuit is operated with the refrigerant of a large amount of high boiling point components.

[0575] On the other hand, in STEP 8, in the case that the difference between the intake air temperature "t" of the indoor unit 325, which is detected by the indoor thermal sensor 326, and the set air temperature "to", which is stored in the memory apparatus 327, exceeds the second predetermined value " Δt_2 " ($|t - t_o| > \Delta t_2$), that is to say, in the case that the refrigerant load becomes larger, the process returns to STEP 1 so that the closing signal of the two-way valve 320 and the opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328.

[0576] As a result of this, the two-way valve 320 becomes in the closed condition while the two-way valves 323 and 324 become in the open condition. By converting to these conditions the refrigerant collected in the reservoir unit 319 is absorbed into the compressor 311 via the two-way valves 323 and 324, and the refrigerant components of the main circuit return to the form of filler components of high performance. In addition the refrigerant amount in the main circuit increases so that the operation of high performance in response to the load can be restarted.

[0577] In this way, in the heat pump apparatus of Embodiment 13, the size of the load is detected by using the difference between the temperature of the intake air of the indoor unit 325 and the set air temperature so that performance control is carried out through a simple operation of opening and closing the two-way valves 320, 323 and 324. The heat pump apparatus of Embodiment 13 can operate by switching between the means for carrying out performance control by reducing the refrigerant amount in the main circuit in the case that the load is slightly reduced and the means for carrying out performance control by reducing the refrigerant

amount in the main circuit and, additionally, can operate by shifting the refrigerant components into the condition corresponding to the load in the case that the load is greatly reduced. Thereby, the heat pump apparatus of Embodiment 13 becomes an apparatus which allows even greater control in response to the load change.

[0578] In addition, by detaching the closed circuit formed of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 from the main circuit at the time of completion of the rectifying separation operation the two-phase refrigerant can be made not to flow into the low pressure side so as to enable the elimination of the loss of the heat amount required for the rectifying separation. Due to such a structure the heat pump apparatus of Embodiment 13 can carry out a highly efficient operation at the time of performance reduction.

[0579] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling, of which the description is omitted. The opening and closing operation of the two-way valves 320, 323 and 324 is the same as that of the control flow chart indicating the control operation as shown in FIG. 25.

[0580] Here, in the above-mentioned Embodiment 13, though both the two-way valve 323 and the two-way valve 324 are in the open condition, either one, only, of the two-way valve 323 or the two-way valve 324 may be open in the structure so as to gain the same effects as in the above-mentioned Embodiment 13.

《Embodiment 14》

[0581] Next, a heat pump apparatus of Embodiment 14 in accordance with the present invention is described with reference to FIGS. 26 and 27. FIG. 26 is a system configuration view of the heat pump apparatus of Embodiment 14. FIG. 27 is a control flow chart of the heat pump apparatus of Embodiment 14.

[0582] In the heat pump apparatus of Embodiment 14, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 12 are referred to using the same numerals.

[0583] The heat pump apparatus of Embodiment 14 is provided with a gas liquid separator 330 between the outdoor main expansion apparatus 314 and the indoor main expansion apparatus 315 in the heat pump apparatus of Embodiment 12.

[0584] The upper part of this gas liquid separator 330 is connected to the two-way valve 320. In addition, the lower part of the gas liquid separator 330 is connected to the inlet of the two-way valve 320 via the sub-expansion apparatus 331.

[0585] Next, the operation of the refrigeration cycle of the heat pump apparatus of Embodiment 14 formed as in the above is described with reference to FIG. 27.

[0586] FIG. 27 is a control flow chart of the heat

pump apparatus of Embodiment 14.

[0587] In the following description the case where high performance is required, such as immediately after the start-up of the compressor 311, is assumed to be the start of the process.

[0588] First, the operation at the time of cooling is described. In STEP 1 the two-way valve 320 is closed while the two-way valves 323 and 324 are open. At this time, the refrigerant of high temperature and high pressure which has been discharged from the compressor 311 passes through the four-way valve 312 and flows into the outdoor heat exchanger 313. The refrigerant which has been condensed and liquefied in the outdoor heat exchanger 313 flows into the outdoor main expansion apparatus 314 and is reduced in pressure, here, to the intermediate pressure.

[0589] Under the above-mentioned conditions, the load determination is carried out (STEP 2). In the case that the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - to| > \Delta t$), that is to say, in the case that the cooling load is large, a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is maintained in the closed condition and the two-way valves 323 and 324 are maintained in the open condition.

[0590] Accordingly, all of the refrigerant of the intermediate pressure which has come out of the outdoor main expansion apparatus 314 passes through the gas-liquid separator 330 and through the indoor main expansion apparatus 315 so as to be put under low pressure and, then, is sent into the indoor heat exchanger 316. The refrigerant which evaporates in the indoor heat exchanger 316 cools the space wherein the indoor unit 325 is provided and, after that, the refrigerant passes through the four-way valve 312 so as to be again absorbed into the compressor 311.

[0591] The two-way valve 320 is closed while the two-way valves 323 and 324 are opened and the cooling unit 318 and the reservoir unit 319 are connected to the intake pipe of the compressor 311, and therefore, the inside of the rectifying separator 317, the inside of the cooling unit 318 and the inside of the reservoir unit 319 are filled with low pressure gas and hold almost no reservoir of the refrigerant.

[0592] By forming the refrigeration cycle as described above, the refrigerant in the main circuit is non-azeotropic refrigerant where the filler components have been mixed in and the operation is carried out in the condition wherein the main circuit has a large amount of refrigerant. Accordingly, the heat pump apparatus can carry out the operation with high performance appropriate to the load.

[0593] Next, a load determination is carried out (STEP 2). In STEP 2, in the case that the difference

between the temperature "t" of the intake air of the indoor unit 325 which is detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 is a predetermined value " Δt " or less ($|t - to| \leq \Delta t$), that is to say, in the case that the cooling load is small, an opening signal of the two-way valves 320 and 323 and a closing signal of the two-way valve 324 are sent from the operation control apparatus 328. As a result of this, the two-way valves 320 and 323 are opened (STEP 3), and therefore, the two-phase refrigerant of intermediate pressure which has come out of the outdoor main expansion apparatus 314 flows into the gas-liquid separator 330 so as to be separated into the gas and the liquid.

[0594] In the gas liquid separator 330 gas components are held, mainly, in the upper part of the gas liquid separator 330 while the liquid components are held, mainly, in the lower part of the gas liquid separator 330. In this gas liquid separator 330 the gas components flow, mainly, to the two-way valve 320 from the pipe connected to the upper part of the gas liquid separator 330 while the liquid components flow, mainly, into the same two-way valve 320 via the sub-expansion apparatus 331 from the pipe connected to the lower part of the gas liquid separator 330.

[0595] Under the above-mentioned conditions, by properly adjusting the resistance amount of the flow of the sub-expansion apparatus 331, the weight of the flow amount of the gas components which flow from the upper part of the gas liquid separator 330 to the two-way valve 320 and that of the liquid components which flow from the lower part of the gas liquid separator 330 via the sub-expansion apparatus 331 can be made approximately the same. The two-phase refrigerant, of which the components are the mixture of gas and liquid, flows into the bottom of the rectifying separator 317.

[0596] At an initial stage of this condition, the insides of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 contain little refrigerant, and are in an almost empty condition, and therefore, the refrigerant passes through the rectifying separator 317 and the cooling unit 318 so as to be collected in the reservoir unit 319. In addition, part of the refrigerant which has flown into the bottom of the rectifying separator 317 passes through the sub-expansion apparatus 322 so as to be reduced in pressure and becomes a two-phase refrigerant of low temperature and, then, flows into the cooling unit 318. In the cooling unit 318 the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 317.

[0597] Under the above-mentioned conditions, the refrigerant of the reservoir unit 319 gradually increases so that the front part of the liquid refrigerant within the reservoir unit 319 flows into the rectifying separator 317 and, then, moves downward into the rectifying separator 317. Under these conditions a small, and diminishing, amount of liquid refrigerant moves upward into the rec-

tifying separator 317 and mainly gas refrigerant starts moving upward into the rectifying separator 317 from the bottom of the rectifying separator 317. The refrigerant which has moved upward into the rectifying separator 317 is cooled and liquefied in the cooling unit 318 and, then, is collected in the reservoir unit 319. Then, the refrigerant which has returned to the top part of the rectifying separator 317 moves downward into the rectifying separator 317.

[0598] When these conditions occur in sequence the refrigerant gas which moves upward into the rectifying separator 317 and the refrigerant liquid which moves downward into the rectifying separator 317 make a contact between the gas and the liquid within the rectifying separator 317. This contact between the gas and the liquid causes rectifying effects so that refrigerant which gradually increases in refrigerant components of low boiling point is collected in the reservoir unit 319. On the other hand, the refrigerant, which moves downward into the rectifying separator 317, gradually increases in refrigerant components of high boiling point. Therefore, the refrigerant which moves downward in the rectifying separator 317 merges together with the two-phase refrigerant which has passed through the two-way valve 320 and the sub-expansion apparatus 321 and which has flown into the bottom of the rectifying separator 317 and, then, passes through the sub-expansion apparatus 322, the cooling unit 318 and, in addition, through the opened two-way valve 323 so as to be absorbed into the compressor 311.

[0599] In this manner, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level can be lowered in response to the load, in the case that the load is small. In addition, since the refrigerant of low boiling point is collected in the reservoir unit 319, the main circuit contains a decreasing amount of refrigerant. Accordingly, the decrease of the refrigerant amount contributes to the further lowering of the performance level so that the heat pump apparatus of Embodiment 14 can carry out the operation of low performance appropriate for the load.

[0600] In the heat pump apparatus of Embodiment 14, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 318, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 318 can be made compact but also the gas in the top part of the rectifying separator 317 can, without fail, be liquefied.

[0601] In addition, the heat pump apparatus of Embodiment 14 is formed so that substantially the same amount of liquid refrigerant, that has the latent heat required for liquefying the gas and which moves upward into the rectifying separator 317, flows into the cooling unit 318, and therefore, it is formed so that the minimum amount of liquid refrigerant required for liquefying the

gas flows into the intake side of the compressor 311 via the cooling unit 318 and the two-way valve 323. Thereby, the heat pump apparatus of Embodiment 14 can reduce the heat loss during the rectifying separation operation so that the performance and efficiency can be prevented from being reduced.

[0602] Next, under the above-mentioned conditions the load determination is carried out (STEP 4). In STEP 4, when the load becomes large and in the case that the difference between the intake air temperature " t " of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature " t_o " stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is again closed while the two-way valves 323 and 324 are opened (STEP 1).

[0603] In this manner, by closing the two-way valve 320 and by opening the two-way valves 323 and 324, the refrigerant of low boiling point which has been collected in the reservoir unit 319 is absorbed into the compressor 311 via the two-way valves 323 and 324 so that the refrigerant components of the main circuit return to the condition of the filler components of high performance. Then the refrigerant amount in the main circuit increases so that the heat pump apparatus can restart the operation of high performance in response to the load.

[0604] In the heat pump apparatus of Embodiment 14, since the two-way valve 324 is, in particular, directly connected to the reservoir unit 319 and the intake pipe of the compressor 311, the refrigerant within the reservoir unit 319 can be made to flow out in a short period of time, which allows excellent control in response to the load change.

[0605] In this way, the conditions of the refrigerant amount and the refrigerant components in the main circuit can be changed, through a simple operation of opening and closing the two-way valves 320, 323 and 324, in response to the size of the load which is detected by using the difference between the temperature of the intake air of the indoor unit 325 and the set air temperature. Accordingly, the refrigerant amount and the refrigerant components of the main circuit can be adjusted in response to the load. As a result, the heat pump apparatus of Embodiment 14 can carry out performance control appropriately and with high precision in response to the load.

[0606] In addition, in the heat pump apparatus of Embodiment 14, since the ratio between the gas components and the liquid components of the refrigerant which flows into the two-way valve 321 from the gas liquid separator 330 at the time of the separation operation can be made approximately the same, an excessive and wasteful amount of liquid refrigerant is not made to flow into the intake side of the compressor 311 so as to

enable the reduction of heat loss during the rectifying separation operation. Therefore, the heat pump apparatus of Embodiment 14 becomes an excellent apparatus which can prevent the performance and the efficiency from being reduced so as to achieve energy conservation.

[0607] Next, the operation at the time of heating is described.

[0608] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling.

[0609] In the case that, at the time of heating, a high heating performance is required, such as immediately after the start-up of the compressor 311, the two-way valve 320 is closed while the two-way valves 323 and 324 are open (STEP 1). The refrigerant of high temperature and high pressure discharged from the compressor 311 in this condition passes through the four-way valve 312 and flows into the indoor heat exchanger 316. In the indoor heat exchanger 316, the refrigerant which has contributed to the heating so as to be condensed and liquefied flows into the indoor main expansion apparatus 315 and is reduced in pressure, here, to the intermediate pressure.

[0610] Under the above-mentioned conditions, a load determination is carried out (STEP 2). In STEP 2, in the case that the difference between the temperature "t" of the intake air of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" which is stored in the memory apparatus 327 exceeds a predetermined value " Δt ", that is to say, in the case that the heating load is large, a closing signal of the two-way valve 320 and an opening signal of two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is maintained in the closed condition while the two-way valves 323 and 324 are maintained in the open condition.

[0611] Accordingly, the refrigerant of intermediate pressure, which has come out of the indoor main expansion apparatus 315, passes through the gas liquid separator 330 and is, all, sent to the outdoor expansion apparatus 314. The refrigerant which has been put under low pressure in the outdoor expansion apparatus 314 evaporates in the outdoor heat exchanger 313 by taking in heat from the outside air and, afterwards, passes through the four-way valve 312 so as to be again absorbed into the compressor 311.

[0612] Under the above-mentioned conditions since the two-way valve 320 is closed and the cooling unit 318 and the reservoir unit 319 are connected to the intake pipe of the compressor 311 via the opened two-way valves 323 and 324, the insides of the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 contain gas of low pressure with almost no reservoir of refrigerant.

[0613] In this manner, by closing the two-way valve 320 and by opening the two-way valves 323 and 324, the operation is carried out under the conditions where the refrigerant in the main circuit is non-azeotropic refrigerant as the filled in components have been mixed and where the main circuit has a large amount of refrigerant. Accordingly, the heat pump apparatus of Embodiment 14 can carry out the operation of high performance appropriate to the load.

[0614] Next a load determination is carried out (STEP 2). In STEP 2, in the case that the difference between the temperature "t" of the intake air of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 is a predetermined value " Δt " or less ($|t - t_o| \leq \Delta t$), that is to say, in the case that the heating load is small, an opening signal of the two-way valves 320 and 323 and a closing signal of the two-way valve 324 are sent from the operation control apparatus 328. As a result of this, the two-way valves 320 and 323 are opened (STEP 3), and therefore, the two-phase refrigerant of intermediate pressure which has come out of the indoor main expansion apparatus 315 flows into the gas liquid separator 330 so as to be separated into gas and liquid. In the gas liquid separator 330, the gas components are, mainly, held in the upper part while the liquid components are held, mainly, in the lower part.

[0615] Accordingly, the gas components flow, mainly, into the two-way valve 320 from the pipe connected to the upper part of the gas liquid separator 330 while the liquid components flow, mainly, into the same two-way valve 320 via the sub-expansion apparatus 331 from the pipe connected to the lower part of the gas liquid separator 330. Accordingly, by adjusting the resistance amount of the flow of the sub-expansion apparatus 331, the weight of the flow amount of the gas components and the liquid components which flow from the gas liquid separator 330 to the two-way valve 320 can be made approximately the same. In this way, the mixed two-phase refrigerant, which has come out of the gas liquid separator 330, flows into the bottom of the rectifying separator 317 via the sub-expansion apparatus 331 and the two-way valve 320.

[0616] Initially under the above-mentioned conditions the rectifying separator 317, the cooling unit 318 and the reservoir unit 319 contain almost no refrigerant and are in a substantially empty condition, and therefore, the refrigerant which has passed through the rectifying separator 317 and the cooling unit 318 is collected in the reservoir unit 319. In addition, part of the refrigerant which has flown into the bottom of the rectifying separator 317 passes through the sub-expansion apparatus 322 so as to be reduced in pressure and becomes the two-phase refrigerant of low temperature and flows into the cooling unit 318. In this cooling unit 318, the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 317.

[0617] Under the above-mentioned conditions, the refrigerant of the reservoir unit 319 gradually increases so that the front part of the liquid refrigerant within the reservoir unit 319 allows the liquid refrigerant to move downward into the rectifying separator 317. Under these conditions, almost no liquid refrigerant moves upward into the rectifying separator 317. The main gas refrigerant starts moving upward into the rectifying separator 317 from the bottom of the rectifying separator 317 and is cooled and liquefied in the cooling unit 319 so as to be collected in the reservoir unit 319. Then, the refrigerant returns to the top part of the rectifying separator 317 and moves downward into the rectifying separator 317.

[0618] When these conditions occur in sequence the refrigerant gas which moves upward into the rectifying separator 317 and the refrigerant liquid which moves downward into the rectifying separator 317 make a contact between the gas and the liquid within the rectifying separator 317 so as to cause rectifying effects. As a result of this, the refrigerant which gradually increases in refrigerant components of low boiling point is collected in the reservoir unit 319. On the other hand, the refrigerant, which moves downward into the rectifying separator 317, gradually increases in refrigerant components of high boiling point, and passes through the two-way valve 320 and the sub-expansion apparatus 321 and merges together with the two-phase refrigerant which has flown into the bottom of the rectifying separator 317. The resultant refrigerant which has merged in this way passes through the sub-expansion apparatus 322, the cooling unit 318 and the opened two-way valve 323 and is absorbed into the compressor 311.

[0619] In this manner, in the heat pump apparatus of Embodiment 14, the main circuit contains the refrigerant of which the high boiling point refrigerant components gradually increase, and the performance level is lowered in response to the load, in the case that the load is small. In addition, in the heat pump apparatus of Embodiment 14, since the refrigerant of low boiling point is collected in the reservoir unit 319, the main circuit contains a decreasing amount of refrigerant and the decrease of the refrigerant amount contributes to the further lowering of the performance level so that the operation of low performance appropriate for the load can be carried out.

[0620] In addition, in the heat pump apparatus of Embodiment 14, the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 318, and therefore, the latent heat of the refrigerant can be utilized effectively so that not only the cooling unit 318 can be made compact but also the gas in the top part of the rectifying separator 317 can, without fail, be liquefied.

[0621] In addition, the heat pump apparatus of Embodiment 14 is formed so that the same amount of

liquid refrigerant, which has the latent heat required for liquefying the gas that moves upward into the rectifying separator 317, is made to flow into the cooling unit 318 and no liquid refrigerant exceeding the necessary amount is made to flow into the intake side of the compressor 311 via the cooling unit 318 and the two-way valve 323. Accordingly, the heat pump apparatus of Embodiment 14 can reduce heat loss during the rectifying separation operation, that is to say, the amount of liquid refrigerant which can be effectively utilized for cooling and which is bypassed to the compressor 311, and therefore, can reduce the loss of performance and efficiency.

[0622] Next, under the above-mentioned conditions (STEP 3) the load determination is carried out (STEP 4). In STEP 4, in the case that the load becomes large and the difference between the intake air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt " ($|t - t_o| > \Delta t$), a closing signal of the two-way valve 320 and an opening signal of the two-way valves 323 and 324 are sent from the operation control apparatus 328. As a result of this, the two-way valve 320 is again closed and the two-way valves 323 and 324 are opened (STEP 1).

[0623] Thereby, the reservoir which has been collected in the reservoir unit 319 is absorbed into the compressor 311 via the two-way valves 323 and 324 so that the refrigerant composition of the main circuit returns to the condition of the filler components of high performance. In addition, the refrigerant amount of the main circuit increases so that the operation of high performance in response to the load can be restarted.

[0624] In the heat pump apparatus of Embodiment 14 the two-way valve 324, in particular, makes a direct connection between the reservoir unit 319 and the intake pipe of the compressor 311, and therefore, the refrigerant within the reservoir unit 319 can be made to flow out in a short period of time so that excellent control is achieved in response to the load.

[0625] In this manner, in the heat pump apparatus of Embodiment 14, the refrigerant amount of the main circuit and the refrigerant composition can be changed through a simple operation of opening and closing the two-way valves 320, 323 and 324, by detecting the size of the load through the difference between the intake air temperature of the indoor unit 325 and the set air temperature. Therefore, the heat pump apparatus of Embodiment 14 can carry out an appropriate performance control with high precision in response to the load.

[0626] In addition, in the heat pump apparatus of Embodiment 14 the ratio between the gas components and the liquid components of the refrigerant which flows into the two-way valve 321 from the gas liquid separator 330 at the time of separation operation can be made approximately equal, and therefore, heat loss during the rectifying separation operation can be reduced.

[0627] Thereby, the heat pump apparatus of Embodiment 14 becomes an apparatus which can prevent the performance and the efficiency from being lowered so as to be excellent in energy conservation.

[0628] Here, in Embodiment 14, under either of the operation conditions of cooling or heating, in the case that the load becomes large and the difference between the in take air temperature "t" of the indoor unit 325 detected by the indoor thermal sensor 326 and the set air temperature "to" stored in the memory apparatus 327 exceeds a predetermined value " Δt ", only one of either the two-way valve 323 or the two-way valve 324 may be opened. Even in this configuration, the same effects as in the above-mentioned Embodiments are gained.

(Embodiment 15))

[0629] Next, a heat pump apparatus of Embodiment 15 in accordance with the present invention is described with reference to FIGS. 28 and 29. FIG. 28 is a system configuration view of the heat pump apparatus of Embodiment 15. FIG. 29 is a control flow chart of the heat pump apparatus of Embodiment 15.

[0630] In the heat pump apparatus of Embodiment 15, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 12 are referred to using the same numerals.

[0631] The heat pump apparatus of Embodiment 15 is provided with a discharge thermal sensor 341 which detects the discharge temperature of the compressor 311. In addition, the memory apparatus 342 of the heat pump apparatus of Embodiment 15 is formed so as to store the set discharge temperature value which has been preset. In addition, the operation control apparatus 343 of the heat pump apparatus of Embodiment 15 compares the set discharge temperature value of the memory apparatus 342 with the discharge temperature detected by the discharge thermal sensor 341 for operation so as to control the two-way valves 320, 323 and 324 to open and to close.

[0632] Next, the operation of the refrigeration cycle in the heat pump apparatus of Embodiment 15 formed as in the above is described with reference to FIG. 29.

[0633] FIG. 29 is a flow chart of the discharge temperature control in the heat pump apparatus of Embodiment 15.

[0634] In the following the case where high performance is required, such as immediately after the start-up of the cooling operation of the compressor 311, is assumed to be the start of the process.

[0635] At the time of cooling operation, immediately after the start up of the compressor 311, the two-way valve 320, 324 and 324 are in the closed condition (STEP 1). In the following STEP 2 the discharge temperature T_d of the compressor 311 which is detected by the discharge temperature sensor 341 is compared with

the first set discharge temperature T_1 stored in the memory apparatus 342. Then, in the case that the discharge temperature T_d is the first set discharge temperature T_1 or less ($T_d \leq T_1$), the process returns to STEP 1 and the closing signal of the two-way valves 320, 323 and 324 is sent from the operation control apparatus 343. As a result of this, the two-way valves 320, 323 and 324 maintain the closed condition. In this case, no refrigerant passes through the two-way valves 320, 323 and 324 and the refrigerant circulates only through the main circuit.

[0636] On the other hand, in the case that in STEP 2, the discharge temperature T_d of the compressor 311 which is detected by the discharge thermal sensor 341 exceeds the first set discharge temperature T_1 which is stored in the memory apparatus 342 ($T_d > T_1$), the process moves to STEP 3. In STEP 3, the opening signal of the two-way valve 320 and 324 and the closing signal of the two-way valve 323 are sent from the operation control apparatus 343. As a result of this, the two-way valves 320 and 324 are opened and the two-way valve 323 maintains the closed condition.

[0637] In this case, part of the refrigerant of intermediate pressure, which has come out of the outdoor expansion apparatus 314, passes through the two-way valve 320 and the sub-expansion apparatus 321, and flows into the bottom of the rectifying separator 317. Then the refrigerant which has flown into the bottom of the rectifying separator 317 passes through the opened two-way valve 324 via the reservoir unit 319 and flows into the intake pipe of the compressor 311. Here, the refrigerant which has flown in is mixed with the refrigerant gas which has passed through the four-way valve 312 and is absorbed into the compressor 311 while lowering the temperature or degree of dryness of the refrigerant gas. Thereby, the discharge temperature of the compressor 311 can be lowered to a safer value.

[0638] Next, in the case that in STEP 4 the discharge temperature T_d of the compressor 311, which is detected by the discharge thermal sensor 341, is the second set discharge temperature T_2 , which is stored in the memory apparatus 342, or less ($T_d \leq T_2$), the process returns to STEP 2. Here, the second set discharge temperature T_2 is a value larger than the first set discharge temperature T_1 ($T_2 > T_1$). In this case, when the process returns to STEP 2, the opening signal of the two-way valves 320 and 324 and the closing signal of the two-way valve 323 are sent from the operation control apparatus 343 in the next STEP 3 so that the two-way valves 320 and 324 are opened and the two-way valve 323 maintains the closed condition.

[0639] On the other hand, in the case that in STEP 4, the discharge temperature T_d of the compressor 311, which is detected by the discharge thermal sensor 341, exceeds the second set discharge temperature T_2 ($T_d > T_2$), the process moves to STEP 5. In STEP 5 the opening signal of the two-way valves 320, 323 and 324 is sent from the operation control apparatus 343 and the

two-way valves 320, 323 and 324 are opened.

[0640] In this case, part of the refrigerant of intermediate pressure which has come out of outdoor expansion apparatus 314 passes through the two-way valve 320 and sub-expansion apparatus 321 and flows into the bottom of the rectifying separator 317. Then, part of the refrigerant which has flown into the bottom of the rectifying separator 317 passes through the reservoir unit 319 and passes through the opened two-way valve 324 so as to flow into the intake pipe of the compressor 311.

[0641] On the other hand, part of the refrigerant which has flown into the bottom of the rectifying separator 317 flows into the intake pipe of the compressor 311 via the sub-expansion apparatus 322, the cooling unit 318 and the two-way valve 323. Here, the refrigerant which has flown in is mixed with the refrigerant gas which has passed through the four-way valve 312 and is absorbed by the compressor 311 while lowering the temperature and the degree of dryness.

[0642] In the heat pump apparatus of Embodiment 15 since the two-way valve is controlled to open and to close, as described above, a greater amount of two-phase refrigerant of intermediate pressure can be made to flow into the intake pipe of the compressor 311. Accordingly, the heat pump apparatus of Embodiment 15 can allow the discharge temperature of the compressor 311 to be instantly lowered to a safer value.

[0643] Next, the operation at the time of heating is described.

[0644] The flow of the refrigerant at the time of the heating operation is in the opposite direction in the main circuit and the remaining part of the operation is the same as the above-mentioned operation at the time of cooling, of which the description is omitted.

[0645] Here, though, in Embodiment 15, the relationship between the opening and closing control of the two-way valve and the rectifying separation operation is not described in detail, the discharge temperature control method in accordance with the present invention is, of course, operable under any load circumstances, as shown in the above-mentioned Embodiment 12.

[0646] As described above, in Embodiment 15 a discharge thermal sensor 341 which detects the discharge temperature of the compressor 311 is provided and simply through a simple operation of opening and closing, which compares the two-way valves 320, 323 and 324 with the set discharge temperature value, which has been preset, the discharge temperature of the compressor 311 can be reduced to a safe value. In addition, in the heat pump apparatus of Embodiment 15, since a large amount of two-phase refrigerant can be made to flow through the switching operation of the two-way valves in the case that the discharge temperature is higher, the temperature can be swiftly lowered to a safe temperature and, since the flow amount is adjusted in accordance with the discharge temperature, no excessive two-phase refrigerant is made to flow to

lower the reliability of the compressor.

(Embodiment 16)

[0647] Next, a heat pump apparatus of Embodiment 16 in accordance with the present invention is described with reference to FIG. 30. FIG. 30 is a system configuration view of the heat pump apparatus of Embodiment 16. A non-azeotropic refrigerant is charged in the heat pump apparatus of Embodiment 16 which forms the main circuit of a refrigeration cycle by connecting, through pipes, a compressor 421, a four-way valve 422, an outdoor heat exchanger 423, an outdoor expansion apparatus 424, an indoor expansion apparatus 425 and an indoor heat exchanger 426 in an annular structure.

[0648] The heat pump apparatus of Embodiment 16 is provided with a heat regenerator 427. One end of the heat regenerator 427 is connected, via the two-way valve 428, to the pipe which links the four-way valve 422 and the indoor heat exchanger 426. This two-way valve 428 is operated so as to be opened at the time of the heat storage operation. And, one end of the heat regenerator 427 is connected to the intake pipe of the compressor 421 via the two-way valve 430. This two-way valve 430 is operated so as to be opened at the time of usage of stored heat. The other end of the heat regenerator 427 is connected, via the heat storage expansion apparatus 429, to the pipe which links the outdoor expansion apparatus 424 and the indoor expansion apparatus 425. In addition, the heat regenerator 427 is provided within the heat storage tank 439, while the inside of the heat storage tank 439 is filled in with heat storage material 440, such as water.

[0649] The rectifying separator 431 is formed of a straight pipe which is long in the vertical direction into which filling material (not shown) is filled. In addition, the top part of the rectifying separator 431 is communicated to the top of a reservoir unit 433 via a cooling unit 432. And the bottom of the reservoir unit 433 is communicated to the top part of the rectifying separator 431. The top part of the rectifying separator 431, the cooling unit 432 and the reservoir unit 433 are connected in an annular structure so as to form a closed circuit.

[0650] In the heat pump apparatus of Embodiment 16, the top part of the reservoir unit 433 is arranged to be in a higher position than the top part of the rectifying separator 431. In addition, the cooling unit 432 is arranged in a position higher than the top part of the reservoir unit 433.

[0651] The pipe which makes a connection between the top part of the rectifying separator 431 and the cooling unit 432 is connected to the opening of the ceiling of the top part of the rectifying separator 431. The pipe which makes a connection between the bottom of the reservoir unit 433 and the top part of the rectifying separator 431 is connected to the opening formed on the side of the top part of the rectifying separator.

rator 431.

[0652] The pipe which links the outdoor expansion apparatus 424 and the indoor expansion apparatus 425 is connected to the bottom of the rectifying separator 431, via the two-way valve 434 and the sub-expansion apparatus 435. In addition, the bottom of the rectifying separator 431 is connected to the intake pipe of the compressor 421 which create a linkage between the compressor 421 and the four-way valve 422 via the sub-expansion apparatus 436, the cooling unit 432 and the two-way valve 437. In addition, the cooling unit 432 is formed so that the refrigerant moving from the bottom of the rectifying separator 431 toward the two-way valve 437 via the sub-expansion apparatus 436 and the refrigerant in the top part of the rectifying separator 431 indirectly exchange heat. As for the cooling unit 432, it is possible to adopt a double pipe structure. In addition, the bottom of the reservoir unit 433 is connected, via the two-way valve 438, to the intake pipe of the compressor 421 which creates a linkage between the compressor 421 and the four-way valve 422.

[0653] Next, the operation of the refrigeration cycle of the heat pump apparatus of Embodiment 16, formed as described above, is described.

[0654] In the cooling operation mode the two-way valves 428 and 430 are closed and the refrigerant gas of high pressure, which has come out of the compressor 421, passes through the four-way valve 422 and is condensed and liquefied when releasing heat to the outside air in the outdoor heat exchanger 423. The liquid refrigerant which has condensed and liquefied passes through the outdoor expansion apparatus 424 and the indoor expansion apparatus 425 and is reduced in pressure so as to be sent to the indoor heat exchanger 426. The refrigerant which has been sent to the indoor heat exchanger 426 absorbs heat from the indoor space so as to contribute to the cooling operation and evaporates so as to, again, pass through the four-way valve 422 and, then, returns to the compressor 421.

[0655] In the heating operation mode the two-way valves 428 and 430 are closed and the refrigerant gas of high pressure which has come out of the compressor 421 passes through the four-way valve 422 and releases heat into the indoor space in the indoor heat exchanger 426 so as to contribute to the heating operation and condenses so as to pass through the indoor expansion apparatus 425 and the outdoor expansion apparatus 424 and, then, is reduced in pressure. The refrigerant which has been reduced in pressure evaporates by absorbing heat from the outside air in the outdoor heat exchanger 423 and, again, passes through the four-way valve 422 so as to return to the compressor 421.

[0656] Next, the heat storage operation mode which stores heat in the heat storage material 440 within the heat storage tank 439 is described. In the heat storage operation mode the two-way valve 428 is opened while the two-way valve 430 is closed. And, the outdoor

expansion apparatus 424 is in the opened condition while the indoor expansion apparatus 425 is either closed or is in, when the apparatus is somewhat opened, a slightly opened condition.

[0657] Because of the opening and closing control in this manner the refrigerant gas of high pressure, which has come out of the compressor 421 passes through the four-way valve 422, and almost none of the refrigerant flows into the indoor heat exchanger 426, rather, most of the refrigerant gas passes through the two-way valve 428 so as to flow into the heat regenerator 427. Then, the refrigerant which has flown into the heat regenerator 427 releases heat to the heat storage material 440 which is placed within the heat storage tank 439 and the heat is stored in the heat storage material 440.

[0658] The refrigerant liquid which has come out of the heat regenerator 427 passes through the heat storage expansion apparatus 429 as well as the outdoor expansion apparatus 424, and is reduced in pressure and, then, flows into the outdoor heat exchanger 423. The refrigerant which has absorbed heat from the outside air in the outdoor heat exchanger 423 and which has contributed to the cooling operation evaporates and passes through the four-way valve 422 again so as to return to the compressor 421.

[0659] Next, the stored heat usage operation mode wherein the stored heat of the heat storage material 440 within the outdoor heat storage tank 439 is utilized for the heating operation is described.

[0660] In the stored heat usage operation mode, the two-way valve 428 is closed while the two-way valve 430 is opened. And, the outdoor expansion apparatus 424 is in the completely closed condition while the indoor expansion apparatus 425 is in the opened condition.

[0661] Because of the opening and closing control in this manner the refrigerant gas of high pressure, which has come out of the compressor 421, passes through the four-way valve 422 and all of the refrigerant flows into the indoor heat exchanger 426. The refrigerant which has released heat into the indoor space in the indoor heat exchanger 426 and which has contributed to the heating operation condenses and passes through the indoor expansion apparatus 425 and the heat storage expansion apparatus 429 so as to be reduced in pressure and flows into the heat regenerator 427.

[0662] The refrigerant which has flown into the heat regenerator 427 absorbs heat from the heat storage material 440 which has stored heat and is of a high temperature. The refrigerant which has evaporated in the heat regenerator 427 passes through the two-way valve 430 and returns to the compressor 421. By carrying out the stored heat usage operation mode in this manner, the evaporation temperature of the refrigerant is maintained at a high level, the pressure becomes high and the circulation amount of the refrigerant in the main circuit increases. As a result of this, the heating perform-

ance becomes excellent.

[0663] Here, in this stored heat usage operation mode, it is possible to implement the operation of the mode which absorbs heat only from the heat storage material 440 and the operation of the mode which uses the outdoor heat exchanger 423 as an additional evaporator. In the case that the operation is carried out while adjusting the opening degree of the outdoor expansion apparatus 424 by using the outdoor heat exchanger 423 in this manner, this operation is effective when the amount of stored heat in the heat storage material 440 is lowered in comparison with the heating load.

[0664] In the above-mentioned refrigeration cycle, the operation utilizes three heat exchangers of the outdoor heat exchanger 423, the indoor heat exchanger 426 and the heat regenerator 427, and therefore, the optimal refrigerant amount is not constant in each operation mode and an extra refrigerant amount is generated in certain operation modes. In that case, by opening the two-way valve 434 while closing the two-way valves 437 and 438, the extra refrigerant passes through the sub-expansion apparatus 435 and the rectifying separator 431 so as to be collected in the reservoir unit 433. Through opening and closing control in this manner it becomes possible to adjust to the optimal refrigerant amount in each operation mode so as to increase the operational efficiency.

[0665] In Embodiment 16 storing heat in the heat storage material 440 and utilizing the stored heat can be easily implemented through a simple operation of switching the two-way valves 428 and 430.

[0666] On the other hand, in the case that the performance level is desired to be reduced when the load becomes small at the time of the cooling operation or at the time of the heating operation or in the case that the temperature of the stored heat in the heat storage material 440 has increased at the time of the heat storage operation and the pressure has increased to a high level, then the two-way valves 434 and 437 are opened while the two-way valve 438 is closed in either operation mode. Through the opening and closing control in this manner, part of the two-phase refrigerant of intermediate pressure which is in the middle of the indoor expansion apparatus 425 and the storage expansion apparatus 429 passes through the two-way valve 434 and the sub-expansion apparatus 435 and flows into the bottom of the rectifying separator 431. The refrigerant which has passed through the rectifying separator 431 is collected in the reservoir unit 433. In addition, part of the refrigerant which has flown into the bottom of the rectifying separator 431 passes through the sub-expansion apparatus 436 so as to be reduced in pressure and becomes a two-phase refrigerant of low temperature so as to flow into the cooling unit 432. In the cooling unit 432 the two-phase refrigerant of low temperature indirectly exchanges heat with the refrigerant in the top part of the rectifying separator 431.

[0667] The refrigerant within the storage unit 433

gradually increases and the front part of the liquid refrigerant within the reservoir unit 319 moves downward into the rectifying separator 431. Under these conditions, almost no liquid refrigerant moves upward into the rectifying separator 431 and, mainly, the gas refrigerant starts moving upward into the rectifying separator 431 from the bottom, which is cooled in the cooling unit 432 so as to be liquefied and is collected in the reservoir unit 433. Then, the refrigerant returns to the top part of the rectifying separator 431 and moves downward into the rectifying separator 431.

[0668] When this condition occurs continuously the refrigerant gas which moves upward into the rectifying separator 431 and the refrigerant liquid which moves downward into the rectifying separator 431 makes a gas-liquid contact within the rectifying separator 431 and this gas-liquid contact causes the rectifying operation so that the refrigerant of low boiling point is gradually collected in the reservoir unit 433.

[0669] On the other hand, the refrigerant which moves downward into the rectifying separator 431 gradually becomes refrigerant of high boiling point and merges together with the two-phase refrigerant which has passed through the two-way valve 434 and the sub-expansion apparatus 435 and which has flown into the bottom of the rectifying separator 431 and passes through the sub-expansion apparatus 436, the cooling unit 432 and the opened two-way valve 437 so as to be absorbed into the compressor 411.

[0670] In this manner, the main circuit gradually begins to contain refrigerant of high boiling point so as to enable the reduction of the performance in accordance with the case wherein the load is small. In addition, even in the case that the temperature of the heat storage material 440 increases and the condensation temperature increases at the time of the heat storage operation since the pressure is lowered, the high pressure can be maintained at a low level and it is possible to generate a high condensation temperature while maintaining the pressure of the compressor 421 within the upper limit range and the heat storage temperature can be enhanced so as to increase the amount of stored heat.

[0671] Moreover, in Embodiment 16, since the two-phase refrigerant of low temperature and low pressure of which the enthalpy is the lowest in the refrigeration cycle is utilized as the cooling source of the cooling unit 432, the latent heat of the refrigerant can be utilized efficiently and not only the cooling unit 432 can be made compact but, also, the gas in the top part of the rectifying separator 431 can be liquefied without fail.

[0672] On the other hand, in the case that load becomes large at the time of the cooling operation and at the time of the heating operation or in the case that the temperature of stored heat of the heat storage material 440 is low and high performance is necessary at the time of the initial heat storage operation, or the like, the two-way valve 434 is closed while the two-way valves

437 and 438 are opened. Through the opening and closing control in this manner the refrigerant which has been collected in reservoir unit 433 is absorbed into the compressor 421 via the two-way valve 437 and 438 and the refrigerant composition of the main circuit returns to the condition of the filler composition of high performance. As a result of this, the heat pump apparatus of Embodiment 16 can restart the operation of high performance in accordance with the load.

[0673] In the heat pump apparatus of Embodiment 16, since the two-way valve 438 is directly connected, in particular, to the reservoir unit 433 and to the intake pipe of the compressor 421, the refrigerant within the reservoir unit 433 can be made to flow out in a short period of time so as to allow for excellent control in response to the load change.

[0674] As described above, in the heat pump apparatus of Embodiment 16, it becomes possible to switch to the heat storage mode or to the stored heat usage mode merely through a simple operation of opening and closing the two-way valves 428 and 430. In addition, the extra refrigerant is collected through the opening and closing operation of the two-way valve 434 so as to enable the adjustment to the optimal refrigerant amount in each mode, and therefore, the heat pump apparatus of Embodiment 16 can be operated in a highly efficient manner.

[0675] In addition, in the case that the heat storage temperature has increased it becomes possible to store heat at high temperature while maintaining a safe pressure merely through a simple operation of opening and closing the two-way valves 434, 437 and 438.

[0676] In addition, the heat pump apparatus of Embodiment 16 can change the refrigerant composition in the main circuit at the time of the cooling operation as well as at the time of the heating operation merely through a simple operation of opening and closing the two-way valves 428 and 430. Accordingly, the heat pump apparatus of Embodiment 16 can carry out performance control with high precision in response to the load.

[0677] In addition, in Embodiment 16 the compressor 421 doesn't have a particular limitation but, rather, it is possible to use a performance variable type compressor such as an inverter compressor or a plurality of compressors may be used so as to gain the same effects as in the above-mentioned embodiment.

[0678] In addition, the refrigerant gas which is led into the bottom of the rectifying separator 431 may be led in from the refrigerant gas of the intake pipe of the compressor or from the intake pipe of the compressor 421 and other cooling sources may be used as the cooling source of the cooling unit 432 to gain the same effects.

(Embodiment 17)

[0679] Next, a heat pump apparatus of Embodi-

ment 17 in accordance with the present invention is described with reference to FIGS. 31 and 32. FIG. 31 is a system configuration view of the heat pump apparatus of Embodiment 17. FIG. 32 is a control flow chart of the heat pump apparatus of Embodiment 17.

[0680] In the heat pump apparatus of Embodiment 17, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 16 are referred to using the same numerals.

[0681] The heat pump apparatus of Embodiment 17 is provided with a heat storage thermal sensor 441 which detects the temperature of the heat storage material 440 within the heat storage tank 439. The heat storage thermal sensor 441 is arranged inside of the representative heat storage material 440 and is formed so as to detect the temperature thereof. Information of the detected temperature is sent to the operation control apparatus 443 to be operationally processed.

[0682] The memory apparatus 442 stores the preset temperature of the heat storage material 440. The operation control apparatus 443 compares the set temperature "to" of the heat storage material which is stored in the memory apparatus 442 and the heat storage material temperature "t" of the heat storage material 440 detected by the heat storage thermal sensor 441 for operation so as to control the two-way valves 434, 437 and 438 for opening and closing. In addition, the operation control apparatus 443 has a function of determining the period of time of continuous operation of the two-way valve.

[0683] The structure of the refrigeration cycle of the heat pump apparatus of Embodiment 17 is the same as the reflection cycle of the heat pump apparatus of Embodiment 16 as shown in the above-mentioned FIG. 30, of which the description is omitted.

[0684] Next, the operation of the refrigeration cycle of the heat pump apparatus of Embodiment 17, formed as described above, is described with reference to FIG. 32.

[0685] FIG. 32 is a control flow chart showing the control operation of the heat pump apparatus of Embodiment 17. The following description centers on the operation of the heat storage mode and the case wherein the compressor 421 is started up, under the condition where the temperature of the heat storage material is low, is assumed to be the start for the description.

[0686] In the above-mentioned case, since the initial heat storage requires a high performance level, the two-way valve 434 is closed while the two-way valves 437 and 438 are opened (STEP 1). Through the opening and closing control in this manner, the refrigerant gas of high pressure which has come out of the compressor 421 passes through the four-way valve 422 and most of the refrigerant passes through the two-way valve 428 and flows into the heat regenerator 427. This refrigerant releases heat into the heat storage material 440 which is placed within the heat storage tank 439

and this heat is stored in the heat storage material 440.

[0687] Under these conditions, the temperature of the heat storage material 440 is determined (STEP 2). In the case that the temperature "t" of the heat storage material 440, which has been detected by the heat storage thermal sensor 441, is the set temperature "to" of the heat storage material, which is stored in the memory apparatus 442, or less ($t \leq t_o$) in STEP 2, that is to say, in the case that the temperature of the heat storage material 440 is low and the storage heat load is determined to be continuously large, the closing signal of the two-way valve 434 and the opening signal of the two-way valves 437 and 438 are sent from the operation control apparatus 443. As a result of this, the two-way valve 434 stays closed while the two-way valves 437 and 438 stay opened so as to continue the operation.

[0688] At this time, since the two-way valve 434 is closed and the cooling unit 432 and the reservoir unit 433 are connected to the intake pipe of the compressor 421 via the opened two-way valves 437 and 438, the inside of the rectifying separator 431, the cooling unit 432 and the reservoir unit 433 contain the gas of low pressure with little storage of the refrigerant.

[0689] Through the opening and closing control in this manner, the main circuit is operated with the refrigerant being a non-azeotropic refrigerant, which remains the filler component. Accordingly, it becomes possible for the heat pump apparatus of Embodiment 17 to be operated with high performance in response to the heat storage load.

[0690] On the other hand, the temperature "t" of the heat storage material 440 is determined in STEP 2 and in the case that the temperature "t" of the heat storage material 440, which is detected by the heat storage thermal sensor 441, exceeds the set temperature "to" of the heat storage material, which is stored in the memory apparatus 442, ($t > t_o$), that is to say, in the case that the temperature of the heat storage material 440 is high while the storage heat load is small, the opening signal of the two-way valves 434 and 437 and the closing signal of the two-way valve 438 are sent from the operation control apparatus 443. As a result of this, the two-way valves 434 and 437 are opened while the two-way valve 438 is closed (STEP 3).

[0691] In this case, the condensation temperature of the heat regenerator 437 increases and the discharge pressure of the compressor 421 also increases, and therefore, the pressure approaches to the upper limit where the compressor 421 is operable. Here, part of the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 passes through the two-way valve 434 and the sub-expansion apparatus 435 and flows into the bottom of the rectifying separator 431. The operation of the refrigerant hereinafter is the same operation as described with reference to Embodiment 16. As a result of this, the main circuit gradually contains the refrigerant of high boiling point.

[0692] By making the main circuit to contain the refrigerant of high boiling point in this way, the pressure gradually decreases from that of the non-azeotropic refrigerant which was originally filled in, because the refrigerant of high boiling point attains a lower pressure at the same temperature. Therefore, the heat regenerator 437 maintains the condensation temperature while the discharge pressure of the compressor 421 becomes lower, so as to be far below the operable high pressure limit, wherein continuation of the heat storage operation becomes possible.

[0693] After that, the discharge pressure of the compressor 421 gradually increases and, together with this, the condensation temperature increases. Accordingly, it becomes possible to greatly increase the temperature "t" of the heat storage material 440 so as to increase the amount of stored heat of the heat storage material 440.

[0694] Next, time determination is carried out in STEP 4. In the case that the operation under the conditions of STEP 3 is detected to have continued for a specific period of time (Tset) the process moves to STEP 5. In STEP 5 the two-way valves 434, 437 and 438 are all in the closed condition. Since the two-way valve 434 is in the closed condition the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 will not flow into the rectifying separator 431. Accordingly, it becomes possible to eliminate heat loss when the two-phase refrigerant of intermediate pressure flows into the intake pipe of the compressor 421, such as at the time of the rectifying separation operation. In addition, the refrigerant of low boiling point, which has been collected in the reservoir unit 433 in STEP 3, is maintained in the same collected condition when the main circuit undergoes circulation with the same refrigerant composition of high boiling point. Accordingly, the rectifying separation operation is not required to be carried out again, even at the time of restart up after the apparatus has been stopped, and therefore, the heat storage operation can be maintained while increasing the operational efficiency.

[0695] Next, the temperature "t" of the heat storage material 440 is determined in STEP 6. In the case that the temperature "t" of the heat storage material 440, which has been detected by the heat storage thermal sensor 441 exceeds the set temperature "to" of the heat storage material, which is stored in the memory apparatus 442, ($t > t_o$), that is to say, in the case that the temperature "t" of the heat storage material 440 is high, the temperature "t" of the heat storage material 440 is determined as to whether or not it has exceeded a prescribed value (STEP 7). In the case that the temperature "t" of the heat storage material 440 is the preset upper limit temperature "tmax" of the heat storage material 440 or more ($t \geq t_{max}$) in STEP 7, the heat storage operation is completed. On the other hand, in the case that the temperature "t" of the heat storage material 440 is lower than the upper limit temperature tmax (t

< tmax) in STEP 7, the process returns to STEP 5 so as to continue the heat storage operation.

[0696] On the other hand, in the case that the temperature "t" of the heat storage material 440, which has been detected by the heat storage thermal sensor 441, is the set temperature "to" of the heat storage material, which is stored in the memory apparatus 442, or less ($t \leq t_o$) in STEP 6, that is to say, in the case that the temperature of the heat storage material 440 is low and the heat storage load becomes large, the process returns to STEP 1. Then, the closing signal of the two-way valve 434 and the opening signal of the two-way valves 437 and 438 are sent from the operation control apparatus 443 so that the two-way valve 434 remains closed while the two-way valves 437 and 438 are opened.

[0697] Thereby, the refrigerant of low boiling point, which has been collected in the reservoir unit 433, is absorbed into the compressor 421 via the two-way valves 437 and 438 so that the refrigerant composition of the main circuit returns to the condition of filler composition of high performance.

[0698] As a result of this, the heat pump apparatus of Embodiment 17 can restart the operation of high performance in response to the load.

[0699] In the heat pump apparatus of Embodiment 17, the two-way valve 438 is directly connected, in particular, to the reservoir unit 433 and the intake pipe of the compressor 421, and therefore, the refrigerant within the reservoir unit 433 can be made to flow out in a short period of time so as to allow excellent control of change of the load.

[0700] As described above, the heat pump apparatus of Embodiment 17 is formed so that the temperature of the heat storage material 440 is detected, and in the case that the temperature of the heat storage material has increased, the two-way valves 435, 437 and 438 are opened or closed to carry out the rectifying separation operation so that the main circuit contains the refrigerant of high boiling point, and therefore, it becomes possible to store the heat of high temperature while maintaining a safe pressure through a simple operation. In addition, in accordance with Embodiment 17, in the case that the load becomes large the operation of high performance can be carried out with sealed non-azeotropic refrigerant, and therefore, it becomes possible to shorten the time required for heat storage.

[0701] In addition, though the configuration is such that the time determination is carried out in STEP 4 and though in the case that the operation of STEP 3 is continued for a specific period of time, the configuration may be arranged so that the process moves to STEP 5 and the refrigerant composition which circulates through the main circuit may be detected in STEP 4 so that the process moves to STEP 5 in the case that the refrigerant composition has become the preset composition so as to gain the same effects.

[0702] In Embodiment 17 the detection means of the refrigerant composition includes a method of calcu-

lation derived from the pressure and temperature of the main circuit, or the like.

[0703] In addition, though the time determination is carried out in STEP 4 of Embodiment 17, the system may be controlled so that the process moves to STEP 5 in the case that the refrigerant composition of the reservoir unit 433 is detected in STEP 4 and the refrigerant composition has become the refrigerant composition which has been preset. This control becomes possible since it can be determined whether or not the refrigerant composition which circulates through the main circuit has become the set refrigerant composition from the refrigerant composition in the reservoir unit 433 due to the fact that the total amount of the refrigerant doesn't change and such a composition allows the gaining of the same effects as in Embodiment 17. In this configuration the detection means of the refrigerant composition includes a method of calculating from the pressure and temperature of the reservoir unit, the rectifying tower or the like.

[0704] In addition, In Embodiment 17, though the heat storage thermal sensor 441 detects the temperature of the heat storage material 440 and the control of the switching of the composition circulating through the main circuit is carried out, the control may be carried out by detecting the pipe temperature of the heat regenerator 427, or the like, so as to gain the same effects.

[0705] In addition, the compressor 421 is not specifically limited in Embodiment 17, rather, it may be a performance variable type compressor such as an inverter compressor or a plurality of compressors so as to gain the same effects.

[0706] In addition, the refrigerant gas led into the bottom of the rectifying separator 431 may be led in from the discharge gas of the compressor and the intake pipe of the compressor 421 and other cooling sources may be used as the cooling source of the cooling unit 432 so as to gain the same effects.

《Embodiment 18》

[0707] Next, a heat pump apparatus of Embodiment 18 in accordance with the present invention is described with reference to FIGS. 33 and 34. FIG. 33 is a system configuration view of the heat pump apparatus of Embodiment 18. FIG. 34 is a control flow chart of the heat pump apparatus of Embodiment 18.

[0708] In the heat pump apparatus of Embodiment 18, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 16 are referred to using the same numerals.

[0709] In the heat pump apparatus of Embodiment 18 the discharge pressure sensor 444 which detects the discharge pressure of the compressor 421 is arranged in the discharge pipe of the compressor 421. And, in the heat pump apparatus of Embodiment 18 the memory apparatus 445 stores the first set pressure P1 which

has been preset and the second set pressure P2 which is smaller than this first set pressure P1. The operation control apparatus 446 compares the first set pressure P1 and the second set pressure P2 which are stored in the memory apparatus 445 as well as the discharge pressure Pd which has been detected by the discharge pressure sensor 444 for the operation so as to control the two-way valves 434, 437 and 438 for opening and closing. The operation control apparatus 446 also has a function of determining a period of time of continuous operation of the two-way valve.

[0710] The structure of the refrigeration cycle of the heat pump apparatus of Embodiment 18 is the same as the reflection cycle of the heat pump apparatus of Embodiment 16 as shown in the above-mentioned FIG. 30, of which the description is omitted.

[0711] Next, the operation of the refrigeration cycle of the heat pump apparatus of Embodiment 18, formed as described above, is described with reference to FIG. 34. FIG. 34 is a control flow chart showing the control operation in the heat pump apparatus of Embodiment 18. The following description centers on the operation of the heat storage mode and the case wherein the compressor 421 is started up, under the condition where the temperature of the heat storage material 440 is low, is assumed to be the start for the description.

[0712] In the above-mentioned case, since the initial heat storage requires a high performance level, the two-way valve 434 is closed while the two-way valves 437 and 438 are opened (STEP 1). Through the opening and closing control in this manner, the refrigerant gas of high pressure which has come out of the compressor 421 passes through the four-way valve 422 and most of the refrigerant passes through the two-way valve 428. Then the refrigerant which has passed through the two-way valve 428 flows into the heat regenerator 427 and releases heat into the heat storage material 440 which is placed within the heat storage tank 439 and this heat is stored in the heat storage material 440.

[0713] Under the above-mentioned conditions, a determination of the discharge pressure of the compressor 421 is carried out (STEP 2). In the case that the discharge pressure Pd of the compressor 421, which has been detected by the discharge pressure sensor 444, is the first set pressure P1, which is stored in the memory apparatus 445, or less ($P_d \leq P_1$), the temperature of the heat storage material 440 is low and condensation temperature in the heat regenerator 427 is low, and therefore, it is determined that the heat storage capacity is insufficient and the heat storage load is large. Based on this determination, the closing signal of the two-way valve 434 and the opening signal of the two-way valves 437 and 438 are sent from the operation control apparatus 446 so that the two-way valve 434 remains closed while the two-way valves 437 and 438 remain open.

[0714] Under these conditions, since the two-way

valve 434 is closed and the cooling unit 432 and the reservoir unit 433 are connected to the intake pipe of the compressor 421 via the opened two-way valves 437 and 438, the inside of the rectifying separator 431, the cooling unit 432 and the reservoir unit 433 contain the gas of low pressure with little storage of the refrigerant.

[0715] Through the opening and closing control in this manner, the main circuit is operated with the refrigerant being a mixed non-azeotropic refrigerant, which remains the filler component. As a result of this, it becomes possible for the heat pump apparatus to be operated with high performance in response to the heat storage load.

[0716] On the other hand, in STEP 2 in the case that the determination of the discharge pressure of the compressor 421 is carried out and the discharge pressure Pd of the compressor 421 which has been detected by the discharge pressure sensor 444 is higher than the first set pressure P1 which is stored in the memory apparatus 445 ($P_d > P_1$), the temperature of the heat storage material 440 is high and the condensation temperature in the heat regenerator 427 is high. Therefore, the heat storage load is determined to be small and the opening signal of the two-way valves 434 and 437 and the closing signal of the two-way valve 438 are sent from the operation control apparatus 443. As a result of this, the two-way valves 434 and 437 are opened while the two-way valve 438 is closed (STEP 3).

[0717] In this case, the condensation temperature of the heat regenerator 427 and the discharge pressure of the compressor 421 both increase and the discharge pressure of the compressor 421 approaches to the upper limit where the compressor 421 is operable. Under these conditions, part of the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 passes through the two-way valve 434 and the sub-expansion apparatus 435 and flows into the bottom of the rectifying separator 431. Then the refrigerant operates in the same manner as that in the above-mentioned Embodiment 16 and the main circuit gradually contains the refrigerant of high boiling point.

[0718] Through the opening and closing operation in this manner, the pressure gradually decreases from that of the non-azeotropic refrigerant which was originally filled in, because the refrigerant of high boiling point attains a lower pressure at the same temperature. As a result of this, the heat regenerator 427 maintains the condensation temperature while the discharge pressure of the compressor 421 becomes lower than the operable high pressure limit. Therefore, the heat pump apparatus converts to the conditions wherein continuation of the heat storage operation becomes possible.

[0719] After that, the discharge pressure of the compressor 421 gradually increases and, together with this, the condensation temperature increases so that it becomes possible to greatly increase the temperature of the heat storage material 440. As a result of this, the

amount of stored heat of the heat storage material 440 increases.

[0720] Next, time determination is carried out in STEP 4, and in the case that the operation under the conditions of STEP 3 continues for a specific period of time (TSET), the process moves to STEP 5. In STEP 5 the two-way valves 434, 437 and 438 are all in the closed condition and, thereby, the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 will not flow into the rectifying separator 431 because the two-way valve 434 is closed. Accordingly, it becomes possible to eliminate heat loss when the two-phase refrigerant of intermediate pressure flows into the intake pipe of the compressor 421, such as at the time of the rectifying separation operation. In addition, the refrigerant of low boiling point, which has been collected in the reservoir unit 433 in STEP 3, is maintained as is collected when the main circuit undergoes circulation with the same refrigerant of high boiling point. Therefore, in the heat pump apparatus in Embodiment 18, the rectifying separation operation is not required to be carried out again, even at the time of restart up after the apparatus has been stopped, so that the heat storage operation can be maintained while increasing the operational efficiency.

[0721] Next, in STEP 6 a determination of the discharge pressure of the compressor 421 is carried out. In the case that the discharge pressure P_d of the compressor 421 which has been detected by the discharge pressure sensor 444 is higher than the second set pressure P_2 which is stored in the memory apparatus 445 ($P_d > P_2$), that is to say, in the case that the temperature of the heat storage material 440 is high and the heat storage load is small, further determination of the discharge pressure is carried out (STEP 7). In STEP 7, in the case that the discharge pressure P_d is the upper limit pressure P_{max} which is stored in the memory apparatus 445 or more ($P_d \geq P_{max}$), the heat storage operation is completed. And, in the case that the discharge pressure P_d is smaller than the upper limit pressure P_{max} ($P_d < P_{max}$), the process returns to STEP 5.

[0722] On the other hand, in the case that the discharge pressure P_d of the compressor 421 which has been detected by the discharge pressure sensor 444 is the second set pressure P_2 which is stored in the memory apparatus 445 or less ($P_d \leq P_2$) in STEP 6, that is to say, in the case where it is determined that the temperature of the heat storage material 440 is low and the heat storage load is large, the process returns to STEP 1. Then, the closing signal of the two-way valve 434 and the opening signal of the two-way valves 437 and 438 are sent from the operation control apparatus 446 so that the two-way valve 434 remains closed while the two-way valves 423 and 424 are opened.

[0723] Thereby, the refrigerant which has been collected in the reservoir unit 433, is absorbed into the compressor 421 via the two-way valves 437 and 438 so that the refrigerant composition of the main circuit

returns to the condition of filler composition of high performance, and the operation of high performance in response to the load can be restarted.

[0724] In the heat pump apparatus of Embodiment 18, the two-way valve 438 is directly connected, in particular, to the reservoir unit 433 and the intake pipe of the compressor 421, and therefore, the refrigerant within the reservoir unit 433 can be made to flow out in a short period of time so as to allow excellent control of change of the load.

[0725] As described above, the heat pump apparatus of Embodiment 18 is formed so that, in the case that the discharge pressure of the compressor 421 is detected and the discharge pressure has risen, the two-way valves 435, 437 and 438 are opened and closed so as to carry out the rectifying separation operation and to make the main circuit to contain the refrigerant of high boiling point. Thereby, it becomes possible for the heat pump apparatus of Embodiment 18 to store heat of high temperature while maintaining a safe pressure through a simple operation. In addition, in the case that the load becomes large the operation of high performance can be carried out with sealed non-azeotropic refrigerant, and therefore, it becomes possible to shorten the time required for heat storage in the heat pump apparatus of Embodiment 18.

[0726] Here, it is desirable that the first set pressure P_1 is a mean saturation pressure which approximately corresponds to the set condensation temperature in the sealed refrigeration composition before rectifying separation and the second set pressure P_2 is a mean saturation pressure which approximately corresponds to the condensation temperature, in the same way as the above, in the composition of high boiling point refrigerant after rectifying separation.

[0727] Here, in the heat pump apparatus of Embodiment 18, though the pressure sensor 444 detects the discharge pressure and the control of the switching of the refrigerant composition, which circulates through the main circuit, is carried out, the condensation pressure of the heat regenerator 427, or the like, may be detected for control so as to gain the same effects.

[0728] In addition, the refrigerant gas led into the bottom of the rectifying separator 431 may be led in from the discharge gas of the compressor and the intake pipe of the compressor 421 and other cooling sources may be used as the cooling source of the cooling unit 432 so as to gain the same effects.

50 (Embodiment 19))

[0729] Next, a heat pump apparatus of Embodiment 19 in accordance with the present invention is described with reference to FIGS. 35 and 36. FIG. 35 is a system configuration view of the heat pump apparatus of Embodiment 19. FIG. 36 is a control flow chart of the heat pump apparatus of Embodiment 19.

[0730] In the heat pump apparatus of Embodiment

19, elements, of which the descriptions are omitted, having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 16 are referred to using the same numerals.

[0731] The heat pump apparatus of Embodiment 19 uses an inverter compressor 447, and the discharge pressure sensor 448 for detecting the discharge pressure thereof is arranged in the discharge pipe of the inverter compressor 447. And, in the heat pump apparatus of Embodiment 19 the memory apparatus 449 stores the first set pressure P1 which has been preset and the second set pressure P2 which is smaller than this first set pressure P1. The operation control apparatus 450 compares the first set pressure P1 and the second set pressure P2 which are stored in the memory apparatus 449 as well as the discharge pressure Pd which has been detected by the discharge pressure sensor 448 for the operation so as to control the two-way valves 434, 437 and 438 for opening and closing. The operation control apparatus 450 also has a function of determining a period of time of continuous operation of the two-way valve.

[0732] In addition, in the heat pump apparatus of Embodiment 19, the control apparatus 451 controls the operation frequency of the inverter compressor 447 and controls the frequency of the signal which is inputted to the inverter compressor 447 so that the discharge pressure becomes close to the first set pressure or the second set pressure.

[0733] In addition, the heat pump apparatus of Embodiment 19 is provided with a thermal sensor 452, which detects the temperature of the refrigerant pipe in the approximate center, longitudinally, of the refrigerant pipe of the indoor heat exchanger 426 and a pressure sensor 453, which detects the refrigerant pressure at the same position of this thermal sensor 452.

[0734] Here, the operation control apparatus 450 also has the function of opening and closing operation of the two-way valves 434, 437 and 438 by detecting the refrigerant composition of the main circuit from the temperature value detected by the thermal sensor 452 and the pressure value detected by the pressure sensor 453 so as to be compared with the preset refrigerant composition.

[0735] The structure of the refrigeration cycle of the heat pump apparatus of Embodiment 19 is the same as the reflection cycle of the heat pump apparatus of Embodiment 16 as shown in the above-mentioned FIG. 30, of which the description is omitted.

[0736] Next, the operation of the refrigeration cycle of the heat pump apparatus of Embodiment 19, formed as described above, is described with reference to FIG. 36.

[0737] FIG. 36 is a control flow chart showing the control operation in the heat pump apparatus of Embodiment 19. The following description centers on the operation of the heat storage mode and the case wherein the inverter compressor 447 is started up, under the

condition where the temperature of the heat storage material 440 is low, is assumed to be the start for the description.

[0738] In the above-mentioned case, since the initial heat storage requires a high performance level, the two-way valve 434 is closed while the two-way valves 437 and 438 are opened (STEP 1). Through the opening and closing control in this manner, the refrigerant gas of high pressure which has come out of the inverter compressor 447 passes through the four-way valve 422 and most of the refrigerant passes through the two-way valve 428 so as to flow into the heat regenerator 427. The refrigerant which has flown into the heat regenerator 427 releases heat into the heat storage material 440 which is placed within the heat storage tank 439 and this heat is stored in the heat storage material 440.

[0739] At this time the discharge pressure Pd of the inverter compressor 447 which has been detected by the discharge pressure sensor 448 is sent to the control apparatus 451. In the control apparatus 451 the discharge pressure Pd is compared with the value of the first set pressure P1 which has been preset in the memory apparatus 449 (STEP 2). In the initial stage of heat storage the condensation temperature of the heat regenerator 427 is low and, thereby, the discharge pressure Pd of the inverter compressor 447 is the first set pressure P1 or less ($P_d \leq P_1$). In this case, an instruction of increasing the frequency of the inverter compressor 447 is sent from the frequency control apparatus 451 (STEP 3-1). As a result of this, the inverter compressor 447 increases in revolution number and the circulation amount increases so that the discharge pressure Pd of the inverter compressor 447 gradually increases. Then, the determination of the discharge pressure Pd is, again, carried out in STEP 2. In the case that the discharge pressure Pd of the inverter compressor 447 which has been detected by the discharge pressure sensor 448 exceeds the first set pressure P1 which is stored in the memory apparatus 449 ($P_d > P_1$), the temperature of the heat storage material 440 is observed to have risen. In this case, an instruction of reducing the frequency of the inverter compressor 447 is sent from the frequency control apparatus 451 (STEP 3-2). As a result of this, the inverter compressor 447 is reduced in revolution number and the circulation volume is reduced so that the discharge pressure Pd of the inverter compressor 447 gradually decreases.

[0740] By adjusting the frequency of the signal inputted into the inverter compressor 447 in the frequency control apparatus 451 in this manner, the discharge pressure Pd of the inverter compressor 447 can be maintained approximately at the first set pressure P1. As a result of this, it becomes possible for the heat pump apparatus of Embodiment 19 to have a heat storage operation which continues safely without exceeding the high pressure upper limit of the inverter compressor 447.

[0741] Next, in STEP 4 it is determined whether or

not the frequency F of the inverter compressor 447 at the time of operation is the minimum frequency F_{min} . In the case that the frequency F of the inverter compressor 447 is a higher frequency than the minimum frequency F_{min} ($F > F_{min}$), the process again returns to STEP 2 so as to carry out the frequency control. On the contrary, in the case that the frequency F of the inverter compressor 447 is the minimum frequency F_{min} or less ($F \leq F_{min}$), the opening signal of the two-way valves 434 and 437, and the closing signal of the two-way valve 438 are sent from the operation control apparatus 450 so that the two-way valves 434 and 437 are opened while the two-way valve 438 is closed (STEP 5).

[0742] In STEP 5 part of the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 passes through the two-way valve 434 and the sub-expansion apparatus 435 and flows into the bottom of the rectifying separator 431. Then, the refrigerant behaves in the same manner as is described in the above Embodiment 16 and the main circuit gradually comes to contain the refrigerant of high boiling point.

[0743] Through the opening and closing operation in this manner the refrigerant of high boiling point is gradually reduced in pressure to a pressure lower than the filled in non-azeotropic refrigerant since the refrigerant of high boiling point becomes a lower pressure at the same temperature. As a result of this, in the heat pump apparatus of Embodiment 19 the discharge pressure of the inverter compressor 447 decreases while the condensation temperature of the heat regenerator 427 is maintained and the pressure becomes lower than the upper limit where the system is operable. Thereby, it becomes possible for the heat pump apparatus of Embodiment 19 to continue the heat storage operation.

[0744] In addition, the discharge pressure P_d of the inverter compressor 447 gradually increases while the heat storage operation proceeds in the heat pump apparatus of Embodiment 19 and, together with that, the condensation temperature increases. Thereby, the temperature of the heat storage material 440 can be greatly increased so that the amount of stored heat increases.

[0745] Next, in STEP 6, the operation control apparatus 450 detects the refrigerant composition C which circulates through the main circuit based on the temperature detection value which has been detected by the thermal sensor 452 and the pressure detection value which has been detected by the pressure sensor 453. In the case that the detected refrigerant composition C has not yet become the preset refrigerant composition C_o (refrigerant composition with a large amount of refrigerant of high boiling point) ($C \leq C_o$), the rectifying separation operation is continued while remaining in STEP 5. On the contrary, in the case that the detected refrigerant components have become the preset refrigerant component C_o (refrigerant component with a large amount of refrigerant of high boiling point) ($C > C_o$), the process

moves to STEP 7.

[0746] Next, the principle according to which the refrigerant composition C that circulates through the main circuit can be detected based on the temperature detection value which has been detected by the thermal sensor 452 and the pressure detection value which has been detected by the pressure sensor 453 is described with reference to FIG. 37.

[0747] FIG. 37 is a characteristics diagram indicating the temperature detection value of the thermal sensor 452 along the horizontal axis and the pressure detection value of the pressure sensor 453 along the vertical axis. In FIG. 37, in the case that the degree of dryness of the refrigerant is maintained at approximately a constant value (here approximately 0.5), the relationship between the temperature detection value and the pressure detection value in a set composition is represented by one curve as shown in curve A.

[0748] In FIG. 37, in the case that the point, which is related by the temperature detection value which has been detected by the thermal sensor 452 and by the pressure detection value, which has been detected by the pressure sensor 453, exists at point B, it can be determined that the pressure of point B is higher than the pressure of curve A of the refrigerant composition set at the same temperature, that is to say, the refrigerant composition of the main circuit at this time has not yet become the set refrigerant composition with a large amount of refrigerant of high boiling point.

[0749] On the other hand, in the case that the point, which is related by the temperature detection value which has been detected by the thermal sensor 452 and by the pressure detection value which has been detected by the pressure sensor 453, exists at point C, it can be determined that the pressure of point C is lower than the pressure of curve A of the set refrigerant composition at the same temperature, that is to say, the refrigerant composition has become the set refrigerant composition with a large amount of refrigerant of high boiling point.

[0750] In STEP 7, the two-way valves 434, 437 and 438 are all in the closed condition. Accordingly, since the two-way valve 434 is closed part of the two-phase refrigerant of intermediate pressure which has come out of the heat storage expansion apparatus 429 will not flow into the rectifying separator 431. Thereby, it becomes possible to eliminate heat loss when the two-phase refrigerant of intermediate pressure flows into the intake pipe of the inverter compressor 447 and the main circuit allows the refrigerant of high boiling point to remain circulating while maintaining the collected condition of the refrigerant of low boiling point which has been collected in the reservoir unit 433 in STEP 5. As a result of this, it is not necessary for the heat pump apparatus of Embodiment 19 to again carry out the rectifying separation operation, even at the time of restart up after the apparatus has been stopped, and the heat storage operation can be continued while increasing the opera-

tional efficiency.

[0751] Next, in STEP 8 a determination of the discharge pressure of the inverter compressor 447 is carried out. In the case that the discharge pressure Pd which has been detected by the discharge pressure sensor 448 exceeds the second set pressure P2 which is stored in the memory apparatus 449, that is to say, in the case that the temperature of the heat storage material 440 is high and the heat storage load is small ($P_d > P_2$), further determination of the discharge pressure is carried out (STEP 9). Then in STEP 9, in the case that the discharge pressure Pd is the upper limit pressure Pmax which is stored in the memory apparatus 449 or more ($P_d \geq P_{max}$), the heat storage operation is completed. On the contrary, in the case that the discharge pressure Pd is smaller than the upper limit pressure Pmax ($P_d < P_{max}$), the process returns to STEP 7.

[0752] On the other hand, in the case that the discharge pressure Pd of the compressor 421 which has been detected by the discharge pressure sensor 447 is the second set pressure P2 which is stored in the memory apparatus 449 or less ($P_d \leq P_2$) in STEP 8, that is to say, in the case where it is determined that the temperature of the heat storage material 440 is low and the heat storage load is large, the process returns to STEP 1 wherein the closing signal of the two-way valve 434 and the opening signal of the two-way valves 437 and 438 are sent from the operation control apparatus 450. As a result of this, the two-way valve 434 remains closed while the two-way valves 423 and 424 are opened.

[0753] Thereby, the refrigerant which has been collected in the reservoir unit 433, is absorbed into the inverter compressor 447 via the two-way valves 437 and 438 so that the refrigerant composition of the main circuit returns to the condition of filler composition of high performance, and the operation of high performance in response to the load can be restarted.

[0754] In the heat pump apparatus of Embodiment 19, the two-way valve 438 is directly connected, in particular, to the reservoir unit 433 and the intake pipe of the inverter compressor 447, and therefore, the refrigerant within the reservoir unit 433 can be made to flow out in a short period of time so as to allow excellent control of change of the load.

[0755] As described above the heat pump apparatus of Embodiment 19 detects the discharge pressure of the inverter compressor 447 and, by controlling the frequency of the compressor so that the discharge pressure becomes approximately a constant, the operation wherein the pressure will not exceed the upper limit of the inverter compressor 447 can easily be carried out and a safe heat storage operation can be achieved.

[0756] In addition, in the heat pump apparatus of Embodiment 19, in the case that the discharge pressure exceeds the set pressure, which has been preset, and the capacity of the compressor is minimum, the performance of the apparatus is fully utilized so that the

time required for the heat storage operation can be shortened since the operation control apparatus is provided for the opening and closing operation of the two-way valves. Moreover, according to Embodiment 19, the heat storage operation of high temperature can be safely carried out while maintaining the high pressure of the refrigeration cycle at a low level so as not to exceed the tolerance pressure of the compressor and the amount of stored heat can be greatly increased.

[0757] Here, in Embodiment 19, it is desirable that the first set pressure P1 is a mean saturation pressure which approximately corresponds to the set condensation temperature in the sealed refrigeration composition before rectifying separation. It is also desirable that the second set pressure P2 is a mean saturation pressure which approximately corresponds to the condensation temperature, in the same way as the above, in the composition of high boiling point refrigerant after rectifying separation.

[0758] In addition, in the heat pump apparatus of Embodiment 19, though the discharge pressure sensor 447 detects the discharge pressure and the control of the switching of the refrigerant composition, which circulates through the main circuit, is carried out, the condensation pressure of the heat regenerator 427, or the like, may be detected for control so as to gain the same effects as in Embodiment 19.

[0759] In addition, the refrigerant gas led into the bottom of the rectifying separator 431 may be led in from the discharge gas of the compressor and the intake pipe of the compressor 421 and other cooling sources may be used as the cooling source of the cooling unit 432 so as to gain the same effects as in Embodiment 19.

[0760] In addition, in the heat pump apparatus of Embodiment 19, in the case that R407C, which is a substitute refrigerant for R22 and which is a mixture of three types of single refrigerants R32, R125 and R134a, is used as the sealed non-azeotropic refrigerant, the difference of boiling points of refrigerants R32 and R125, of which the boiling points are low, and a refrigerant R134a, of which the boiling point is high, can be made large, which is advantageous for the rectifying separation performance, and moreover, the ratio of lowering of the performance can be made large so that the most suitable performance control becomes possible for a large load variation.

《Embodiment 20》

[0761] Next, a heat pump apparatus of Embodiment 20 in accordance with the present invention is described with reference to FIGS. 38 and 39. FIG. 38 is a system configuration view of the heat pump apparatus of Embodiment 20. FIG. 39 is a control flow chart of the heat pump apparatus of Embodiment 20.

[0762] In the heat pump apparatus of Embodiment 20, elements, of which the descriptions are omitted,

having the same function or the same structure as in the heat pump apparatus of the above-mentioned Embodiment 16 are referred to using the same numerals.

[0763] The heat pump apparatus of Embodiment 20 is provided with a thermal sensor 455 which detects the refrigerant temperature of the reservoir unit 433 and a pressure sensor 456 which detects the refrigerant pressure of the reservoir unit 433.

[0764] The operation control apparatus 457 in the heat pump apparatus of Embodiment 20 compares the first set pressure P1 and the second set pressure P2, which are stored in the memory apparatus 449 as well as the discharge pressure Pd, which has been detected by the discharge pressure sensor 448, for the operation and controls the two-way valves 434, 437 and 438 in opening and closing. In addition, the operation control apparatus 457 has a function of determining the time of continuous operation of the two-way valves and a function of detecting the refrigerant composition of the refrigerant which has been collected in the reservoir unit 433 from temperature detection value of the reservoir unit 433 detected by the thermal sensor 455 and the pressure detection value of the refrigerant in the reservoir unit 433 detected by the pressure sensor 456. The operation control apparatus 457 calculates the refrigerant composition in the main circuit from the refrigerant composition of the reservoir unit 433 which has been detected so as to be compared with a preset refrigerant composition and controls the two-way valves 434, 437 and 438 in opening and closing.

[0765] The operation of the heat pump apparatus of Embodiment 20 is different from that of the heat pump apparatus of Embodiment 19 only in a part of STEP 6 of the control flow chart as shown in the above-mentioned FIG. 36, and therefore, this different STEP 6 is described in the following.

[0766] In STEP 6 of Embodiment 20, the temperature detection value of the refrigerant of the reservoir unit 433 which has been detected by the thermal sensor 455 and the pressure detection value of the refrigerant in the reservoir unit 433 which has been detected by the pressure sensor 456 are sent to the operation control apparatus 457.

[0767] In the operation control apparatus 457, the refrigerant composition which circulates in the main circuit is detected based on the temperature detection value of the thermal sensor 455 and the pressure detection value of the pressure sensor 456.

[0768] The operation principle of the this operation control apparatus 457 is described with reference to FIG. 39. FIG. 39 is a characteristic diagram showing the temperature detection value of the thermal sensor 455 along the lateral axis and the pressure detection value of the pressure sensor 456 along the vertical axis.

[0769] The total refrigerant amount W of the heat pump apparatus, the refrigerant amount Ws collected in the reservoir unit 433 and the refrigerant amount Wc in the main circuit have the relationship of $W=W_s + W_c$. In

addition, the refrigerant amount Wh of the refrigerant of high boiling point in the entire heat pump apparatus, the refrigerant amount W_{hs} of the refrigerant of high boiling point collected in the reservoir unit 433 and the refrigerant amount W_{hc} of the refrigerant of high boiling point in the main circuit have the relationship of $W_h=W_{hs} + W_{hc}$.

[0770] Under the conditions which have the above-mentioned relationship, the total refrigerant amount W of the heat pump apparatus and the refrigerant amount Wh, which is contained in the former, of the refrigerant of high boiling point are already known while the refrigerant amount Ws collected in the reservoir unit 433 is determined by the capacity of the reservoir unit 433 and is already known. Thereby, in the case that the refrigerant amount W_{hs} of the refrigerant of high boiling point collected in the reservoir unit 433 is found, the ratio (W_{hc}/W_h) of the refrigerant amount of high boiling point in the main circuit, that is to say the refrigerant composition in the main circuit, can be calculated.

[0771] In other words, it can be calculated at which value the refrigerant composition in the reservoir unit should be set in order for the main circuit to reach the set refrigerant composition.

[0772] In FIG. 39 the lateral axis shows the temperature detection value by the thermal sensor 455 while the vertical axis shows the pressure detection value by the pressure sensor 456. The reservoir unit 433 is occupied, almost completely, with liquid, which can be assumed to be a saturated solution and the relationship between the temperature and the pressure of the refrigerant composition in the reservoir unit 433 for the main circuit to have the set refrigerant composition can be represented with one curve as curve D.

[0773] For example, in the case that the point which is decided by the temperature detection value detected by the thermal sensor 455 and the pressure detection value detected by the pressure sensor 456 exists at the point E, the pressure of the point E is lower than the pressure of the curve D of the set refrigerant composition at the same temperature, that is to say the refrigerant composition of low boiling point in the reservoir unit 433 is small in amount and it is judged that the refrigerant composition which circulates in the main circuit hasn't reached the set refrigerant of high boiling point. Therefore, the rectifying separation operation is continued without leaving STEP 5.

[0774] In addition, in the case that the point which is decided by the temperature detection value detected by the thermal sensor 455 and the pressure detection value detected by the pressure sensor 456 exists at the point F, the pressure of the point F is higher than the pressure of the curve D of the set refrigerant composition at the same temperature, that is to say the refrigerant composition of low boiling point in the reservoir unit 433 is large in amount and it is judged that the refrigerant composition which circulates in the main circuit has reached the set refrigerant of high boiling point. There-

fore, the process moves to STEP 7.

[0775] As described above the heat pump apparatus of Embodiment 20 detects the discharge pressure of the inverter compressor 447 and, by controlling the frequency of the compressor so that the discharge pressure becomes approximately a constant, the operation wherein the pressure will not exceed the upper limit of the inverter compressor 447 can easily be carried out and a safe heat storage operation can be achieved.

[0776] In addition, in the heat pump apparatus of Embodiment 20, in the case that the discharge pressure exceeds the set pressure, which has been preset, and the capacity of the compressor is minimum, the performance of the apparatus is fully utilized so that the time required for the heat storage operation can be shortened since the operation control apparatus is provided for the opening and closing operation of the two-way valves. Moreover, according to Embodiment 20, the heat storage operation of high temperature can be safely carried out while maintaining the high pressure of the refrigeration cycle at a low level so as not to exceed the tolerance pressure of the compressor and the amount of stored heat can be greatly increased.

《Embodiment 21》

[0777] Next, one embodiment of the rectifying separator used in the heat pump apparatus of Embodiment 21 in accordance with the present invention is described. FIG. 40 is a cross section view showing a schematic configuration of the rectifying separator used in the heat pump apparatus of Embodiment 21.

[0778] In FIG. 40, the container 520 of the rectifying separator is formed of a straight cylindrical pipe which extends lengthwise in vertical direction. The refrigerant flows into the rectifying separator via a flow-in connection pipe 521 from the main circuit of the heat pump apparatus. The flow-in connection pipe is provided at the bottom of the container 520 and, mainly, the gas refrigerant in the two-phase gas-liquid refrigerant passes through this flow-in connection pipe 521, flows into the container 520 and moves upward into the container 520.

[0779] The flow-out connection pipe 522 which makes the refrigerant flow out to the main circuit of the heat pump apparatus is provided at the bottom of the container 520 and the liquid refrigerant which has moved downward into the container 520 passes through this flow-out connection pipe and flows out to the main circuit of the heat pump apparatus.

[0780] The cylindrical container 520, into which the filling material 523 has been inserted, is formed of woven material having a mesh, using metal thread material such as stainless steel or copper, and is arranged above the flow-in connection pipe 521 and the open part of the flow-out connection pipe 522.

[0781] The gas flow-out pipe 524 which makes the gas refrigerant in the top part of the container 520 to

flow out to the cooling unit is connected to the ceiling surface of the top part of the container 520 and the open edge thereof is arranged inside of the top part.

[0782] A liquid return pipe 525 which makes the liquid refrigerant return from the reservoir unit pierces, in a substantially horizontal direction, from the side of the top part of the container 520 to the vicinity of the center of the container 520. The open edge of this liquid return pipe 525 is arranged above the filling material 523 within the container 520 and below the gas flow-out pipe 524.

[0783] FIG. 41 is a view showing the filling material 523, which has been inserted into the container 520 of the rectifying separator in Embodiment 21 in accordance with the present invention, in an expanded view. As shown in FIG. 41 the filling material 523 is a woven material 526 which has a mesh.

[0784] The woven material 526 is formed using metal thread material such as stainless steel or copper and this woven material 526 is rolled up to form a columnar shape, which is inserted into the container 520 of the rectifying separator. FIG. 42 is a perspective view showing the condition where the woven material 526 is rolled up.

[0785] The woven material 526 is in a shape which has appropriate spaces between the thread material by being woven as shown in FIG. 41. Then, as shown in FIG. 42, a plurality of woven materials 526 are overlapped and are rolled up from one end of the woven materials 526 so as to form an overall columnar shape with spiral shaped ends.

[0786] The cross-sectional diameter of the filling material 523 is formed larger than the inner diameter of the cylindrical container 520 of the rectifying separator under the conditions where it is formed. This filling material 523 is inserted into the container 520 of the rectifying separator while being pressed toward the center direction of the container 520. By being formed in this way the outer peripheral surface of the filling material 523 contacts with the inner surface of the cylindrical container 520 of the rectifying separator without any gaps.

[0787] Here, in Embodiment 21, the cross-sectional diameter of the thread material forming the filling material 523 is approximately 0.2 mm. And under the conditions where the filling material 523 has been inserted into the container 520 of the rectifying separator, the filling material 523 is manufactured so that the space ratio within the container 520 of the rectifying separator becomes approximately 90%.

[0788] The filling material 523 is formed by weaving the thread material of metal, or the like, into the woven material 526 as shown in FIG. 41, and therefore, a regular texture is generated in the filling material 523 and the gap between the thread material can become even. In addition, the filling material 523 is formed into a cylindrical shape by being rolled up from one end as shown in FIG. 42 and is inserted into the container 520 so that

a uniform space ratio which is appropriate for the gas refrigerant to move upward can be secured. In addition, by forming the filling material 523 as described above, the gas liquid contact area with the liquid refrigerant which moves downward is expanded and the gas-liquid contact is promoted so as to increase the separation performance.

[0789] In addition, the cross-sectional diameter of the filling material 523 is formed larger than the inner diameter of the cylindrical container 520, under the condition immediately after it is formed, which has been inserted into the container 520 while being pressed into the direction to the approximate center of the container 520. Thereby, through the recovery power of the filling material 523 due to the formation of the filling material 523 into the woven material, the outer peripheral surface of the filling material 523 contacts with the inner peripheral surface of the cylindrical container 520 without any gaps. Therefore, through the friction power between the inner peripheral surface of the container 520 and the filling material 523, the filling material 523 can be maintained at the inserted position. Accordingly, even in the case that there is a flow of refrigerant within the rectifying Separator the filling material 523 will not move within the container 520, and therefore, it is not necessary to provide clamps, or the like, to the upper and lower parts of the filling material 523. As a result of this, the configuration of the rectifying separator in Embodiment 21 can be simplified so as to achieve cost reduction for manufacturing the heat pump apparatus.

[0790] In addition, the filling material 523 may be inserted, one time, into the container 520, which eliminates the time and effort for a plurality of insertion when a plurality of small filling materials are sealed according to a prior art, and therefore, the time required for production or assembly can be greatly reduced.

[0791] As for a practical method for evaluating the separation performance of the filling material, there is NTP (Numbers of Theoretical Plate). R407C is used as the non-azeotropic refrigerant in order to evaluate the performance of the filling material 523 in Embodiment 21 and the filling material 523, wherein the cross-sectional diameter of the metal thread material of stainless steel and the space ratio within the container 520 are varied, is inserted into the container 520 and NTP is evaluated. Here, the used container 520 has the inner diameter of approximately 23 mm and the length of the filling material of approximately 200 mm.

[0792] FIG. 43 is a graph showing the experiment results of the separation performance evaluation of the filling material. In this evaluation experiment, comparisons are carried out among five types of cross-sectional diameters of the filling material 0.05 mm, 0.1 mm, 0.2 mm, 0.3 mm and 0.35 mm and among five types of space ratios of 80%, 85%, 90%, 95% and 97.5%. As shown in FIG. 43, in the case that the cross-sectional diameter of the metal thread material is from 0.1 mm to 0.3 mm and the space ratio is from 85% to 95% the NTP

becomes optimal and, in particular, the case of the cross-sectional diameter of 0.2 mm and the space ratio of 90% is found to have the highest NTP.

[0793] As for the tendency of the separation performance in relation to the size of the cross-sectional diameter, the larger the cross-sectional diameter of the thread material the more the surface area is reduced in the case that the space ratio is the same and the gas-liquid contact area decreases and the separation performance deteriorates.

[0794] On the other hand, the smaller the cross-sectional diameter of the thread material is, the more the surface area increases in the case that the space ratio is the same, and therefore, it is generally considered that the separation performance is improved because the gas-liquid contact area can be increased. In the present evaluation, however, in the case that the cross-sectional diameter of the thread material is too small, NTP tends to get lower. This is because, in the case that the cross-sectional diameter of the thread material is too small, the gap between the thread material becomes small so that a liquid bridge, between the thread materials due to the viscosity of the refrigerant liquid which moves downward, becomes easier to create. Therefore, the liquid which moves downward is not dispersed but, rather, is connected continuously and it becomes easy to move downward and it is considered that the degree of the gas-liquid contact with the gas which moves upward deteriorates. This is clarified by the present evaluation for the first time.

[0795] The refrigerant liquid which moves downward into the rectifying separator generally has a tendency to flow in greater volume closer to the wall surface of the container 520, and therefore, the refrigerant liquid which moves downward flows out while the refrigerant gas which moves upward flows in which causes the phenomenon that the gas-liquid contact is not sufficiently created. In Embodiment 21, the filling material 523, which is formed in a columnar shape, is configured so that the space ratio becomes smaller in relation to the direction to the outer periphery. Therefore, the space ratio of the outer periphery side of the filling material 523 is smaller so as to make the refrigerant liquid flow difficult and the flow of the refrigerant liquid is prevented from moving toward the outer periphery and, thus, the flow can be made uniform in the cross-section. In the same way, the gas which moves upward passes through the gaps between the flow of the refrigerant liquid which moves downward, and therefore, the gas-liquid contact becomes uniform in the cross-section so as to enable the further increase of the separation performance.

[0796] As for a manufacturing method for the filling material 523, the woven material 526 may be formed through pressing, or the like, so that the closer the position is to the outer periphery the thinner it becomes, as shown in FIG. 41, and, after that, this woven material 526 may be rolled up from one end, which becomes the

inner periphery direction, and, thereby, the end surfaces form a spiral and the overall form is a columnar shape. By manufacturing the filling material 523 in this way, the space ratio of the filling material 523 becomes smaller in relation to the closer it comes to the outer periphery.

[0797] Here, a variety of materials, such as metal, fiber or plastic, can be considered as the thread material, any of which can gain the same effects, and therefore, they are all included in the scope of the present invention.

[0798] In addition, as for the shape of the woven thread material, not only the one as shown in FIG. 41 but a variety of ways of weaving can be considered so that any manner of weaving is included in the scope of the present invention as long as the gaps between the thread materials are properly distributed.

Applicability in the Industry

[0799] The present invention provides a compact heat pump apparatus which is formed so as to enable the operation of the main circuit in the case of a large load, under the condition of a large amount of refrigerant of which the refrigerant composition is the same as the filled in refrigerant state, and in the case of a small load, under the condition of a small amount of refrigerant which includes a large amount of high boiling point refrigerant derived by collecting the low boiling point refrigerant in the reservoir unit and which, thereby, has a wide performance control range so as to enable appropriate performance control in response to the load and which becomes useful as an apparatus for cooling and heating.

Claims

1. A heat pump apparatus characterized by comprising:

a rectifying separator which has the form of a straight pipe substantially long in the vertical direction, the bottom of which is connected to an intake pipe of a compressor via a sub-expansion apparatus, and which performs rectifying separation of non-azeotropic refrigerant; a cooling unit which exchanges heat between the refrigerant which flows out from the bottom of said rectifying separator and moves toward said intake pipe of said compressor from said sub-expansion apparatus as well as the refrigerant in the top part of said rectifying separator; a reservoir unit which collects the refrigerant cooled and liquefied by said cooling unit; a closed pipe route forming a closed circuit in an annular structure so as to send the refrigerant in the top part of said rectifying separator to said cooling unit and to send the refrigerant from said cooling unit to said reservoir unit and

then to return the refrigerant which has been collected in said reservoir unit to the top part of said rectifying separator;

a main circuit of a refrigeration cycle which, through pipe, connects said compressor, a four-way valve, an outdoor heat exchanger, an expansion apparatus and an indoor heat exchanger in an annular sequence and which seals in said non-azeotropic refrigerant;

an opening and closing apparatus which makes a connection between said closed circuit and said main circuit so as to be able to open and close the connection; and

a control apparatus which performs opening and closing control of said opening and closing apparatus in accordance with a load condition and makes said non-azeotropic refrigerant within said main circuit flow into said closed circuit.

2. A heat pump apparatus according to Claim 1 characterized in that a pipe connecting said main circuit and said closed circuit is provided with a sub-expansion apparatus in series with said opening and closing apparatus.
3. A heat pump apparatus according to Claim 1 characterized in that said closed circuit is connected, via said opening and closing apparatus, to a pipe between an outdoor heat exchanger and an indoor heat exchanger in said main circuit.
4. A heat pump apparatus according to Claim 1 characterized in that an opening and closing apparatus is provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between said cooling unit and the intake pipe of said compressor.
5. A heat pump apparatus characterized by comprising:

a rectifying separator which has the form of a straight pipe substantially long in the vertical direction, the bottom of which is connected to an intake pipe of a compressor via a sub-expansion apparatus, and which performs rectifying separation of non-azeotropic refrigerant; a cooling unit which exchanges heat between the refrigerant which flows out from the bottom of said rectifying separator and moves toward said intake pipe of said compressor from said sub-expansion apparatus as well as the refrigerant in the top part of said rectifying separator; a reservoir unit which collects the refrigerant cooled and liquefied by said cooling unit; a closed pipe route forming a closed circuit in an annular structure so as to send the refrigerant

ant in the top part of said rectifying separator to said cooling unit and to send the refrigerant from said cooling unit to said reservoir unit and then to return the refrigerant which has been collected in said reservoir unit to the top part of said rectifying separator;

a main circuit of a refrigeration cycle which, through pipe, connects said compressor, a four-way valve, an outdoor heat exchanger, an expansion apparatus and an indoor heat exchanger in an annular sequence and which seals in said non-azeotropic refrigerant;

an opening and closing apparatus connecting, via a sub-expansion apparatus, said main circuit and the bottom of said rectifying separator so as to enable the opening and the closing of the connection; and

a control apparatus which performs opening and closing control of said opening and closing apparatus in accordance with a load condition and makes said non-azeotropic refrigerant within said main circuit flow into said closed circuit.

6. A heat pump apparatus according to Claim 5 characterized in that the bottom of said rectifying separator is connected, via said sub-expansion apparatus and said opening and closing apparatus, to a pipe between said outdoor heat exchanger and said indoor heat exchanger in said main circuit.

7. A heat pump apparatus according to Claim 5 characterized in that an opening and closing apparatus is provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between said cooling unit and the intake pipe of said compressor.

8. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, a main expansion apparatus and an indoor heat exchanger in an annular structure;

a first sub-expansion apparatus and a second sub-expansion apparatus connected in series along a pipe bypassing said main expansion apparatus;

a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;

an opening and closing apparatus which connects a pipe between said first sub-expansion apparatus and said second sub-expansion apparatus to a bottom of said rectifying separator so as to enable the opening and the closing

of the connection; and

a third sub-expansion apparatus provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between the bottom of said rectifying separator and said cooling unit,

wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said third sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

9. A heat pump apparatus according to Claim 8 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which exercises control so that in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less said opening and closing apparatus is opened and in the case that said difference exceeds said predetermined value said opening and closing apparatus is closed.

10. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle wherein a compressor, a four-way valve, an outdoor heat exchanger, an outdoor expansion apparatus, an indoor expansion apparatus and an indoor heat exchanger are connected in sequence, through pipes, in an annular structure which has a first check-valve parallel to said outdoor expansion apparatus for bypassing said outdoor expansion apparatus at the time of the cooling operation and which has a second check-valve parallel to said indoor expansion apparatus for bypassing said indoor expansion apparatus at the time of heating operation;
a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;
an opening and closing apparatus for connecting the pipe which links said outdoor expansion apparatus and said indoor expansion apparatus to the bottom of said rectifying separator via the first sub-expansion apparatus so as to enable the opening and the closing of the connection;

tion; and

a second sub-expansion apparatus provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between the bottom of said rectifying separator and said cooling unit,

wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said third sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

11. A heat pump apparatus according to Claim 10 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and an operation control apparatus which exercises control so that in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less said opening and closing apparatus is opened and in the case that said difference exceeds said predetermined value said opening and closing apparatus is closed.

12. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, a main expansion apparatus and an indoor heat exchanger in an annular structure; a first sub-expansion apparatus and a second sub-expansion apparatus connected in series along a pipe bypassing said main expansion apparatus; a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure; a first opening and closing apparatus which connects a pipe between said first sub-expansion apparatus and said second sub-expansion apparatus to a bottom of said rectifying separator so as to enable the opening and the closing of the connection; and a third sub-expansion apparatus provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between the

bottom of said rectifying separator and said cooling unit,

a second opening and closing apparatus for connecting the bottom of said rectifying separator with a discharge pipe of said compressor via a fourth sub-expansion apparatus, wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said third sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

13. A heat pump apparatus according to Claim 12 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and an operation control apparatus which exercises control so that in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less said first opening and closing apparatus and said second opening and closing apparatus are opened and in the case that said difference exceeds said predetermined value said first opening and closing apparatus and said second opening and closing apparatus are closed.

14. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle wherein a compressor, a four-way valve, an outdoor heat exchanger, an outdoor expansion apparatus, an indoor expansion apparatus and an indoor heat exchanger are connected in sequence, through pipes, in an annular structure which has a first check-valve parallel to said outdoor expansion apparatus for bypassing said outdoor expansion apparatus at the time of the cooling operation and which has a second check-valve parallel to said indoor expansion apparatus for bypassing said indoor expansion apparatus at the time of heating operation; a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure; A first opening and closing apparatus for connecting the pipe, which links said outdoor expansion apparatus with said indoor expansion apparatus, to the bottom of said rectifying

separator via a first sub-expansion apparatus so as to enable the opening and the closing of the connection;

a second sub-expansion apparatus provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between the bottom of said rectifying separator and said cooling unit; and
a second opening and closing apparatus for connecting the bottom of said rectifying separator with a discharge pipe of said compressor via a fourth sub-expansion apparatus, wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

15. A heat pump apparatus according to Claim 14 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which exercises control so that in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less said first opening and closing apparatus and said second opening and closing apparatus are opened and in the case that said difference exceeds said predetermined value said first opening and closing apparatus and said second opening and closing apparatus are closed.

16. A heat pump apparatus according to Claim 14 characterized in that an opening and closing apparatus is provided, in a pipe which connects the bottom of the rectifying separator and an intake pipe of the compressor, between the cooling unit and the intake pipe of said compressor.

17. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, a main expansion apparatus and an indoor heat exchanger in an annular structure;
a closed circuit connecting a top part of a recti-

fying separator, a cooling unit and a reservoir unit in an annular structure;

an opening and closing apparatus connected to a pipe leading out from the bottom of said rectifying separator;

a first check-valve, provided in the pipe that links said opening and closing apparatus with said outdoor heat exchanger, which allows a flow of the refrigerant only in the direction from said outdoor heat exchanger to said rectifying separator;

a second check-valve, provided in the pipe, linking the pipe, which links said main expansion apparatus with said indoor heat exchanger, with said opening and closing apparatus in series with a first sub-expansion apparatus which allows a flow of the refrigerant only in the direction from the pipe which links said main expansion apparatus and said indoor heat exchanger with said rectifying separator; and

a second sub-expansion apparatus provided, in a pipe which connects, via said cooling unit, the bottom of said rectifying separator and an intake pipe of said compressor, between the bottom of said rectifying separator and said cooling unit,

wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

18. A heat pump apparatus according to Claim 17 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which exercises control so that in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less said opening and closing apparatus is opened and in the case that said difference exceeds said predetermined value said opening and closing apparatus is closed.

19. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor,

a four-way valve, an outdoor heat exchanger, a main expansion apparatus and an indoor heat exchanger in an annular structure;

a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure; 5

a first opening and closing apparatus for connecting the bottom of said rectifying separator with a pipe of said outdoor heat exchanger;

a second opening and closing apparatus which connects the bottom of said rectifying separator to a pipe between said main expansion apparatus and said indoor heat exchanger via a first sub-expansion apparatus so as to enable the opening and the closing of the connection; 10 15

and
a third opening and closing apparatus which connects the bottom of said rectifying separator and an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection, 20

wherein, said cooling unit is formed so that the refrigerant moving toward said third opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle. 25 30

20. A heat pump apparatus according to Claim 19 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which opens said first opening and closing apparatus and said third opening and closing apparatus as well as closes said second opening and closing apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which closes said first opening and closing apparatus and third opening and closing apparatus as well as opens said second opening and closing apparatus when said difference exceeds a predetermined value at the time of the cooling operation, 35 40 45
wherein said operation control apparatus opens said second opening and closing apparatus and third opening and closing apparatus as well as closes said first opening and closing apparatus in the case that the difference 50 55

between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which closes said second opening and closing apparatus and said third opening and closing apparatus as well as opens said first opening and closing apparatus in the case that said difference exceeds a predetermined value.

21. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus, an indoor main expansion apparatus and an indoor heat exchanger in an annular structure; a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;

a first opening and closing apparatus for connecting the bottom of said rectifying separator to a discharge pipe of said compressor via a first sub-expansion apparatus so as to enable the opening and the closing of the connection; a second sub-expansion apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor; and a second opening and closing apparatus which connects the bottom of said reservoir unit with the pipe which links said outdoor main expansion apparatus to said indoor main expansion apparatus so as to enable the opening and the closing of the connection, 35

wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

22. A heat pump apparatus according to Claim 21 characterized by comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which opens the second opening and closing apparatus for a specific period of time while closing the first opening and closing apparatus and, after that, opens said first opening and closing apparatus and closes said second opening and closing 50

apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which opens said first opening and closing apparatus and said second opening and closing apparatus when said difference exceeds a predetermined value.

23. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus which is able to be completely closed, an indoor main expansion apparatus which is able to be completely closed and an indoor heat exchanger, in an annular structure;

a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;

a first opening and closing apparatus for connecting the bottom of said rectifying separator to a discharge pipe of said compressor via a first sub-expansion apparatus so as to enable the opening and the closing of the connection;

a second sub-expansion apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor; and a second opening and closing apparatus which connects the bottom of said reservoir unit with the pipe which links said outdoor main expansion apparatus to said indoor main expansion apparatus so as to enable the opening and the closing of the connection,

wherein, said cooling unit is formed so that the refrigerant moving toward the intake pipe of said compressor through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

24. A heat pump apparatus according to Claim 23 characterized by comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and

an operation control apparatus which opens the second opening and closing apparatus for a specific period of time while closing the first opening and closing apparatus and, after that, opens said first opening and closing apparatus

and closes said second opening and closing apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less which opens said first opening and closing apparatus and said second opening and closing apparatus when said difference exceeds a predetermined value and which then exercises control to completely close said outdoor main expansion apparatus and said indoor main expansion apparatus in the case that said compressor stops under the condition where said first opening and closing apparatus is open and said second opening and closing apparatus is closed

25. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus, an indoor main expansion apparatus and an indoor heat exchanger in an annular structure; a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;

a first opening and closing apparatus for connecting the bottom of said rectifying separator to a discharge pipe of said compressor via a first sub-expansion apparatus so as to enable the opening and the closing of the connection; a second opening and closing apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection; and

a third opening and closing apparatus which connects the bottom of said reservoir unit with the pipe which links said outdoor main expansion apparatus to said indoor main expansion apparatus so as to enable the opening and the closing of the connection,

wherein, said cooling unit is formed so that the refrigerant moving toward said second opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

26. A heat pump apparatus according to Claim 25 char-

acterized by comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
 5 an operation control apparatus which opens the second opening and closing apparatus for a specific period of time while closing the first opening and closing apparatus and the second opening and closing apparatus and, after that,
 10 opens said first opening and closing apparatus and said second opening and closing apparatus as well as closes said third opening and closing apparatus for a specific period of time and, after that, closes said first opening and
 15 closing apparatus, said second opening and closing apparatus and said third opening and closing apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has
 20 been detected by said indoor thermal sensor, becomes a predetermined or less and which closes said second opening and closing apparatus and opens said first opening and closing apparatus as well as said third opening and
 25 closing apparatus for a specific period of time and, after that, closes said first opening and closing apparatus and said third opening and closing apparatus and opens said opening and closing apparatus when said difference
 30 exceeds a predetermined value and which closes said first opening and closing apparatus, said second opening and closing apparatus and said third opening and closing apparatus in the case that said compressor stops.
 35

27. A heat pump apparatus characterized by comprising:

40 a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus which is able to be completely closed, an indoor main
 45 expansion apparatus which is able to be completely closed and an indoor heat exchanger, in an annular structure;
 a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir
 50 unit in an annular structure;
 a first opening and closing apparatus for connecting the bottom of said rectifying separator to a discharge pipe of said compressor via a
 55 first sub-expansion apparatus so as to enable the opening and the closing of the connection;
 a second opening and closing apparatus which connects the bottom of said rectifying separa-

tor to an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection; and

a third opening and closing apparatus which connects the bottom of said reservoir unit with the pipe which links said outdoor main expansion apparatus, which is able to be completely closed, to said indoor main expansion apparatus, which is able to be completely closed, so as to enable the opening and the closing of the connection,

wherein, said cooling unit is formed so that the refrigerant moving toward said second opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

28. A heat pump apparatus according to Claim 27 characterized by further comprising:

a first pressure sensor provided in an intake pipe of said compressor, a second pressure sensor provided in the discharge pipe of said compressor, an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and

an operation control apparatus which opens the third opening and closing apparatus for a specific period of time while closing the first opening and closing apparatus and the second opening and closing apparatus and, afterwards, opens said first opening and closing apparatus and said second opening and closing apparatus as well as closes said third opening and closing apparatus for a specific period of time and, afterwards, closes said first opening and closing apparatus, said second opening and closing apparatus and said third opening and closing apparatus, when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less;

which closes said second opening and closing apparatus and opens said first opening and closing apparatus as well as said third opening and closing apparatus for a specific period of time and, afterwards, closes said first opening and closing apparatus as well as said third opening and closing apparatus and opens said second opening and closing apparatus when

said difference exceeds a predetermined value;

which completely closes said outdoor main expansion apparatus and said indoor main expansion apparatus in the case that said compressor stops under the condition where said first opening and closing apparatus and said second opening and closing apparatus are open and said third opening and closing apparatus is closed and closes said first opening and closing apparatus, said second opening and closing apparatus and said third opening and closing apparatus after the difference between the measured value of said first pressure sensor and the measured value of said second pressure sensor becomes a preset predetermined value or less; and
which closes said first opening and closing apparatus, said second opening and closing apparatus and said third opening and closing apparatus in the case that the operations of said compressor and said indoor unit stop.

29. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus, an indoor main expansion apparatus and an indoor heat exchanger, in an annular structure; a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;
a first opening and closing apparatus for connecting the bottom of said rectifying separator to a pipe, which creates a linkage between said outdoor expansion apparatus and said indoor main expansion apparatus, via a first sub-expansion apparatus so as to enable the opening and the closing of the connection;
a second opening and closing apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection; and
a third opening and closing apparatus which connects the bottom of said reservoir unit with an intake pipe of said compressor so as to enable the opening and the closing of the connection, wherein, said cooling unit is formed so that the refrigerant moving toward said second opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in

the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

30. A heat pump apparatus according to Claim 29 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which opens the first opening and closing apparatus and the second opening and closing apparatus as well as closes the third opening and closing apparatus in the case that the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which closes said first opening and closing apparatus and opens said second opening and closing apparatus as well as said third opening and closing apparatus when said difference between said set air temperature and said temperature of the intake air exceeds a predetermined value.

31. A heat pump apparatus according to Claim 29 characterized by further comprising:

a discharge thermal sensor for detecting the discharge temperature of said compressor; and
an operation control apparatus which opens said first opening and closing apparatus and opens either or both of said second opening and closing apparatus or said third opening and closing apparatus in the case that the difference between a preset discharge temperature and a discharge temperature detected by said discharge thermal sensor exceeds a predetermined value.

32. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus, a gas-liquid separator, an indoor main expansion apparatus and an indoor heat exchanger, in an annular structure;
a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir unit in an annular structure;
a first opening and closing apparatus for con-

necting the bottom of said rectifying separator to said gas-liquid separator via a first sub-expansion apparatus so as to enable the opening and the closing of the connection;

a second opening and closing apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection; and

a third opening and closing apparatus which connects the bottom of said reservoir unit with an intake pipe of said compressor so as to enable the opening and the closing of the connection,

wherein, said cooling unit is formed so that the refrigerant moving toward said second opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

33. A heat pump apparatus according to Claim 32 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which opens the first opening and closing apparatus and the second opening and closing apparatus as well as closes the third opening and closing apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which closes said first opening and closing apparatus and opens said second opening and closing apparatus as well as said third opening and closing apparatus when said difference exceeds a predetermined value.

34. A heat pump apparatus characterized by comprising:

a main circuit of a refrigeration cycle sequentially connecting through pipes, a compressor, a four-way valve, an outdoor heat exchanger, an outdoor main expansion apparatus, a gas-liquid separator, an indoor main expansion apparatus and an indoor heat exchanger, in an annular structure;

a closed circuit connecting a top part of a rectifying separator, a cooling unit and a reservoir

unit in an annular structure;

a first opening and closing apparatus for connecting the bottom of said rectifying separator to a top part of said gas-liquid separator via a first sub-expansion apparatus so as to enable the opening and the closing of the connection; a third sub-expansion apparatus which connects the bottom of said gas-liquid separator to the pipe which links said first opening and closing apparatus to the top part of said gas-liquid separator;

a second opening and closing apparatus which connects the bottom of said rectifying separator to an intake pipe of said compressor via a second sub-expansion apparatus so as to enable the opening and the closing of the connection; and

a third opening and closing apparatus which connects the bottom of said reservoir unit with an intake pipe of said compressor so as to enable the opening and the closing of the connection,

wherein, said cooling unit is formed so that the refrigerant moving toward said second opening and closing apparatus through said second sub-expansion apparatus from the bottom of said rectifying separator and the refrigerant in the top part of said rectifying separator indirectly exchange heat and non-azeotropic refrigerant is charged in said refrigeration cycle.

35. A heat pump apparatus according to Claim 34 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit having said indoor heat exchanger; and
an operation control apparatus which opens the first opening and closing apparatus and the second opening and closing apparatus as well as closes the third opening and closing apparatus when the difference between a set air temperature, which has been preset, and the temperature of the intake air, which has been detected by said indoor thermal sensor, becomes a predetermined value or less and which closes said first opening and closing apparatus and opens said second opening and closing apparatus as well as said third opening and closing apparatus in the case that said difference exceeds a predetermined value.

36. A heat pump apparatus according to Claim 34 characterized by further comprising:

an indoor thermal sensor for detecting the temperature of the intake air of an indoor unit hav-

ing said indoor heat exchanger; and
 an operation control apparatus which opens
 the first opening and closing apparatus while
 keeping the second opening and closing appara-
 tus and the third opening and closing appara- 5
 tus closed when the difference between a set
 air temperature, which has been preset, and
 the temperature of the intake air, which has
 been detected by said indoor thermal sensor,
 becomes a first predetermined value or less, 10
 which opens said first opening and closing
 apparatus and said second opening and clos-
 ing apparatus while closing said third opening
 and closing apparatus when said difference
 becomes a second predetermined value, which 15
 is smaller than said first predetermined value,
 or less and opens said first opening and closing
 apparatus and said second opening and clos-
 ing apparatus after a predetermined time has
 elapsed and, in addition, closes said first open- 20
 ing and closing apparatus and said second
 opening and closing apparatus after a prede-
 termined time has elapsed;
 and which closes said first opening and closing
 apparatus and opens said second opening and 25
 closing apparatus as well as said third opening
 and closing apparatus when said difference
 exceeds said second predetermined value.

37. A heat pump apparatus characterized by compris- 30
 ing:

a main circuit of a refrigeration cycle which con-
 nects, through pipes, a compressor, a four-way
 valve, an outdoor heat exchanger, an outdoor 35
 main expansion apparatus, an indoor main
 expansion apparatus and an indoor heat
 exchanger in sequence in an annular structure;
 a bypass path which connects one end to a
 point between said four-way valve and said 40
 indoor heat exchanger and which connects the
 other end to a point between said indoor main
 expansion apparatus and said outdoor main
 expansion apparatus;
 a first opening and closing apparatus which is 45
 connected to said bypass path and which
 opens at the time of heat storage operation;
 a heat regenerator which is connected to said
 bypass path and which exchanges heat with a
 heat storage material filled into a heat storage 50
 tank;
 a heat storage expansion apparatus which is
 connected to said bypass path and which is
 provided in series with said first opening and
 closing apparatus and said heat regenerator; 55
 a second opening and closing apparatus which
 connects a point between said first opening
 and closing apparatus and said heat regenera-

tor to an intake pipe of said compressor and
 which opens at the time of stored heat usage
 operation;

a closed circuit which connects a top part of a
 rectifying separator, a cooling unit and a reser-
 voir unit in an annular structure;

a third opening and closing apparatus which
 connects the bottom of said rectifying separa-
 tor to the pipe connecting said outdoor main
 expansion apparatus, said indoor main expan-
 sion apparatus and said heat storage expan-
 sion apparatus via a first sub-expansion
 apparatus so as to enable the opening and
 closing of the connection; and

a fourth opening and closing apparatus for con-
 necting the bottom of said rectifying separator
 to an intake pipe of said compressor via a sec-
 ond sub-expansion apparatus so as to enable
 the opening and the closing of the connection,
 wherein said cooling unit is formed so that the
 refrigerant which moves toward said fourth
 opening and closing apparatus through said
 second sub-expansion apparatus from the bot-
 tom of said rectifying separator and the refrig-
 erant in the top part of said rectifying separator
 indirectly exchange heat and a non-azeotropic
 refrigerant is charged in said refrigeration
 cycle.

38. A heat pump apparatus according to Claim 37 char-
 acterized by further comprising:

a thermal sensor for detecting the temperature
 of a heat storage material which has been filled
 into said heat storage tank;
 an operation control apparatus which opens
 the third opening and closing apparatus and
 the fourth opening and closing apparatus when
 the temperature of said heat storage material
 detected by said thermal sensor becomes
 higher than a set temperature which has been
 preset and which closes said third opening and
 closing apparatus and opens said fourth open-
 ing and closing apparatus in the case that the
 temperature of said heat storage material
 detected by said thermal sensor becomes said
 set temperature or less.

39. A heat pump apparatus according to Claim 37 char-
 acterized by further comprising:

a thermal sensor for detecting the temperature
 of a heat storage material which has been filled
 into said heat storage tank;
 an operation control apparatus which opens,
 for a predetermined time, and, subsequently,
 closes the third opening and closing apparatus
 and the fourth opening and closing apparatus

and in the case that the temperature of said heat storage material detected by said thermal sensor becomes higher than a set temperature which has been preset and which closes said third opening and closing apparatus and opens said fourth opening and closing apparatus in the case that the temperature of said heat storage material detected by said thermal sensor becomes said set temperature or less.

40. A heat pump apparatus according to Claim 37 characterized by further comprising:

a pressure sensor for detecting a discharge pressure of said compressor; and
an operation control apparatus which opens the third opening and closing apparatus and the fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor exceeds the first set pressure which has been preset and which closes said third opening and closing apparatus and opens said fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor becomes the second set pressure, which is smaller than said first set pressure and which has been preset, or less

41. A heat pump apparatus according to Claim 37 characterized by further comprising:

a pressure sensor for detecting a discharge pressure of said compressor; and
an operation control apparatus which opens, for a predetermined time, and, subsequently, closes the third opening and closing apparatus and the fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor exceeds the first set pressure which has been preset and which closes said third opening and closing apparatus and opens said fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor becomes the second set pressure, which is smaller than said first set pressure and which has been preset, or less

42. A heat pump apparatus according to Claim 37 characterized by further comprising:

said compressor being a compressor which is able to control the capacity and a pressure sensor for detecting the discharge pressure of said compressor;
an operation control apparatus which controls the capacity of said compressor so that the dis-

charge pressure of said compressor detected by said pressure sensor becomes, substantially, a constant at the time of the heat storage operation and opens the third opening and closing apparatus and the fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor exceeds the first set pressure which has been preset, and the capacity of said compressor is the minimum, and which closes said third opening and closing apparatus and opens said fourth opening and closing apparatus in the case that said discharge pressure detected by said pressure sensor becomes the second set pressure, which is smaller than said first set pressure and which has been preset, or less.

43. a heat pump apparatus according to Claim 37 characterized by further comprising:

said compressor being a compressor which is able to control the capacity and a pressure sensor for detecting the discharge pressure of said compressor;
an operation control apparatus which controls the capacity of said compressor so that the discharge pressure of said compressor detected by said pressure sensor becomes, substantially, a constant at the time of the heat storage operation and opens, for a predetermined period of time, and, subsequently, closes the third opening and closing apparatus and the fourth opening and closing apparatus in the case that the discharge pressure detected by said pressure sensor exceeds the first set pressure which has been preset, and the capacity of said compressor is the minimum, and which closes said third opening and closing apparatus and opens said fourth opening and closing apparatus in the case that said discharge pressure detected by said pressure sensor becomes the second set pressure, which is smaller than said first set pressure and which has been preset, or less.

44. A heat pump apparatus according to Claim 37 characterized in that a bottom of said reservoir unit and an intake pipe of said compressor are connected via a fifth opening and closing apparatus.

FIG. 1

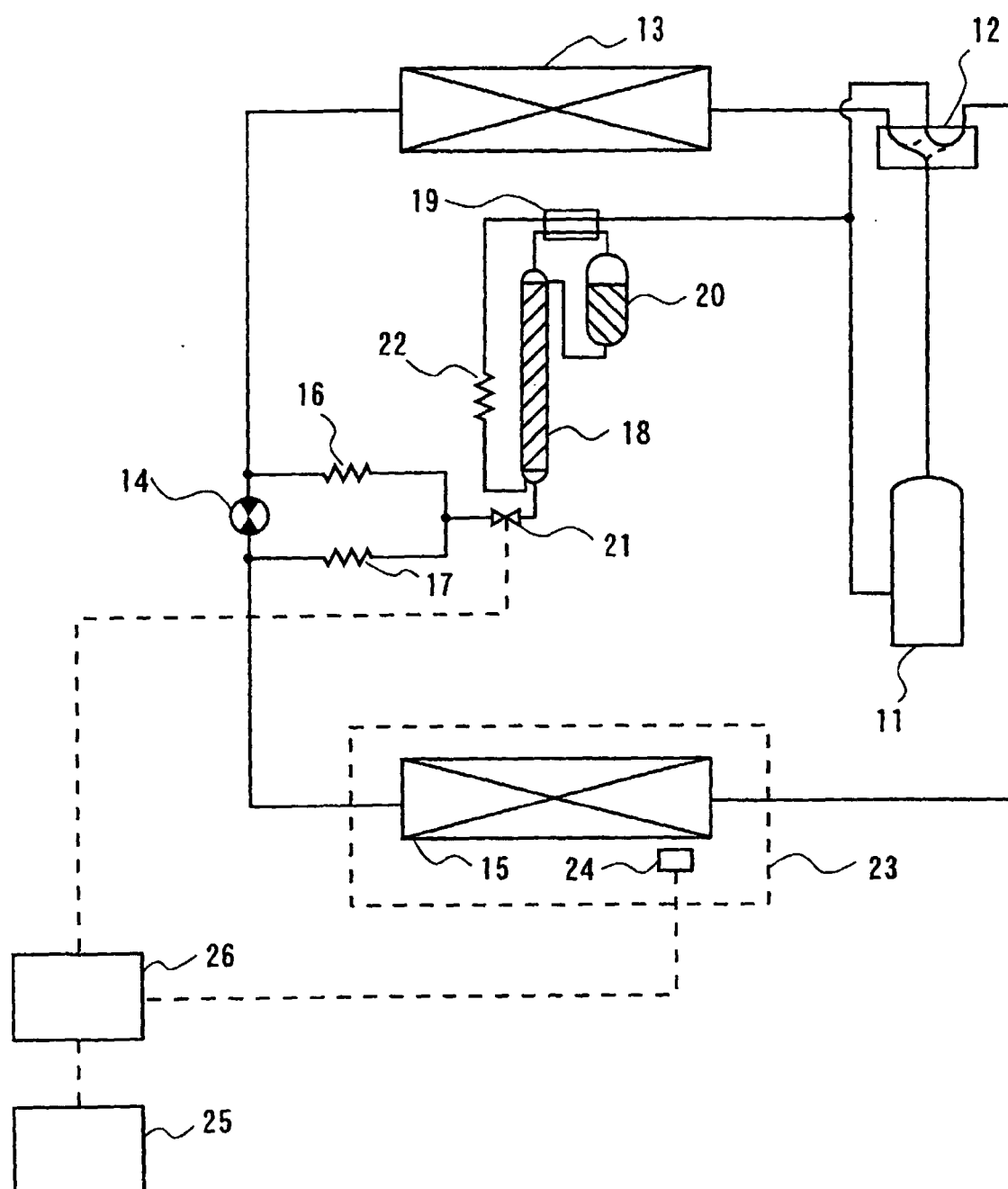


FIG. 2

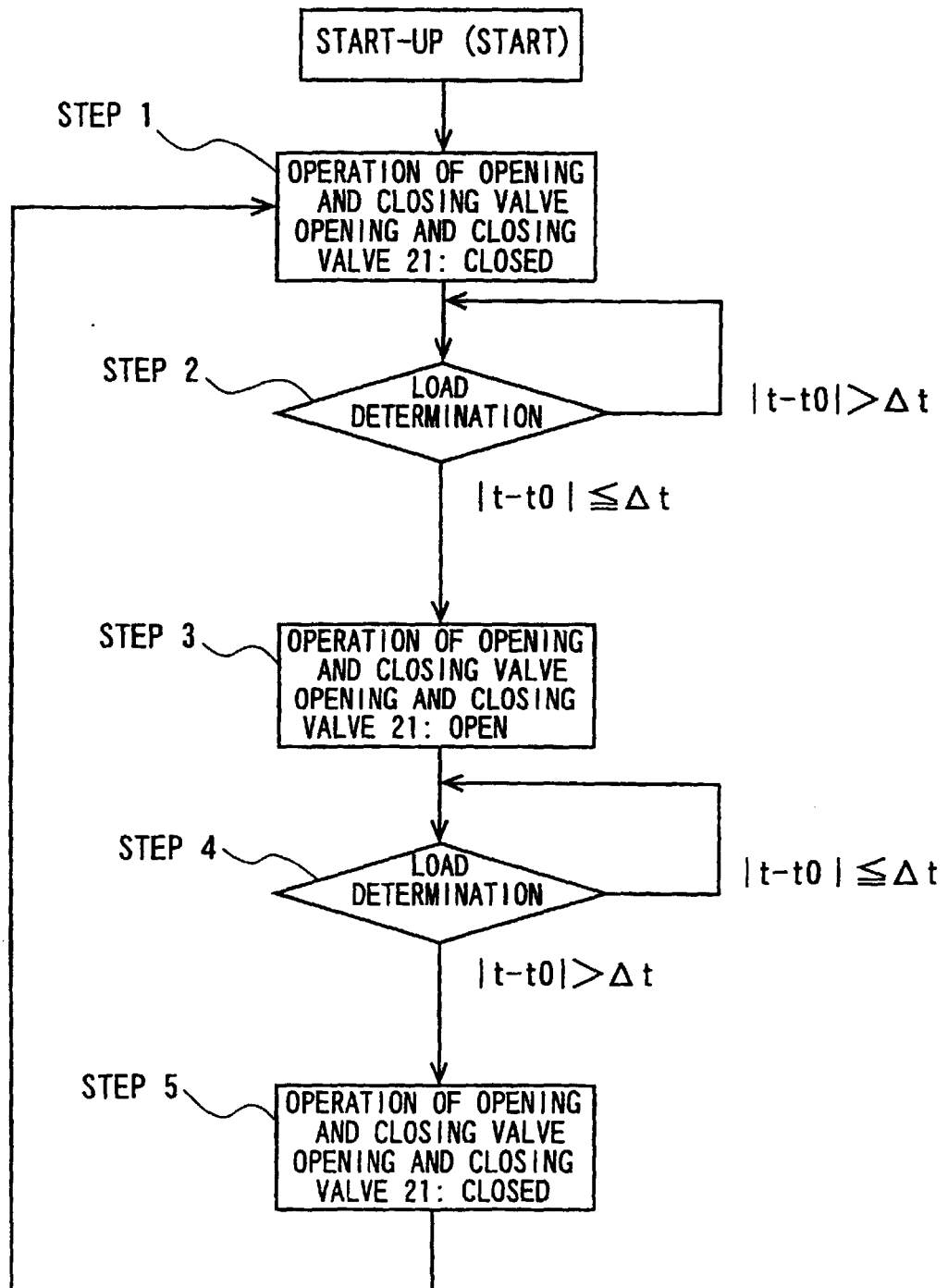


FIG. 3

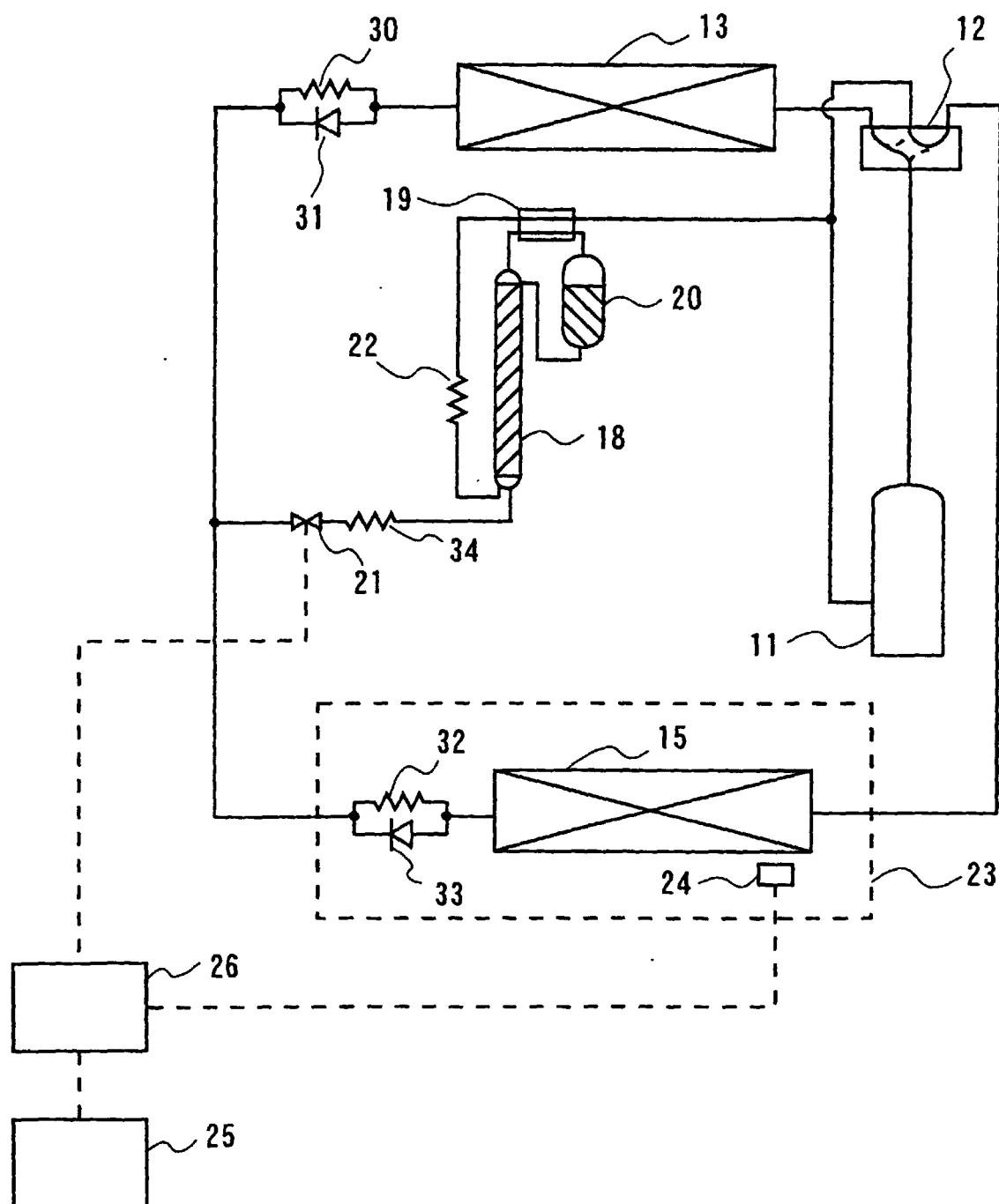


FIG. 4

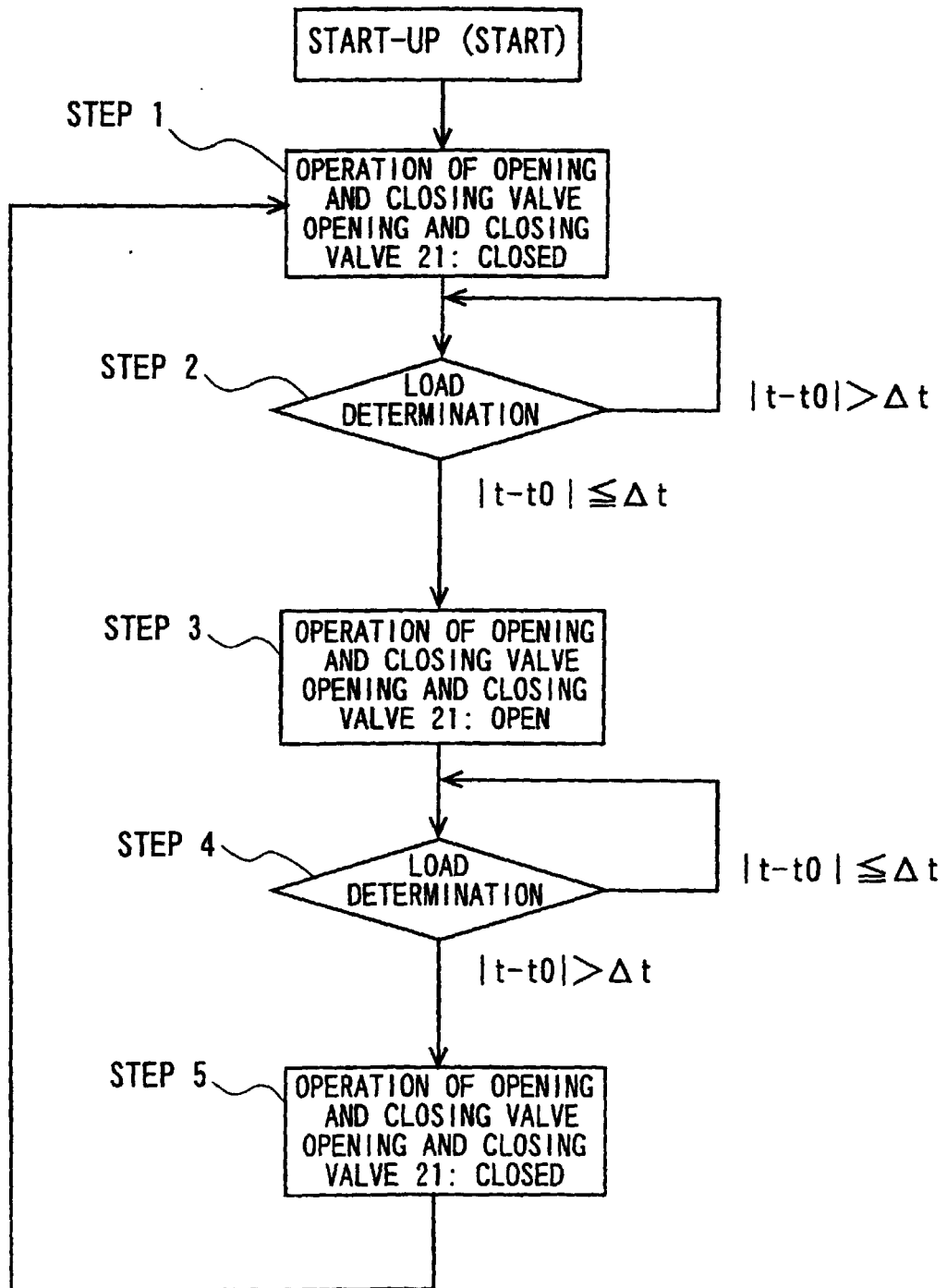


FIG. 5

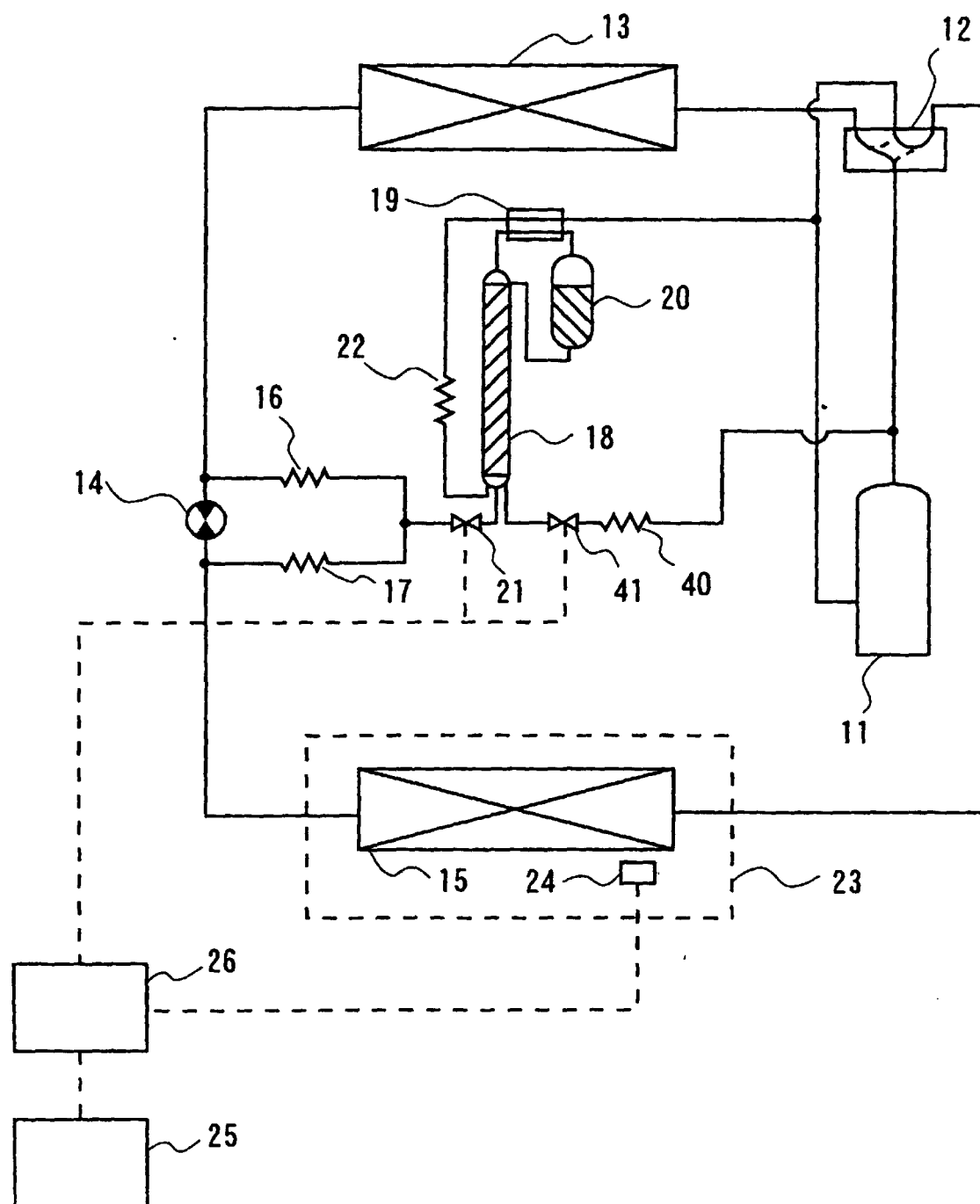


FIG. 6

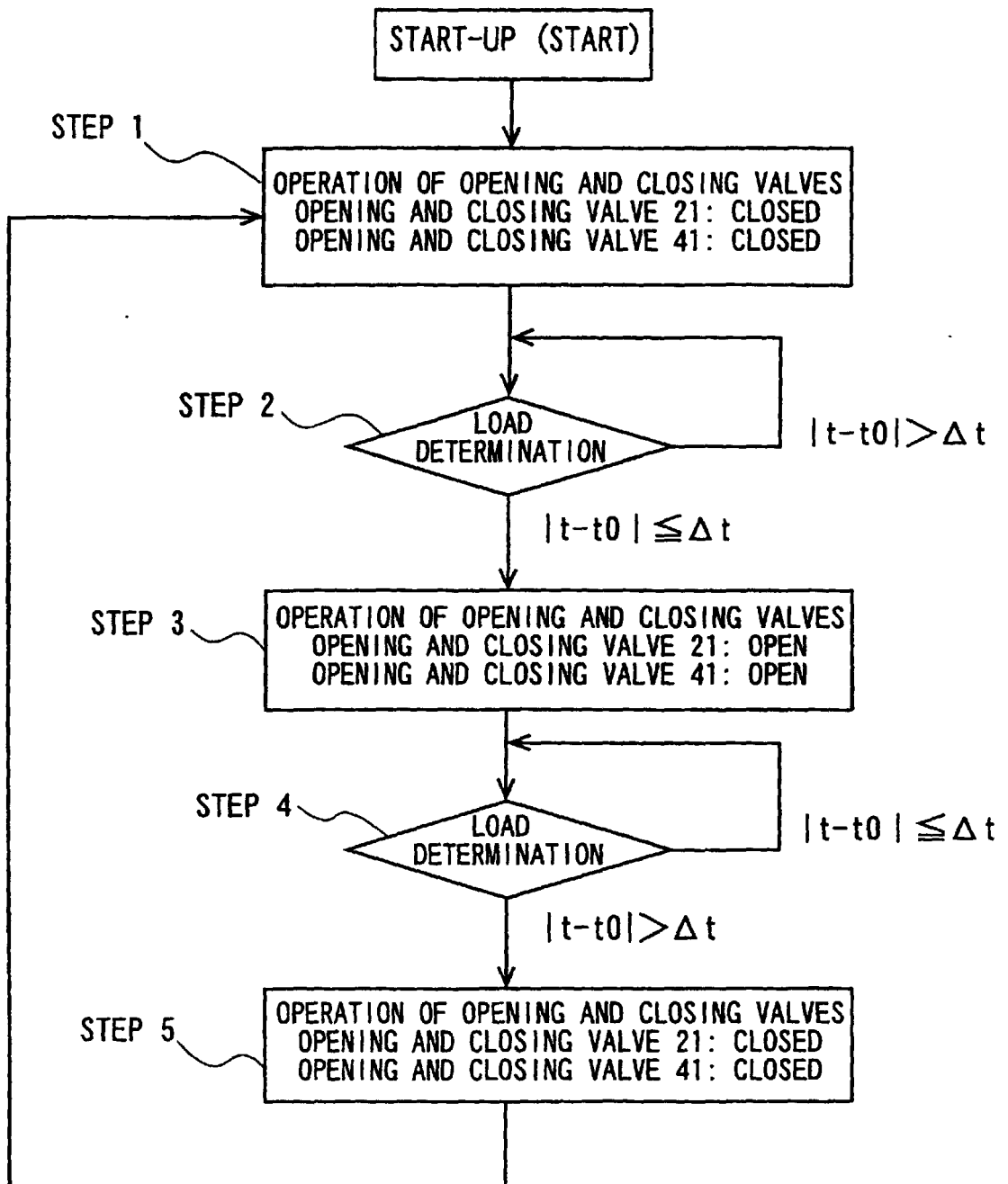


FIG. 7

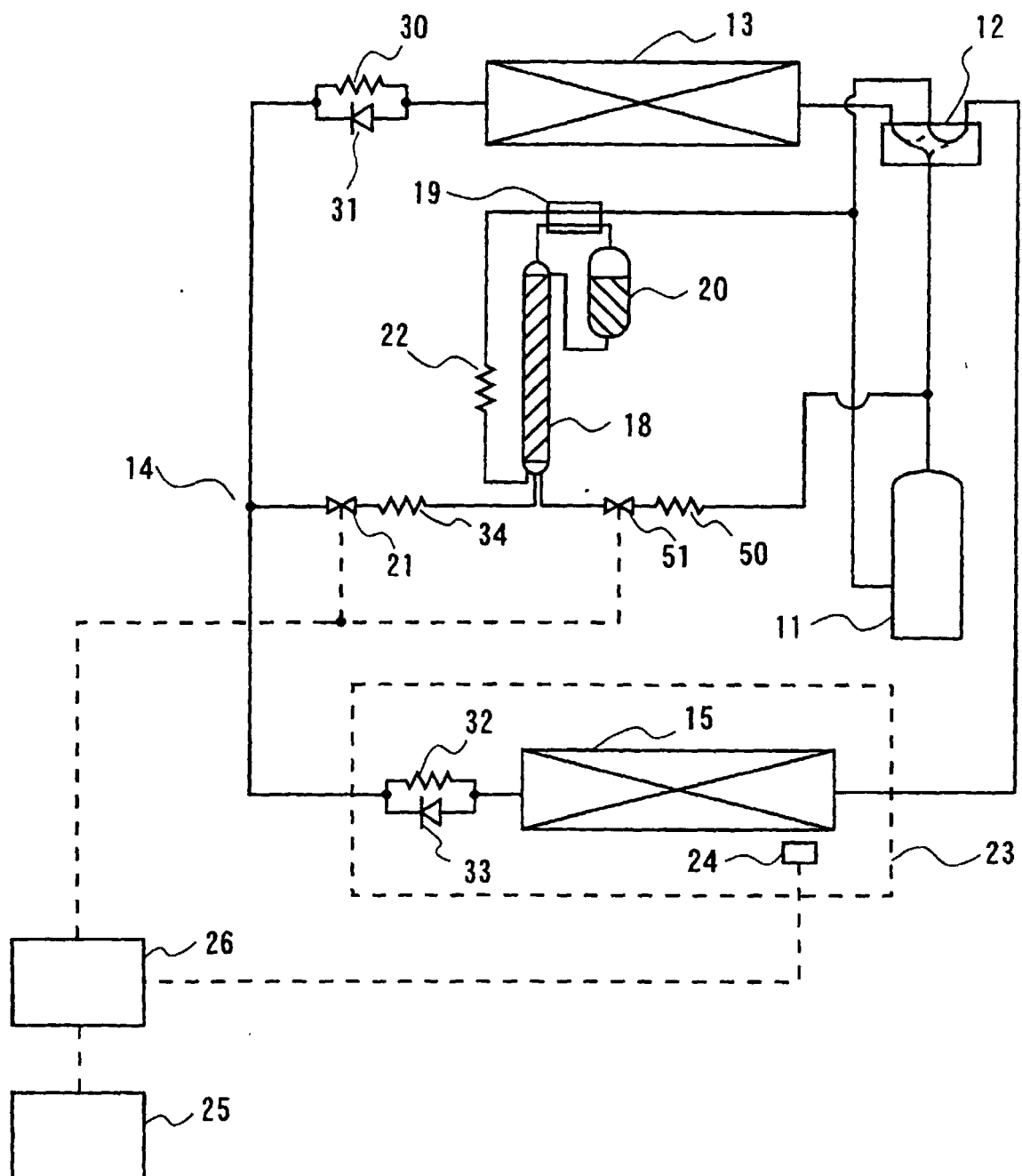


FIG. 8

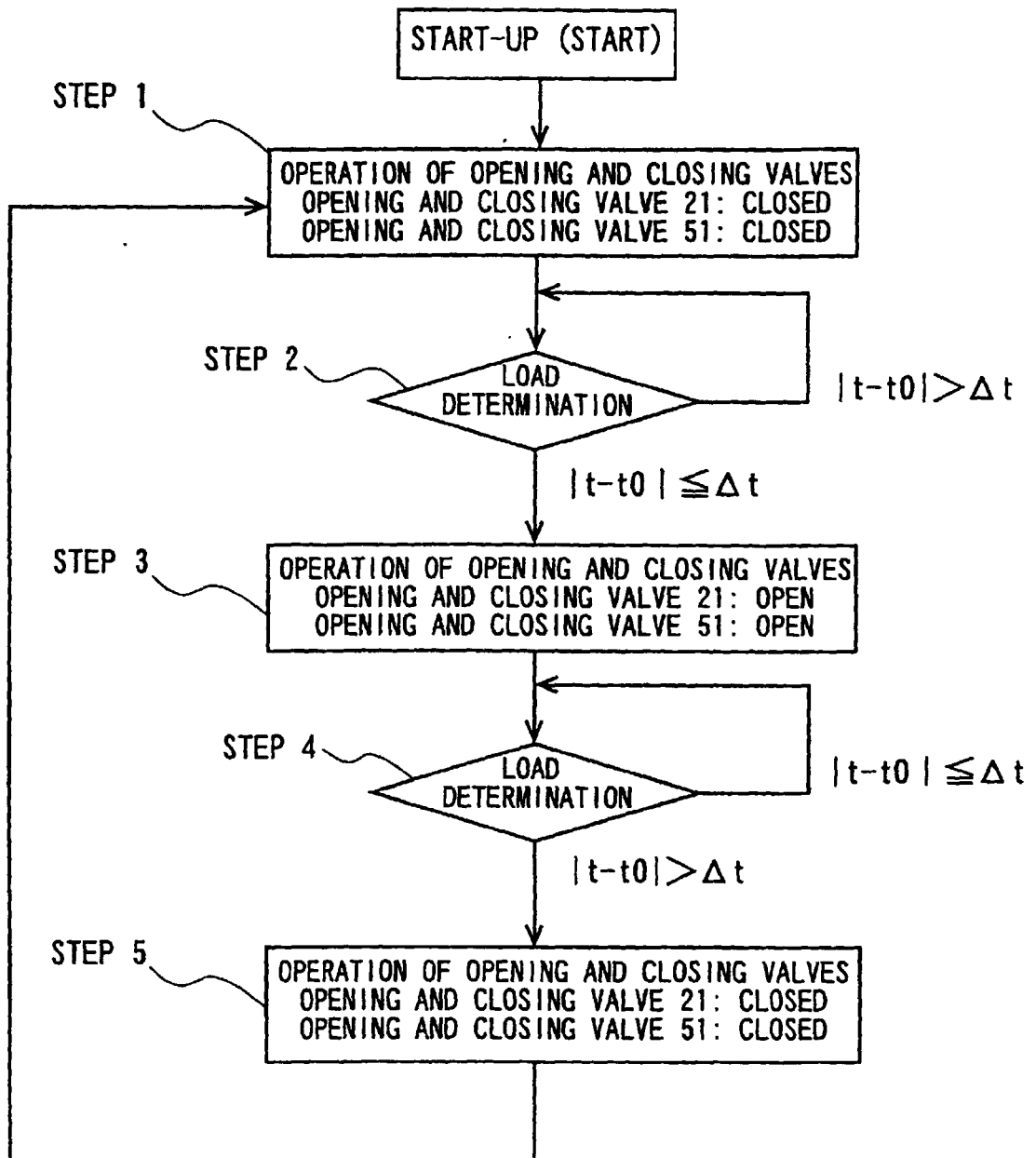


FIG. 9

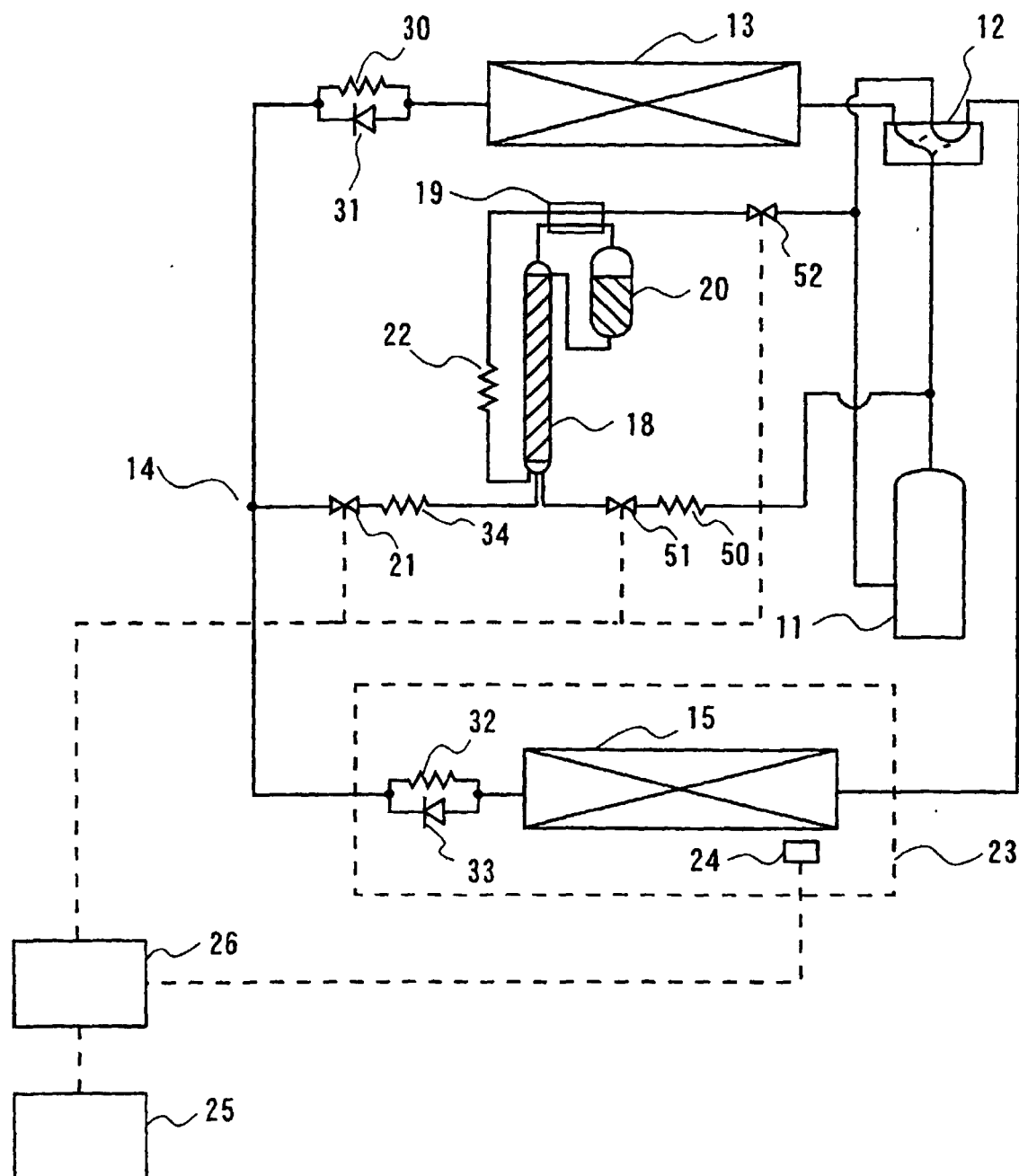


FIG. 10

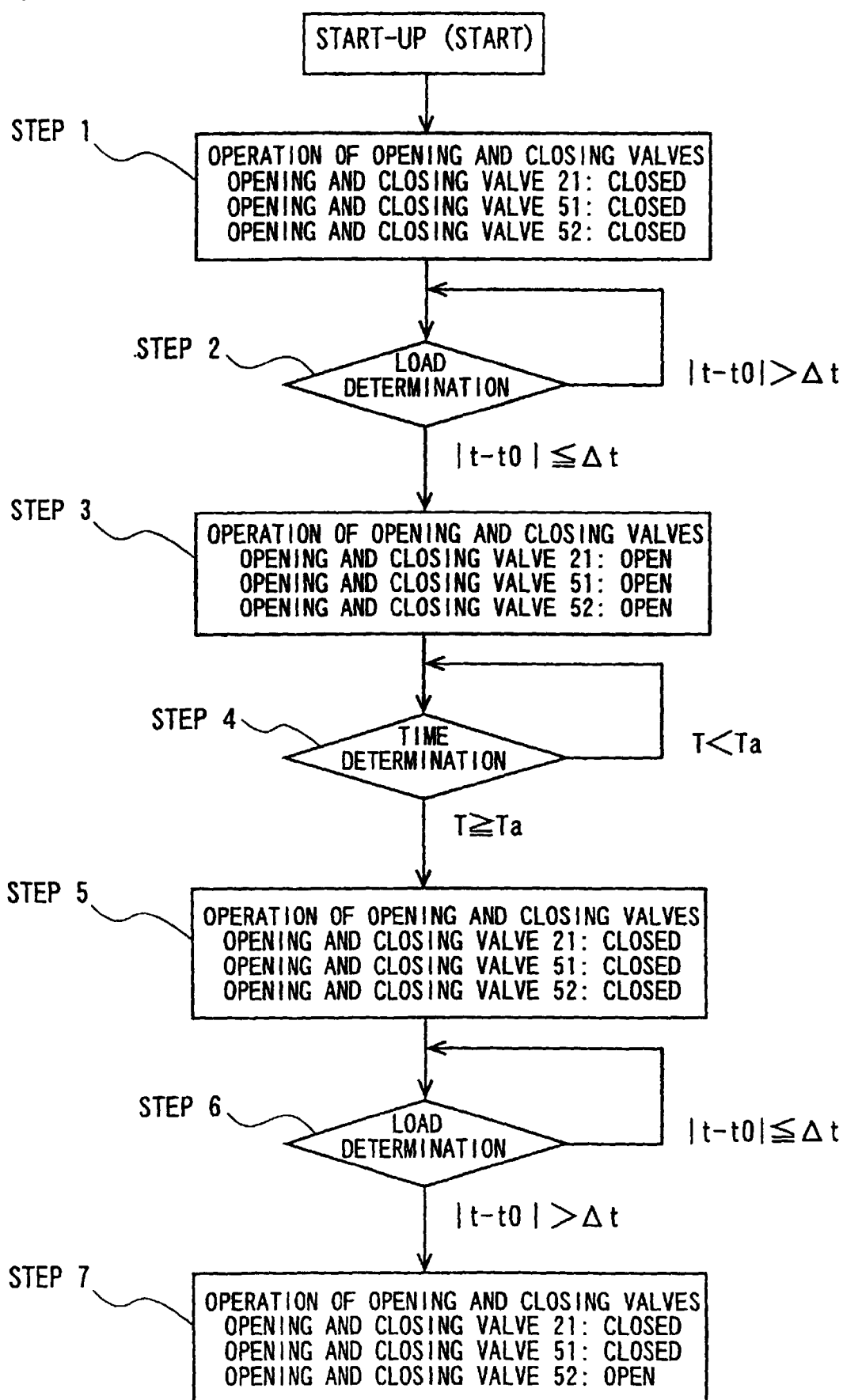


FIG. 11

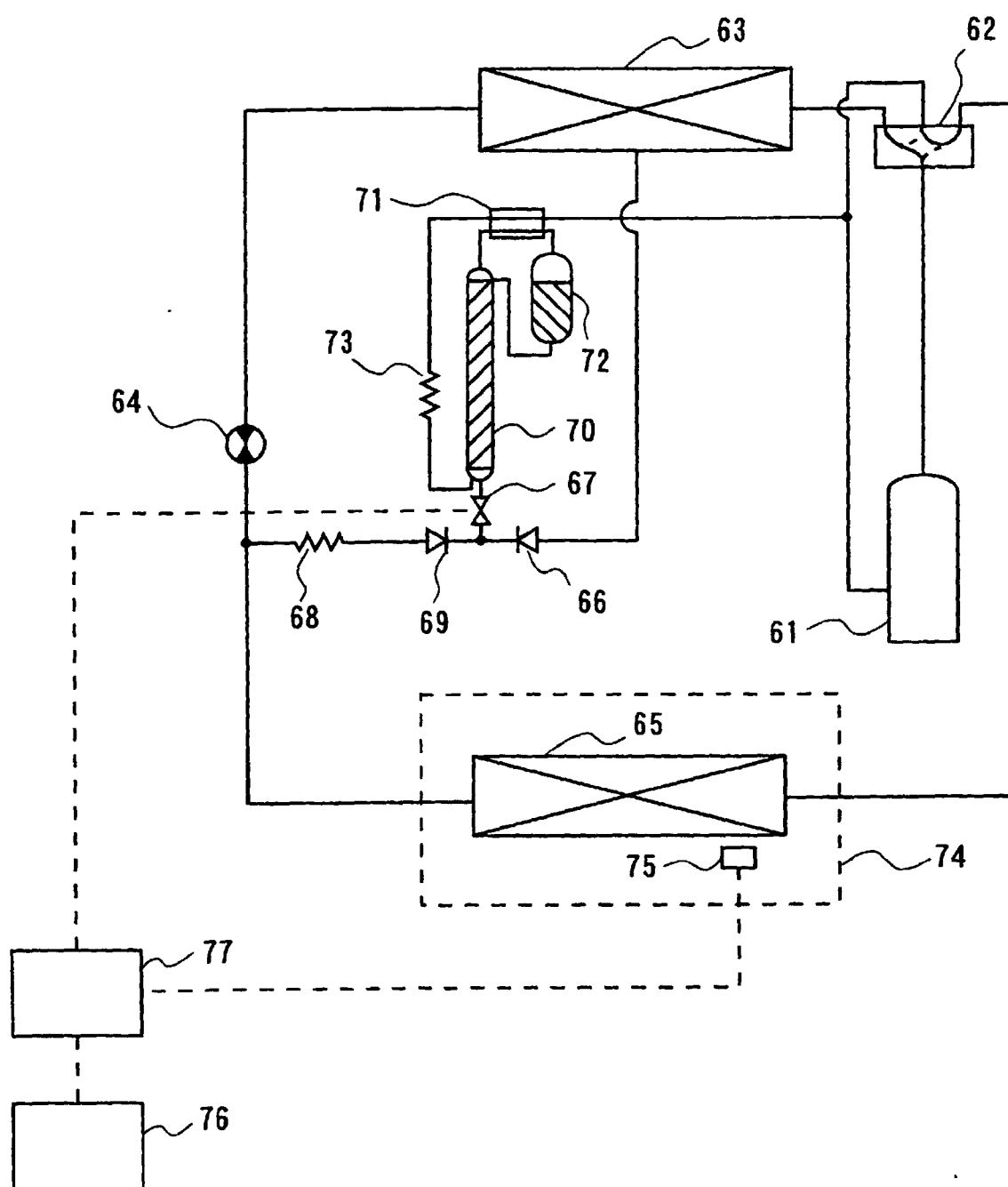


FIG. 12

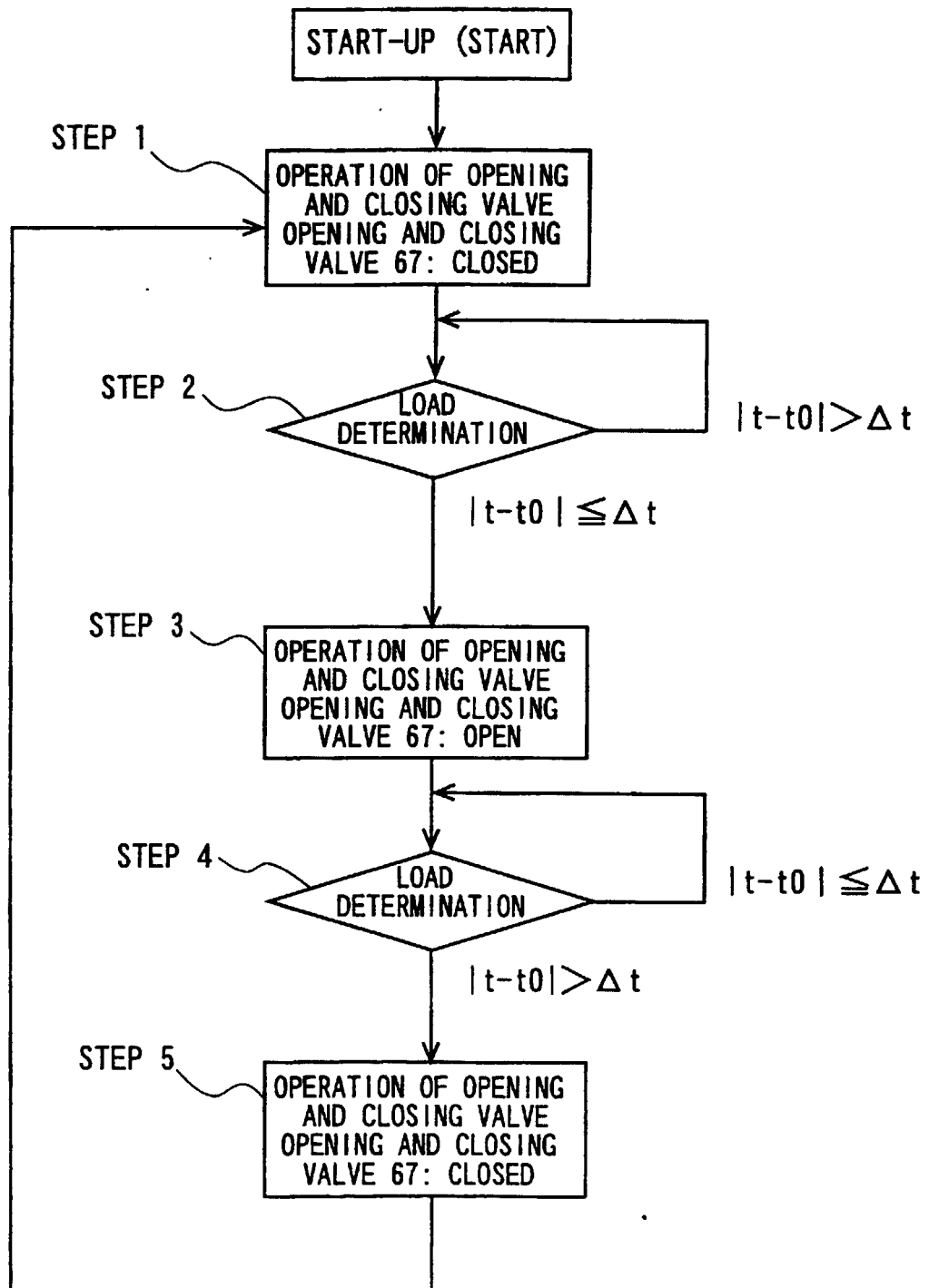


FIG. 13

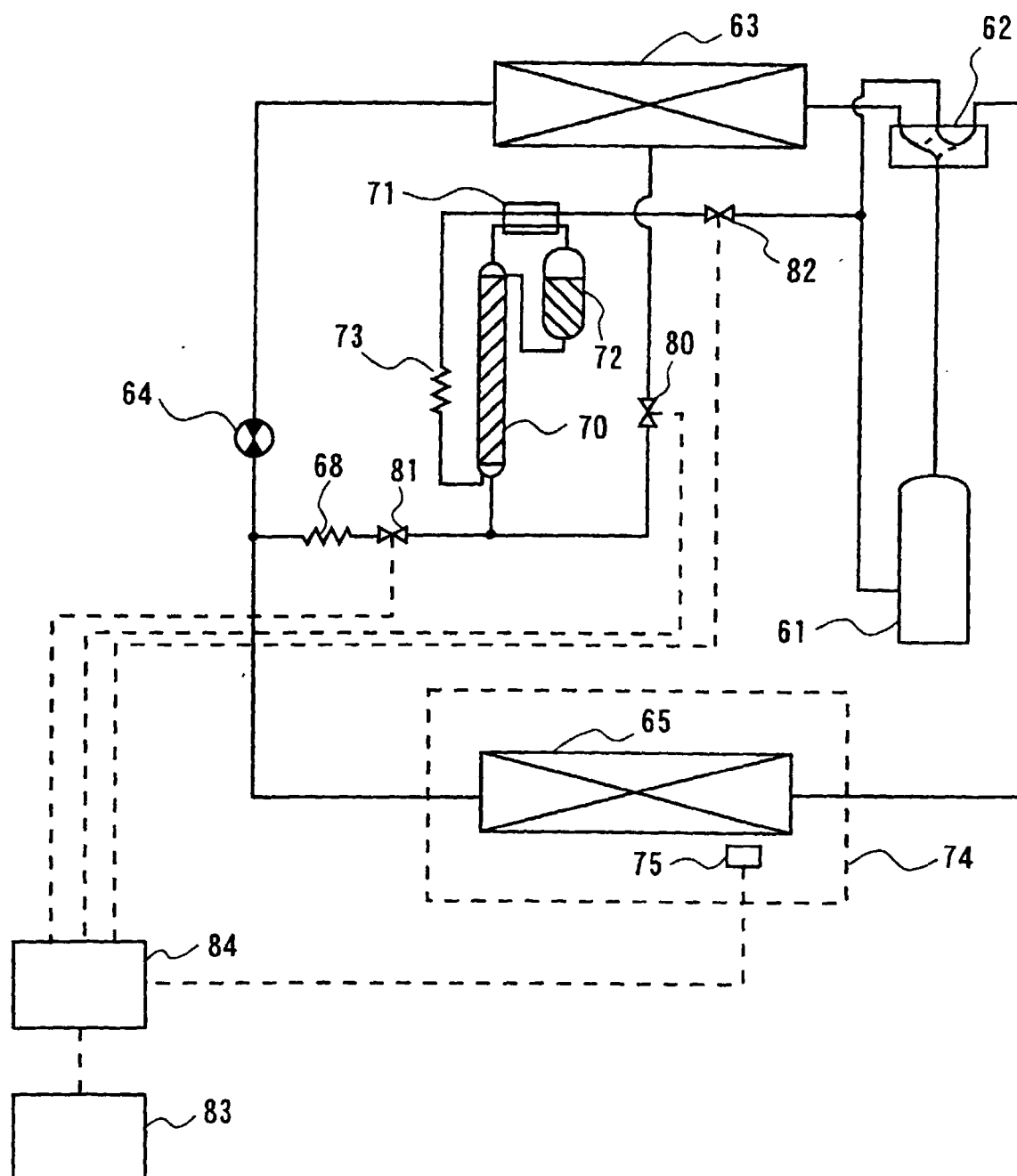


FIG. 14

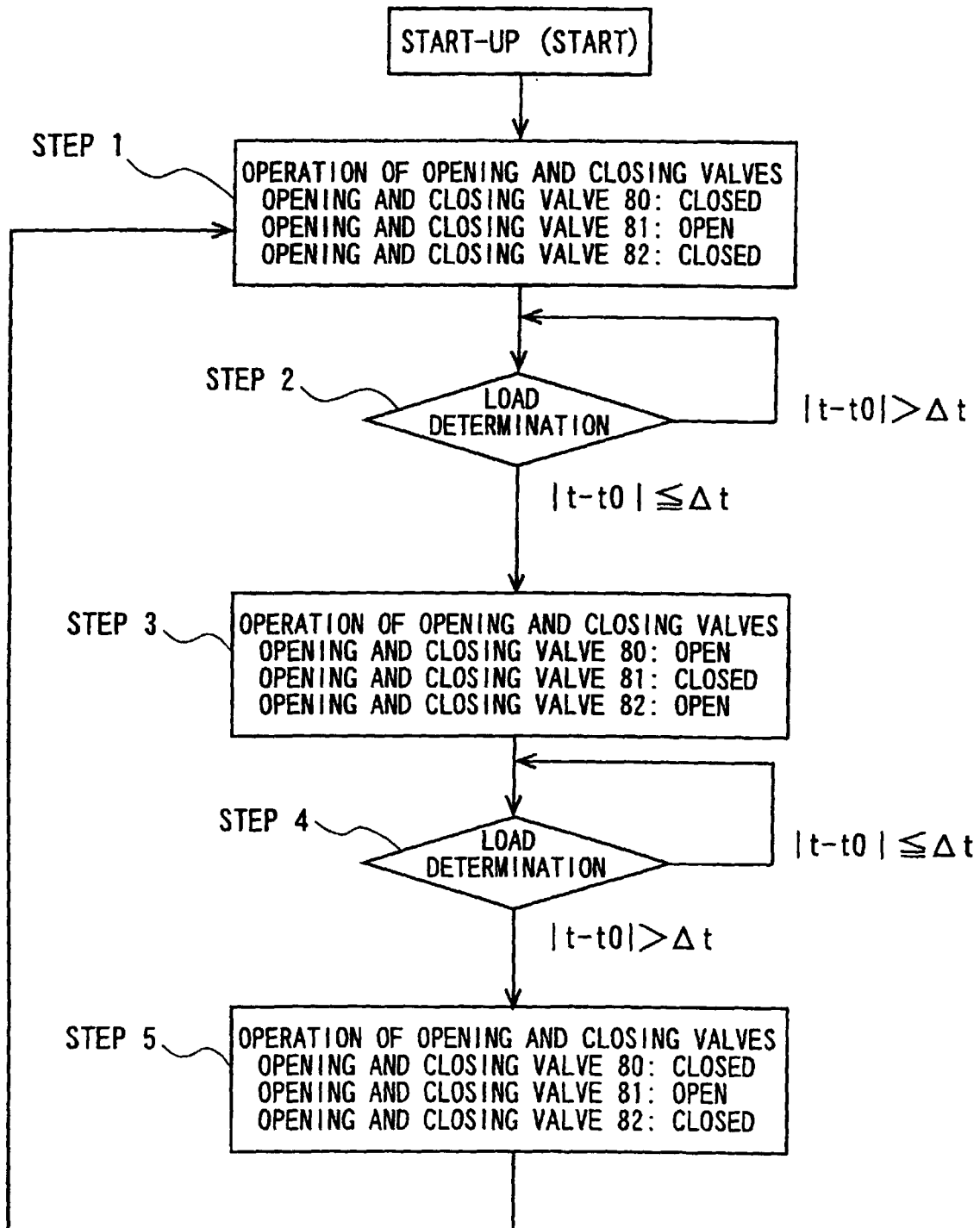


FIG. 15

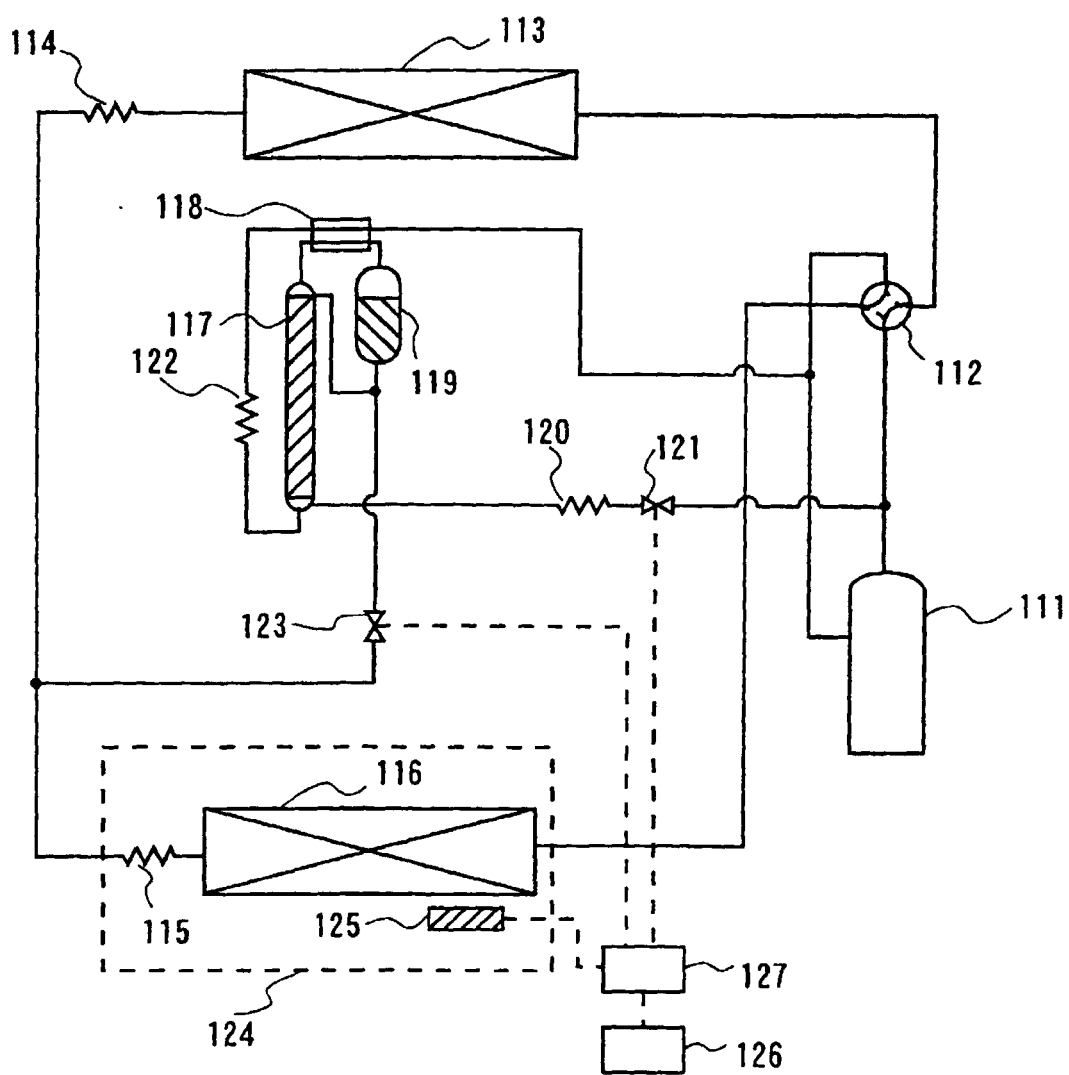


FIG. 16

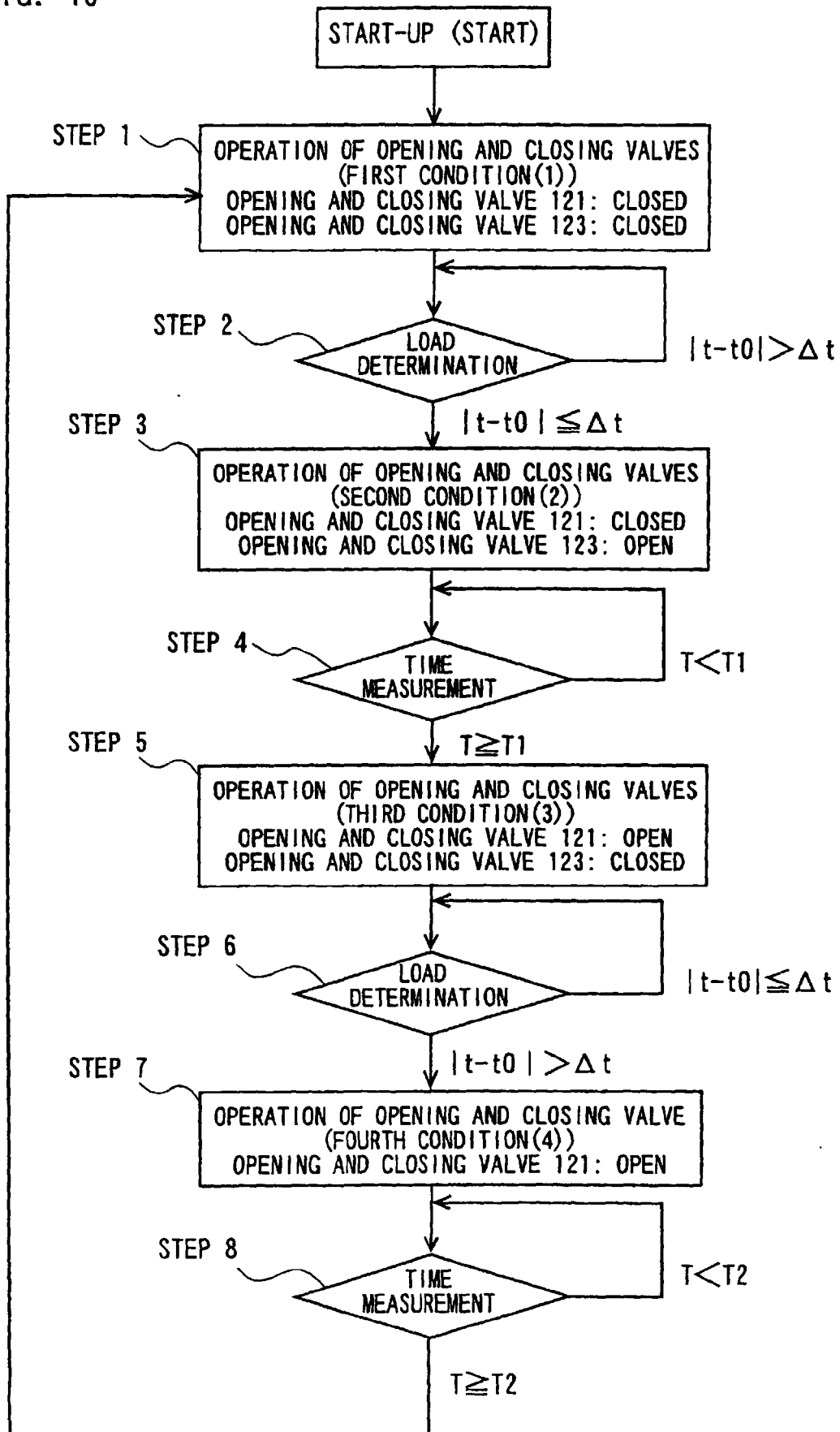


FIG. 17

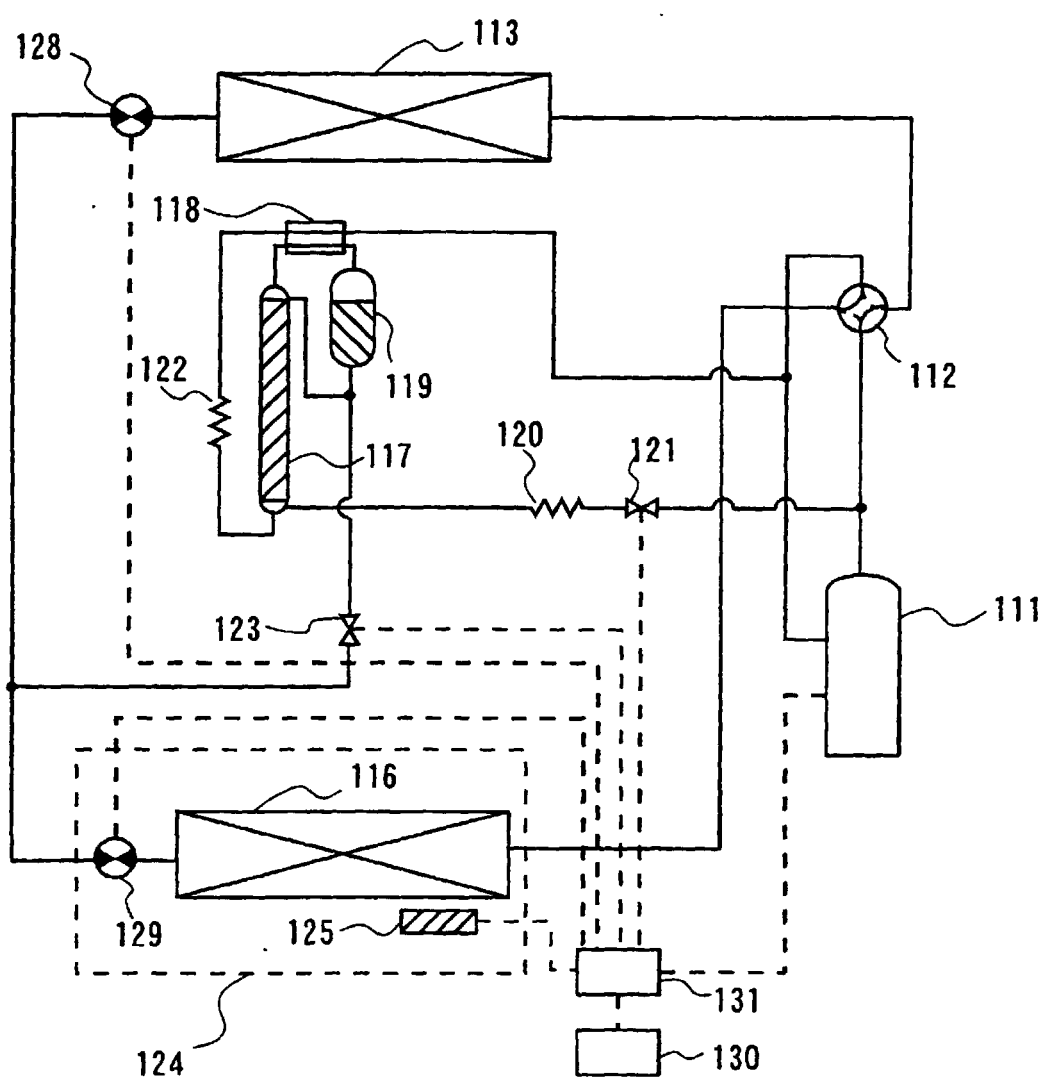


FIG. 18

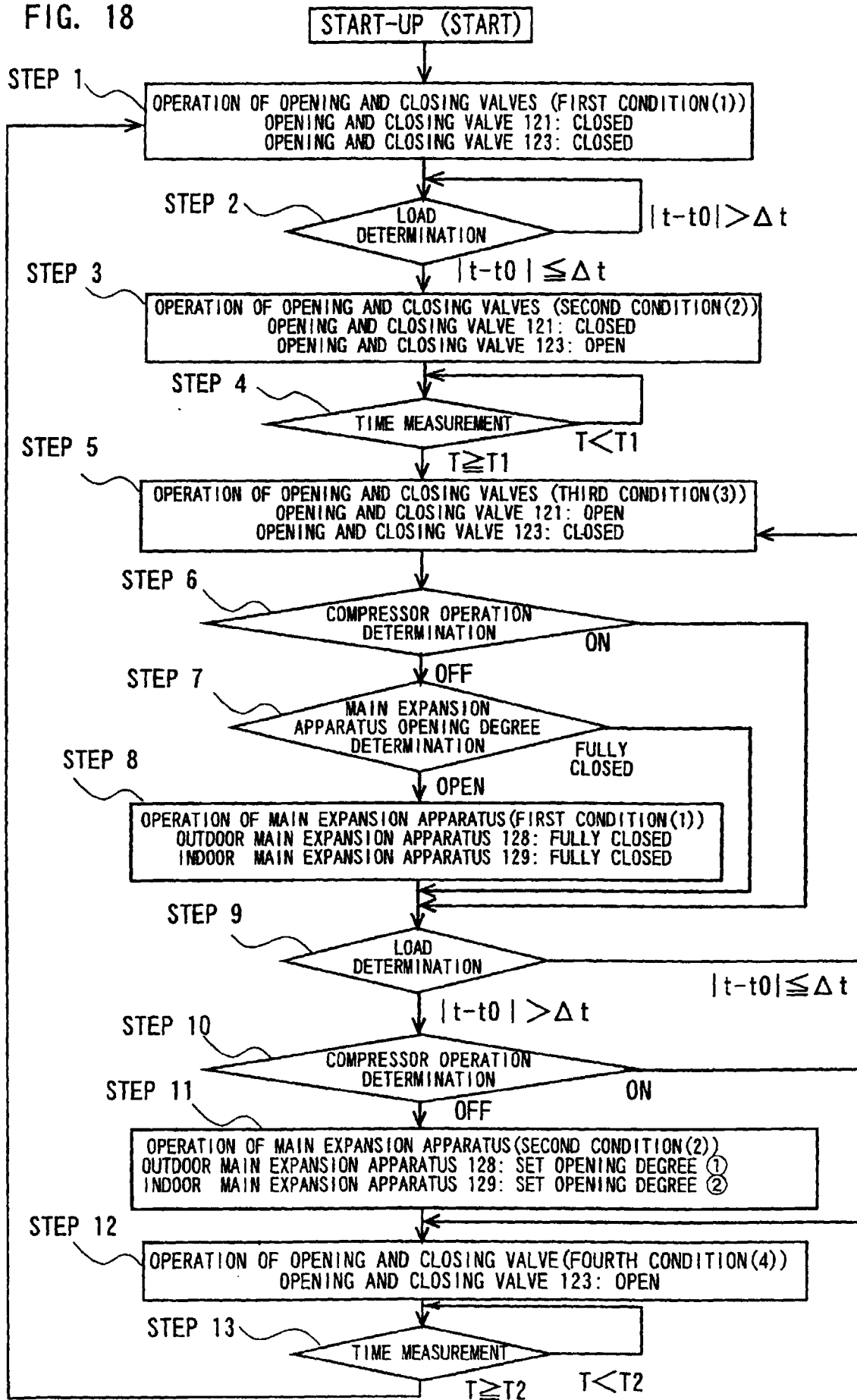


FIG. 19

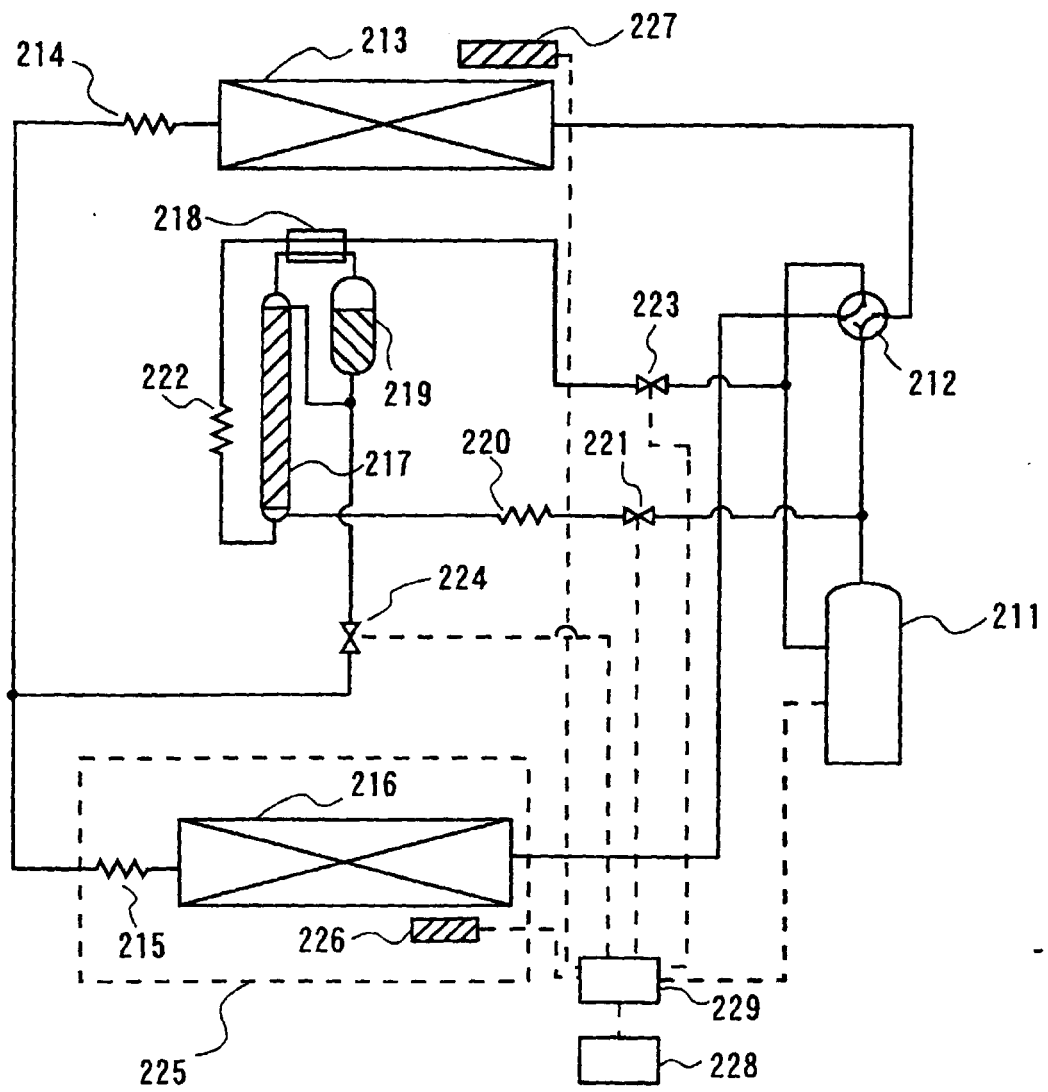


FIG. 20

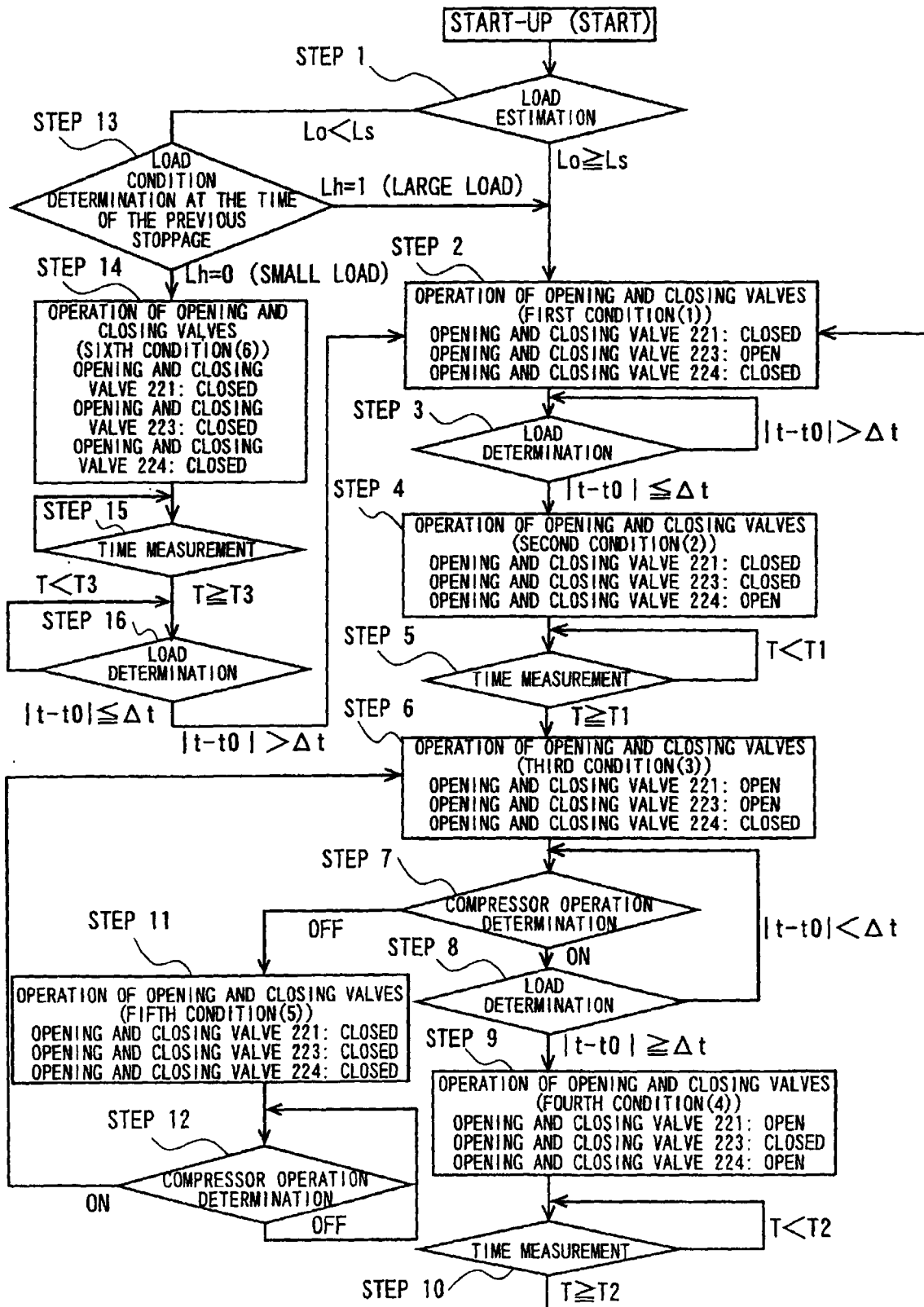


FIG. 21

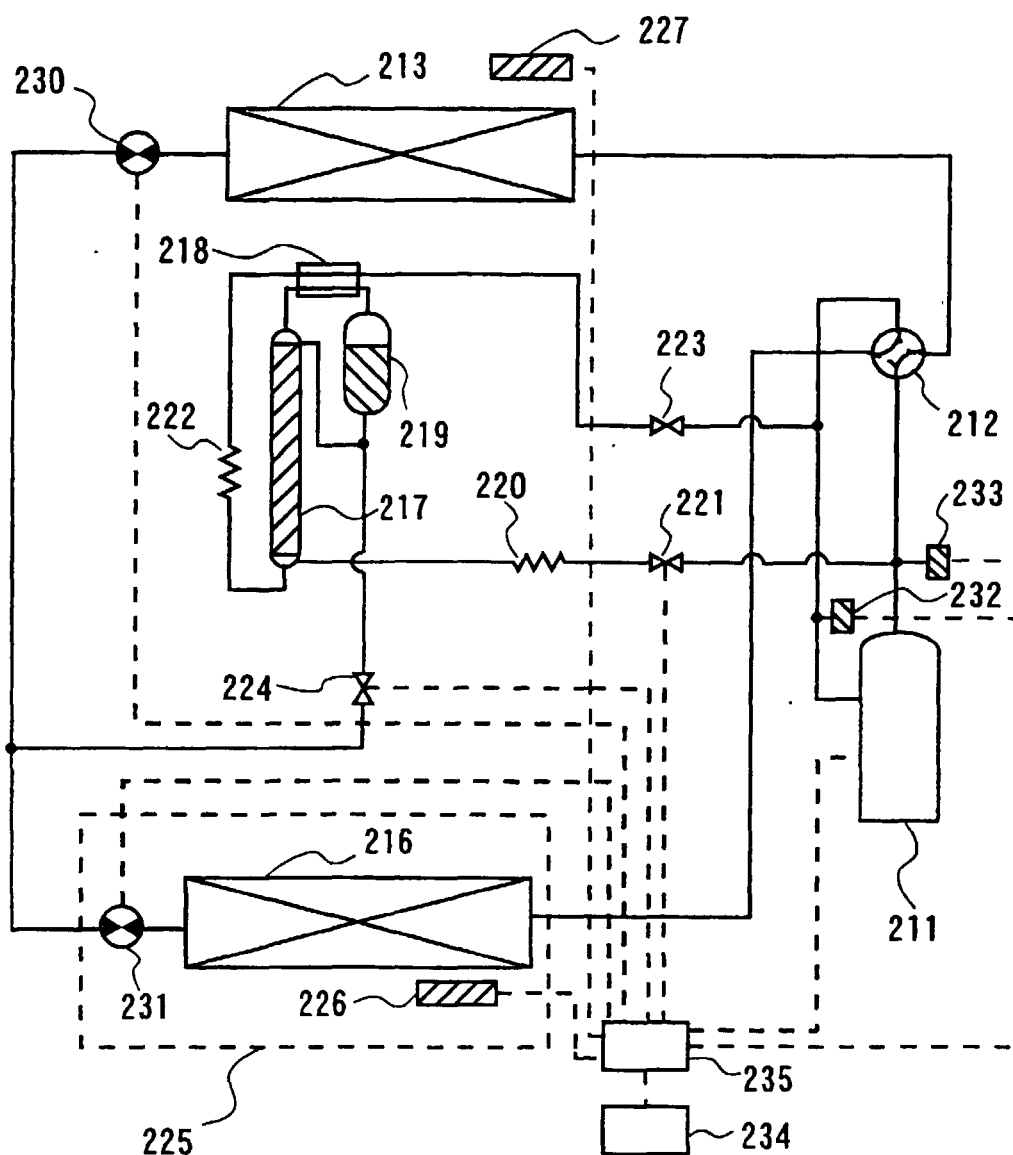


FIG. 22

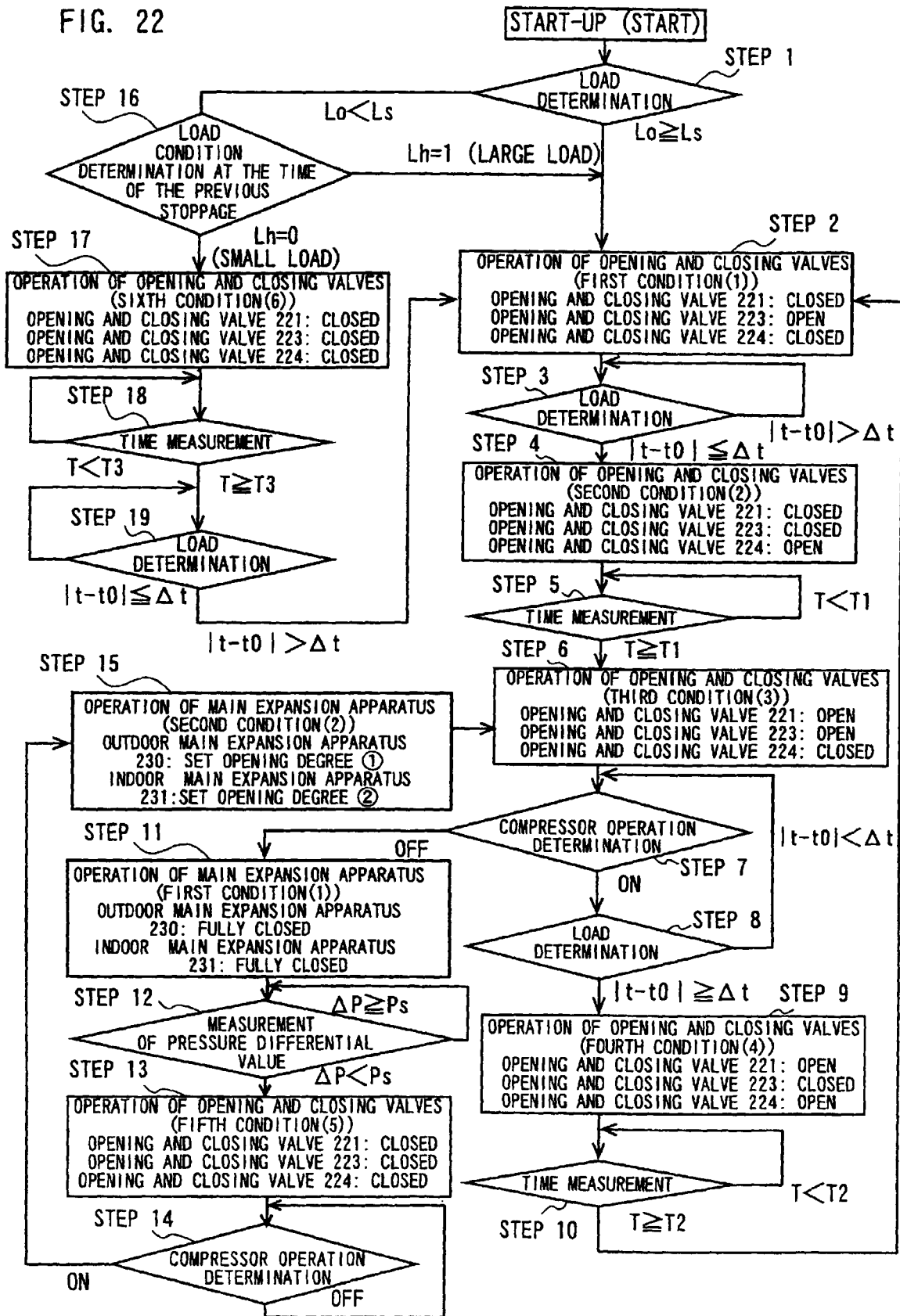


FIG. 23

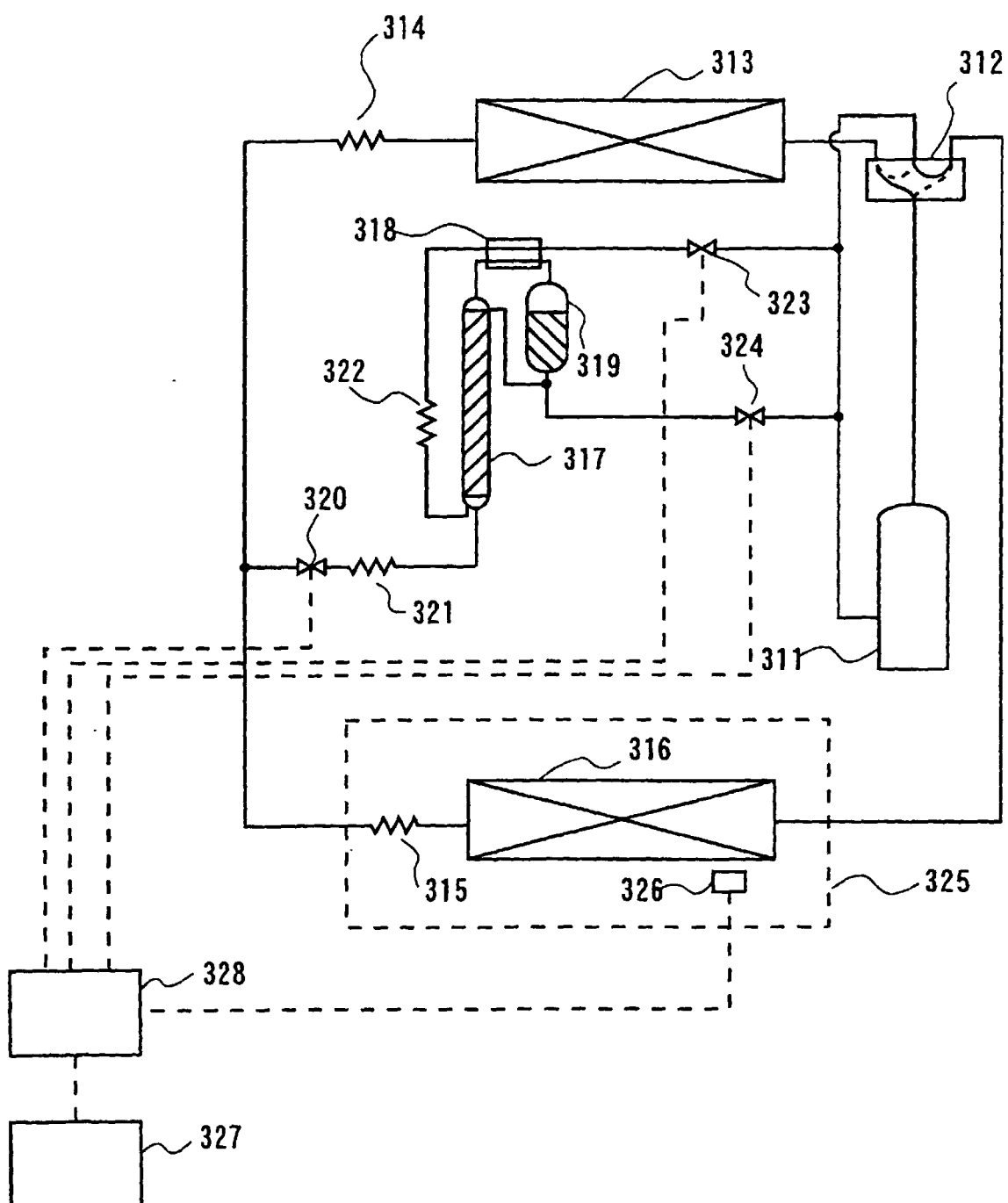


FIG. 24

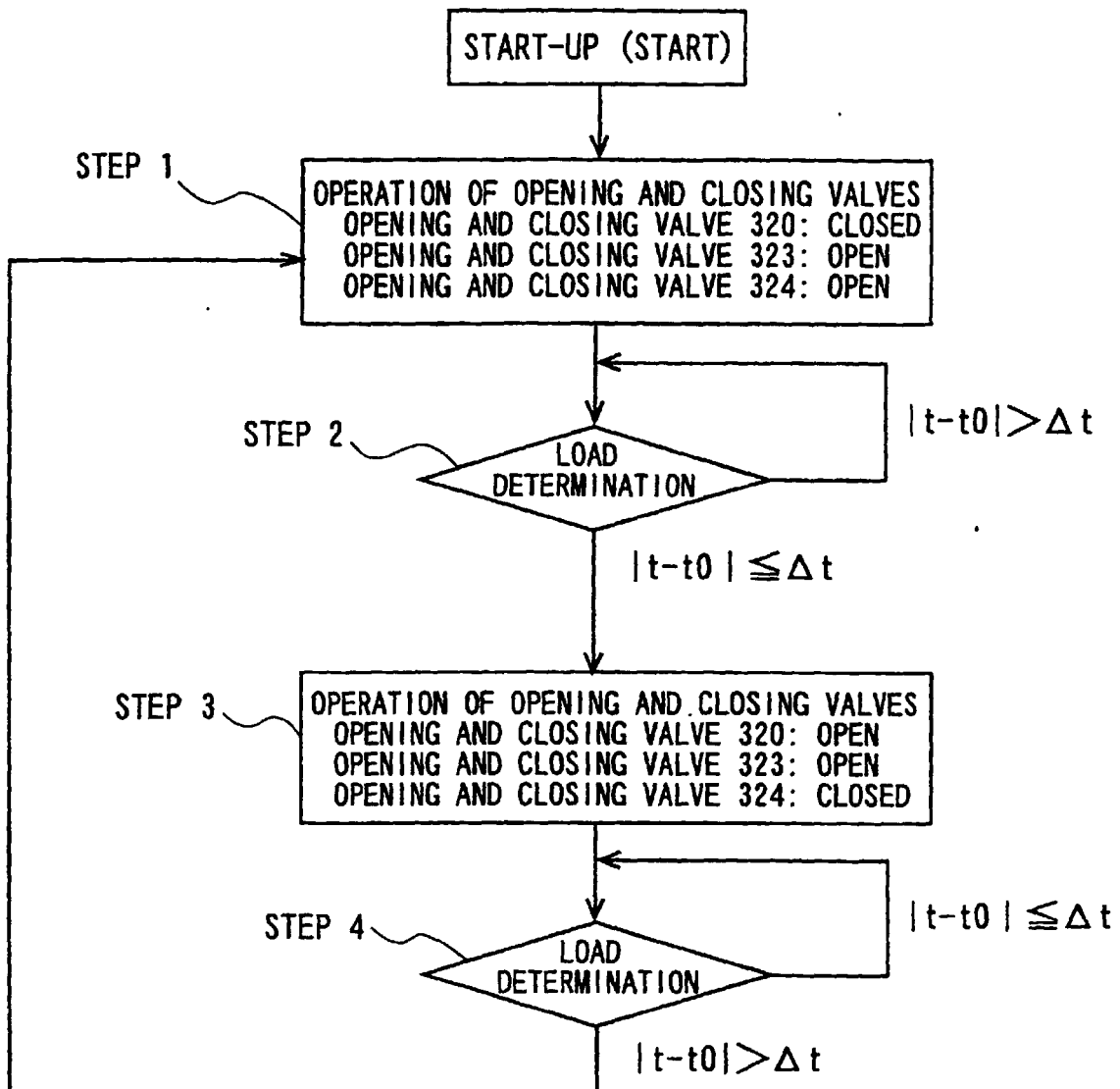


FIG. 25

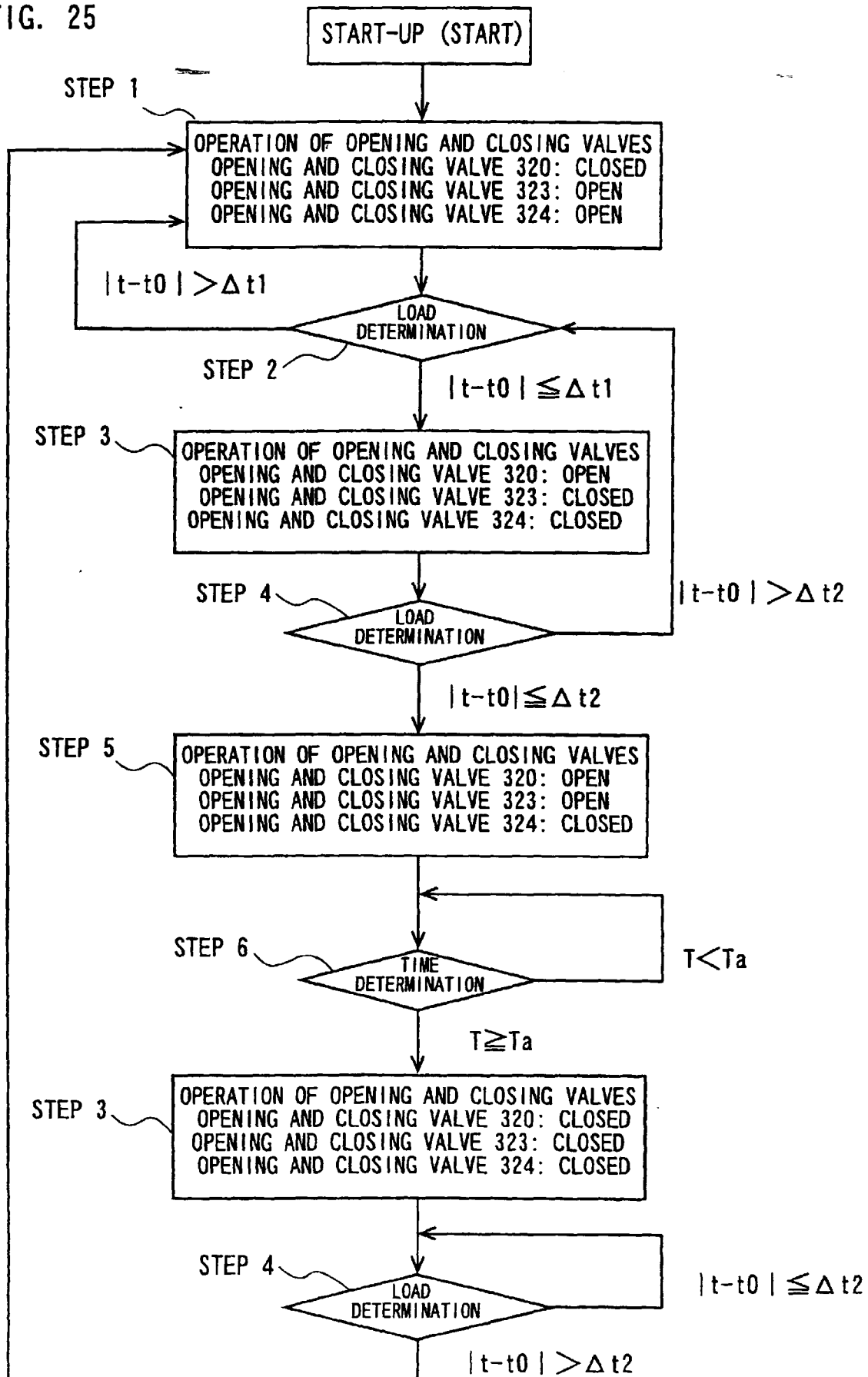


FIG. 26

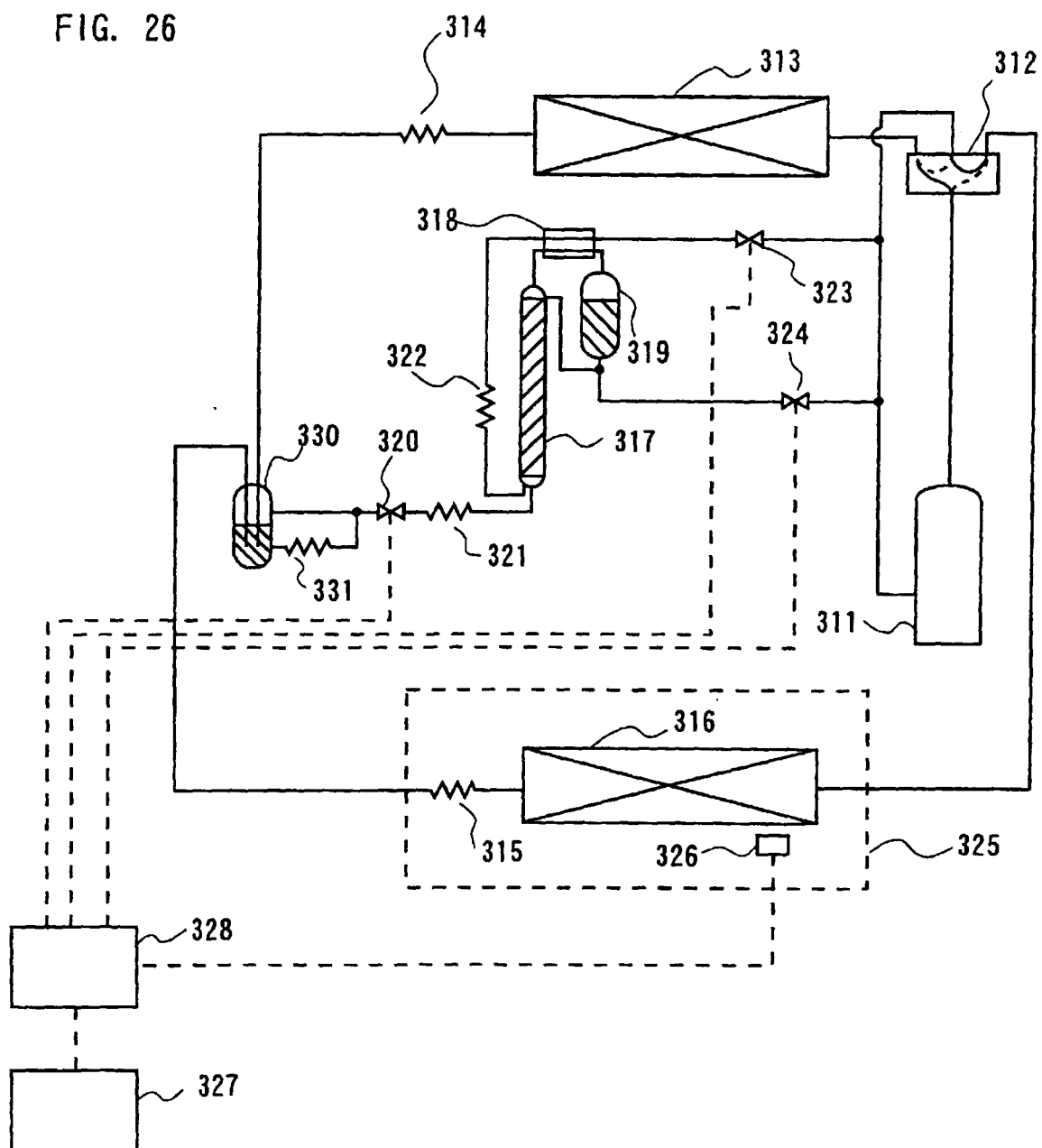


FIG. 27

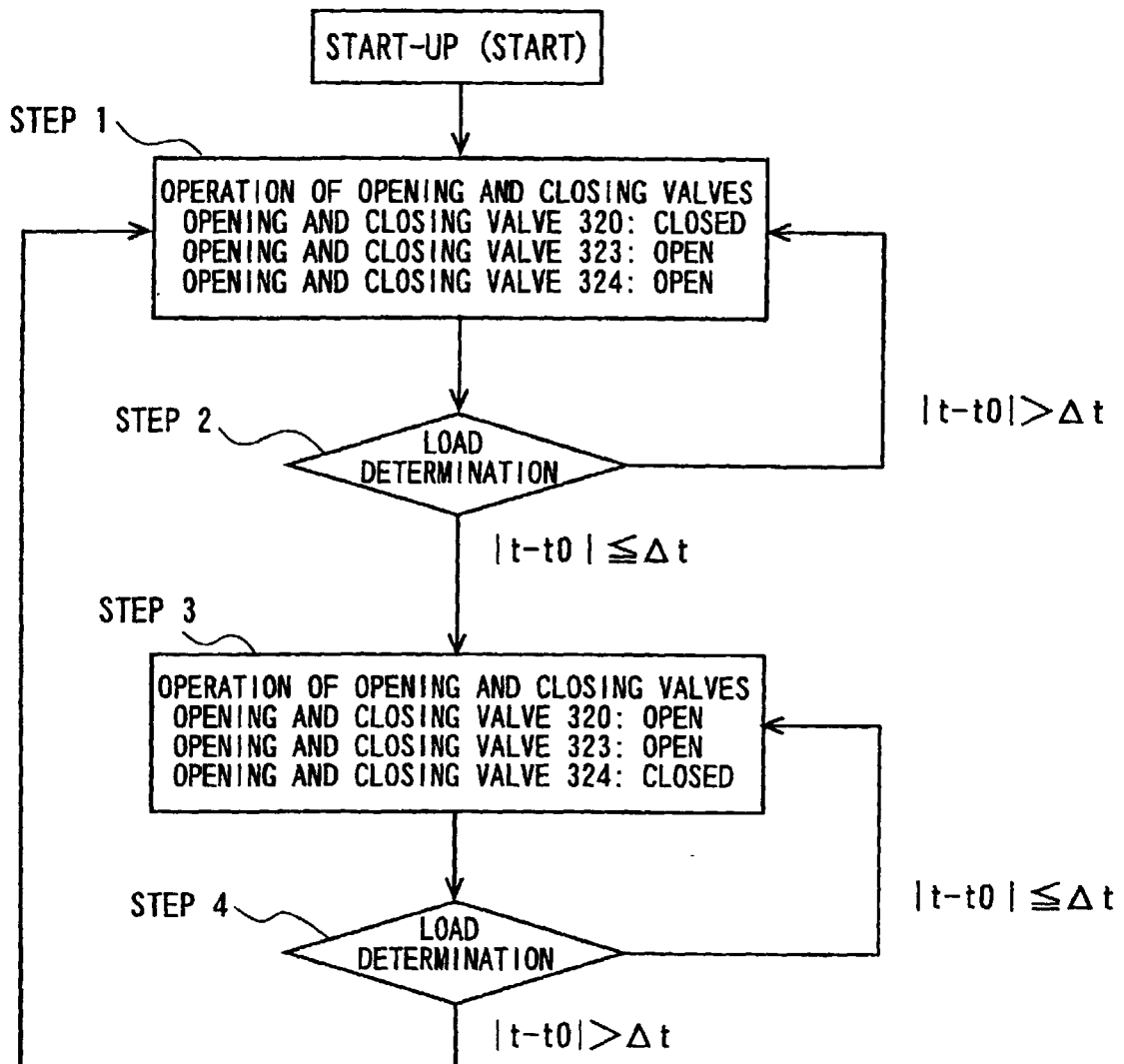


FIG. 28

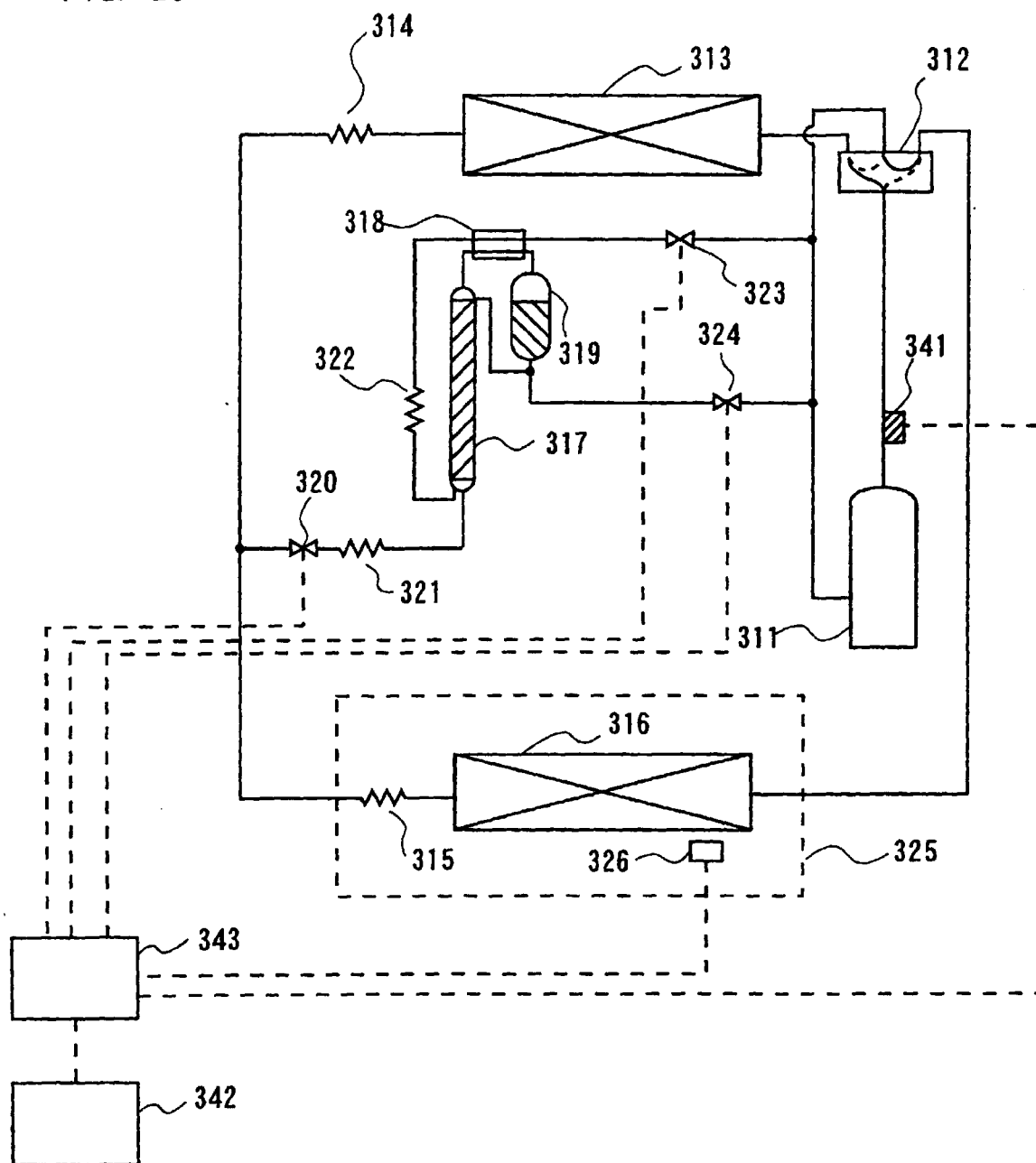


FIG. 29

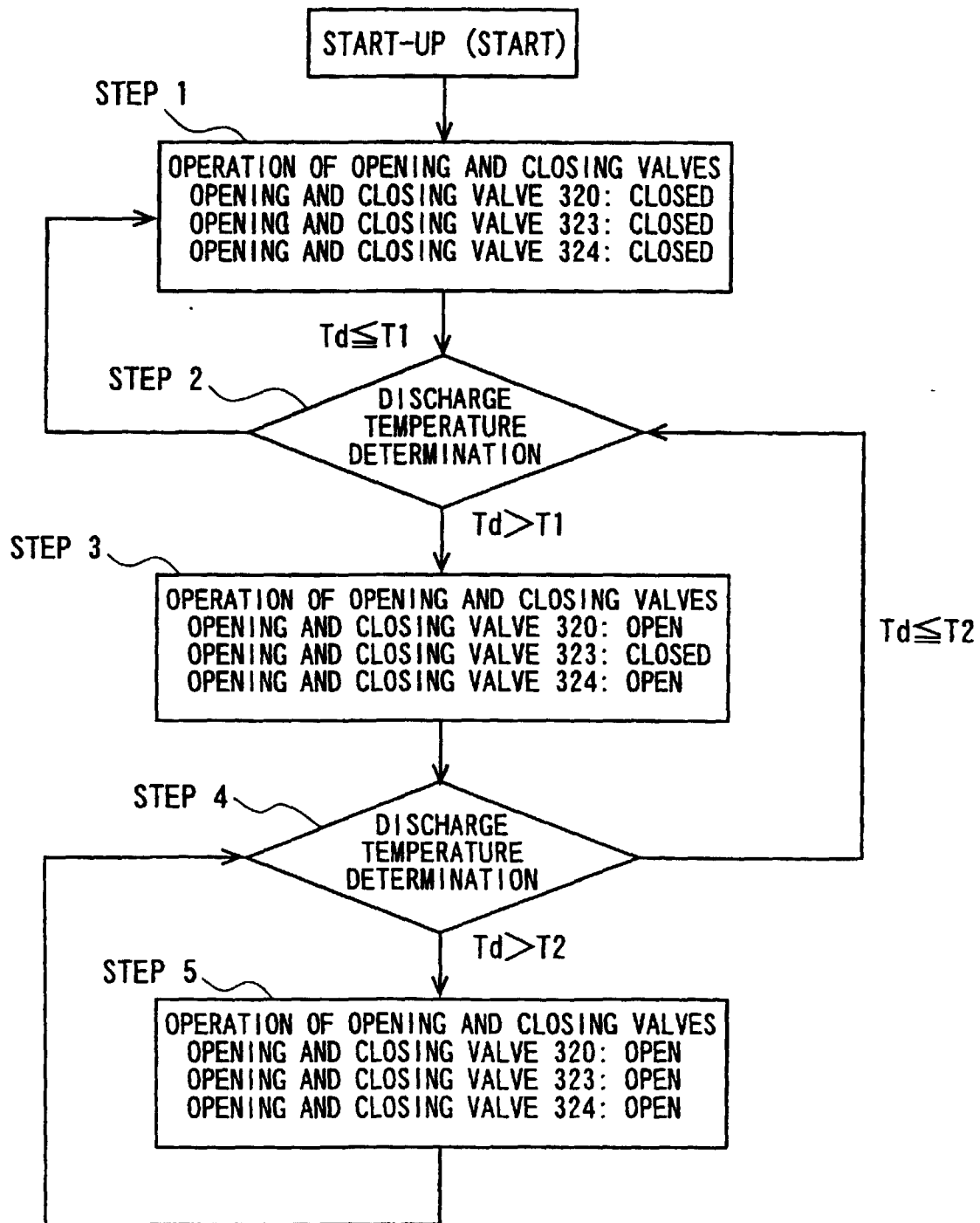


FIG. 30

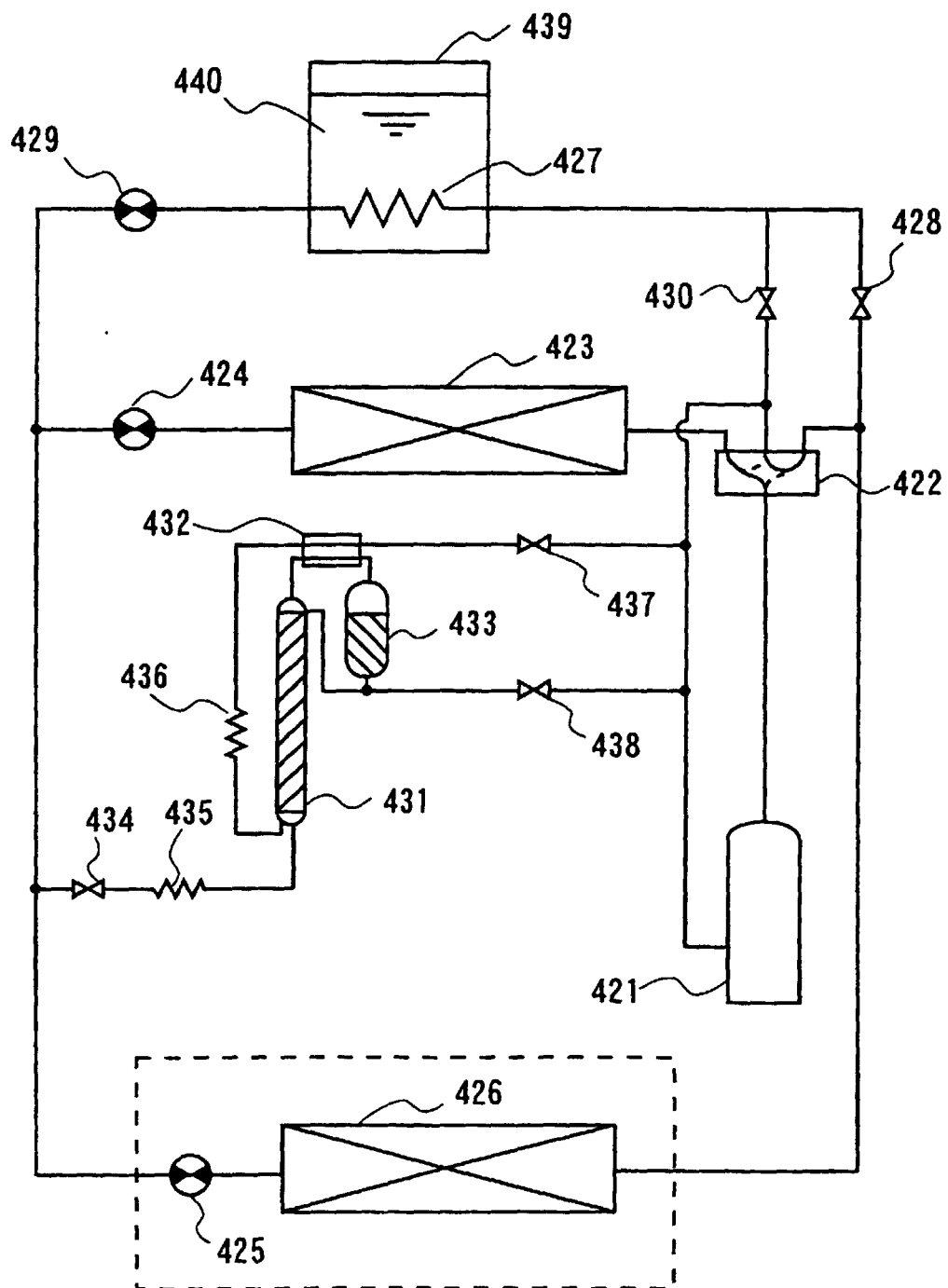


FIG. 31

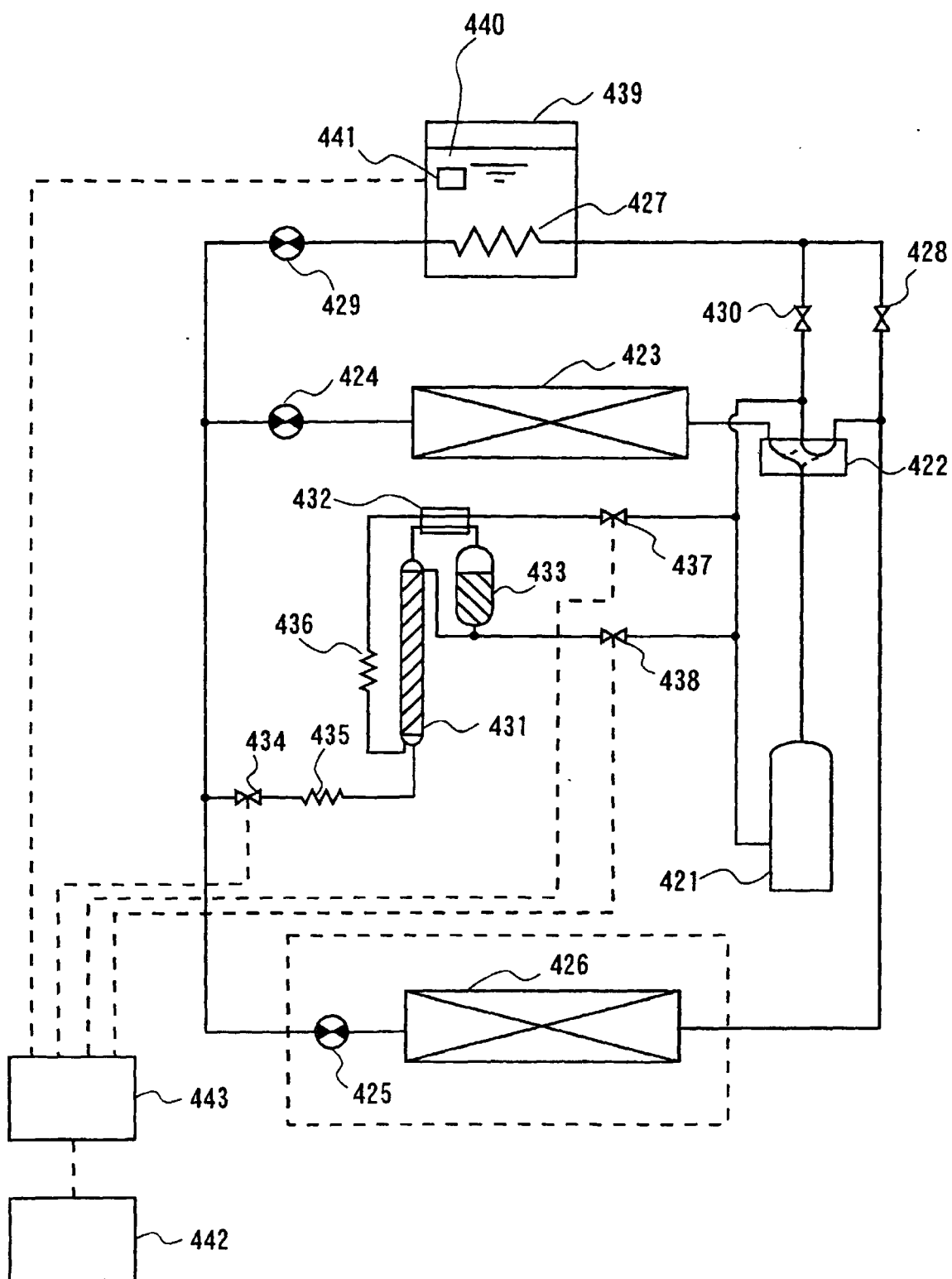


FIG. 32

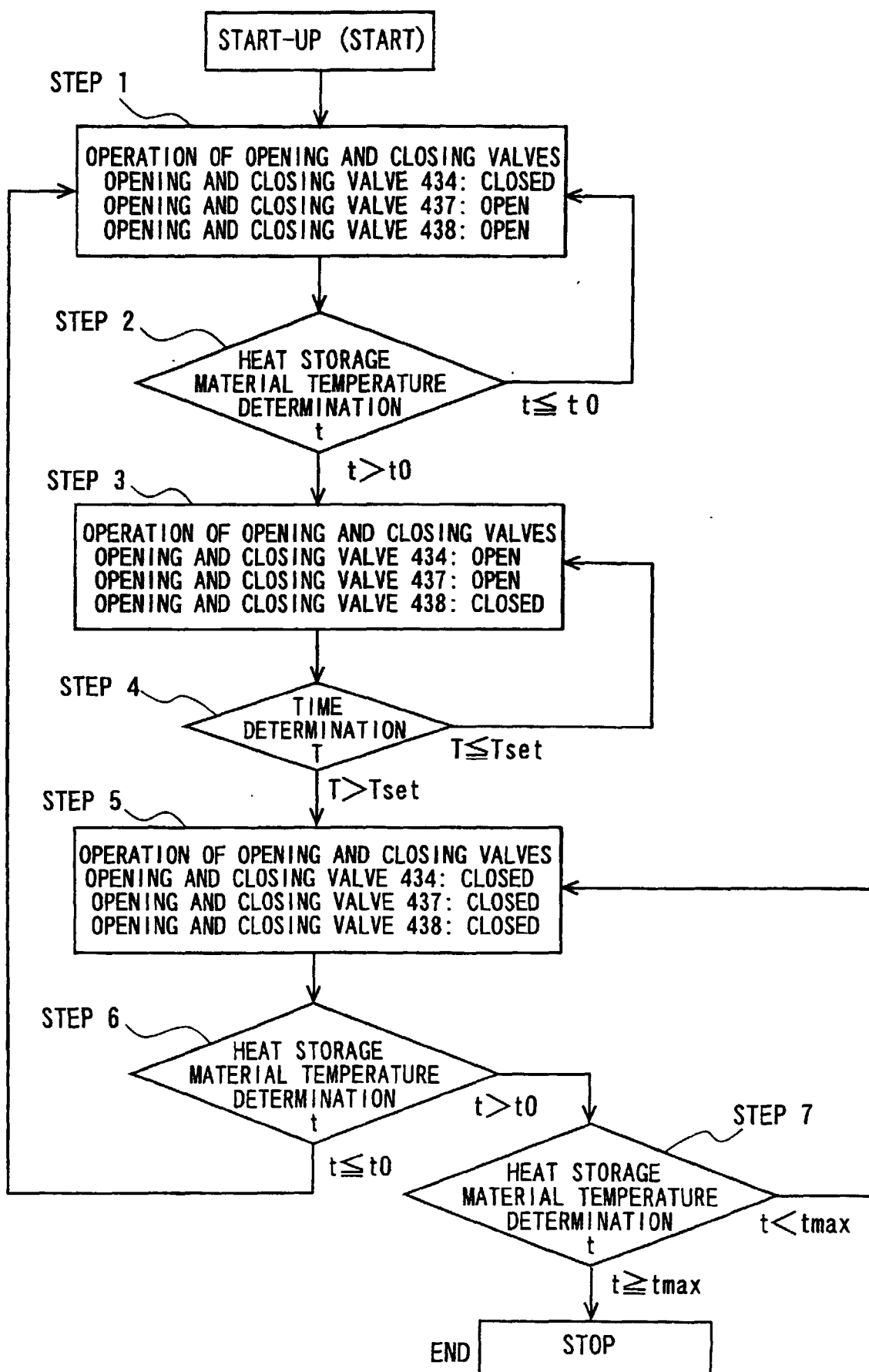


FIG. 33

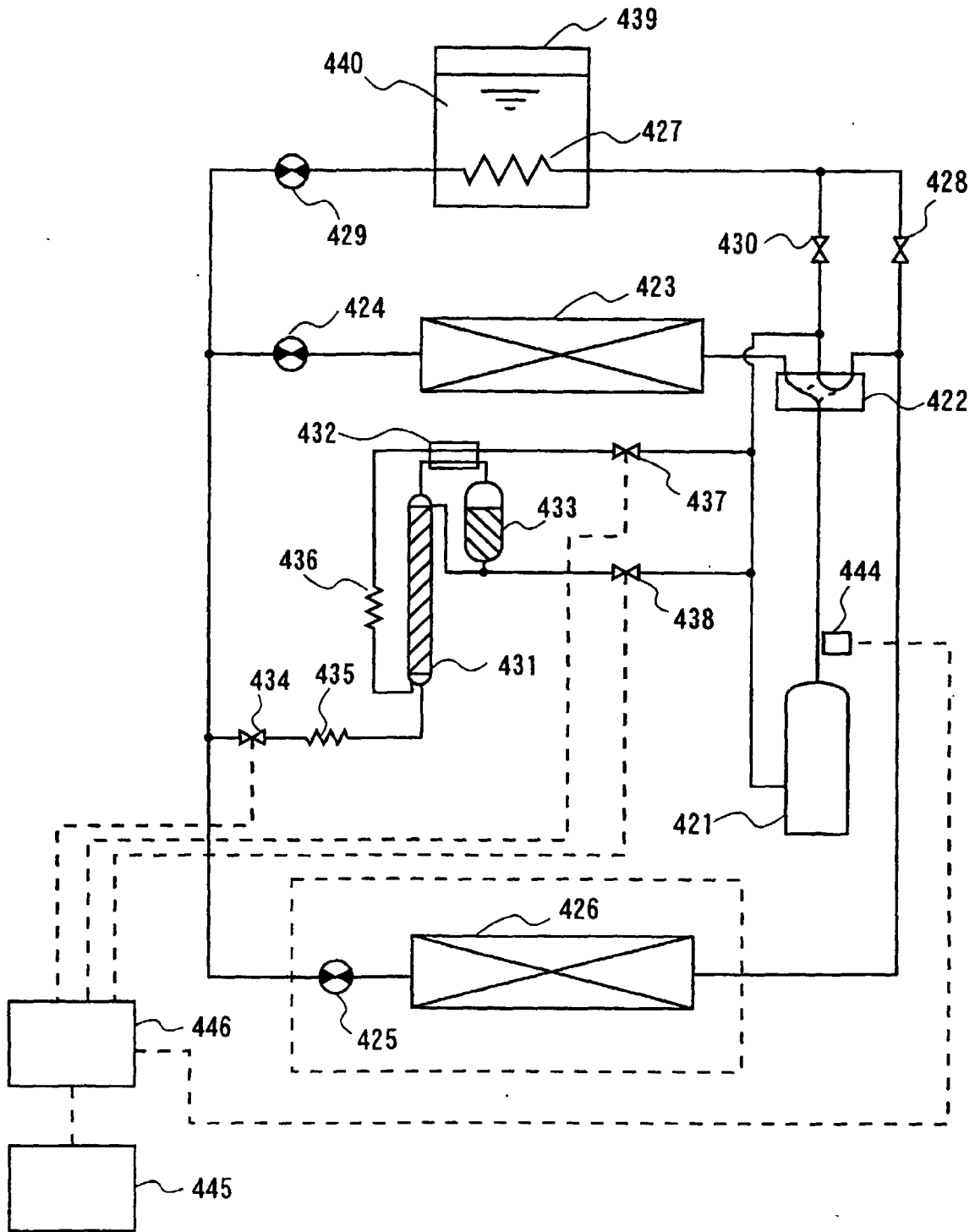


FIG. 34

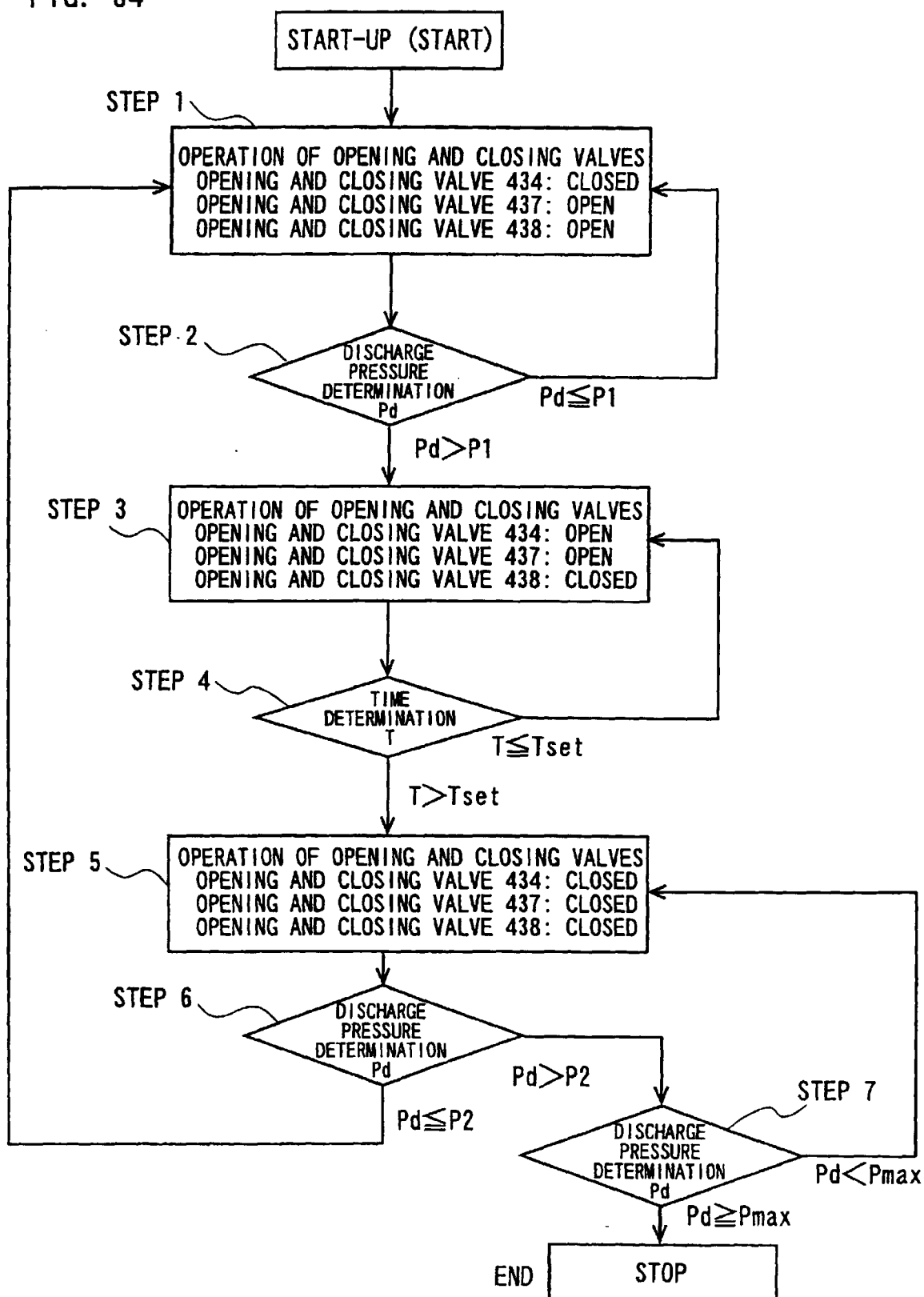


FIG. 35

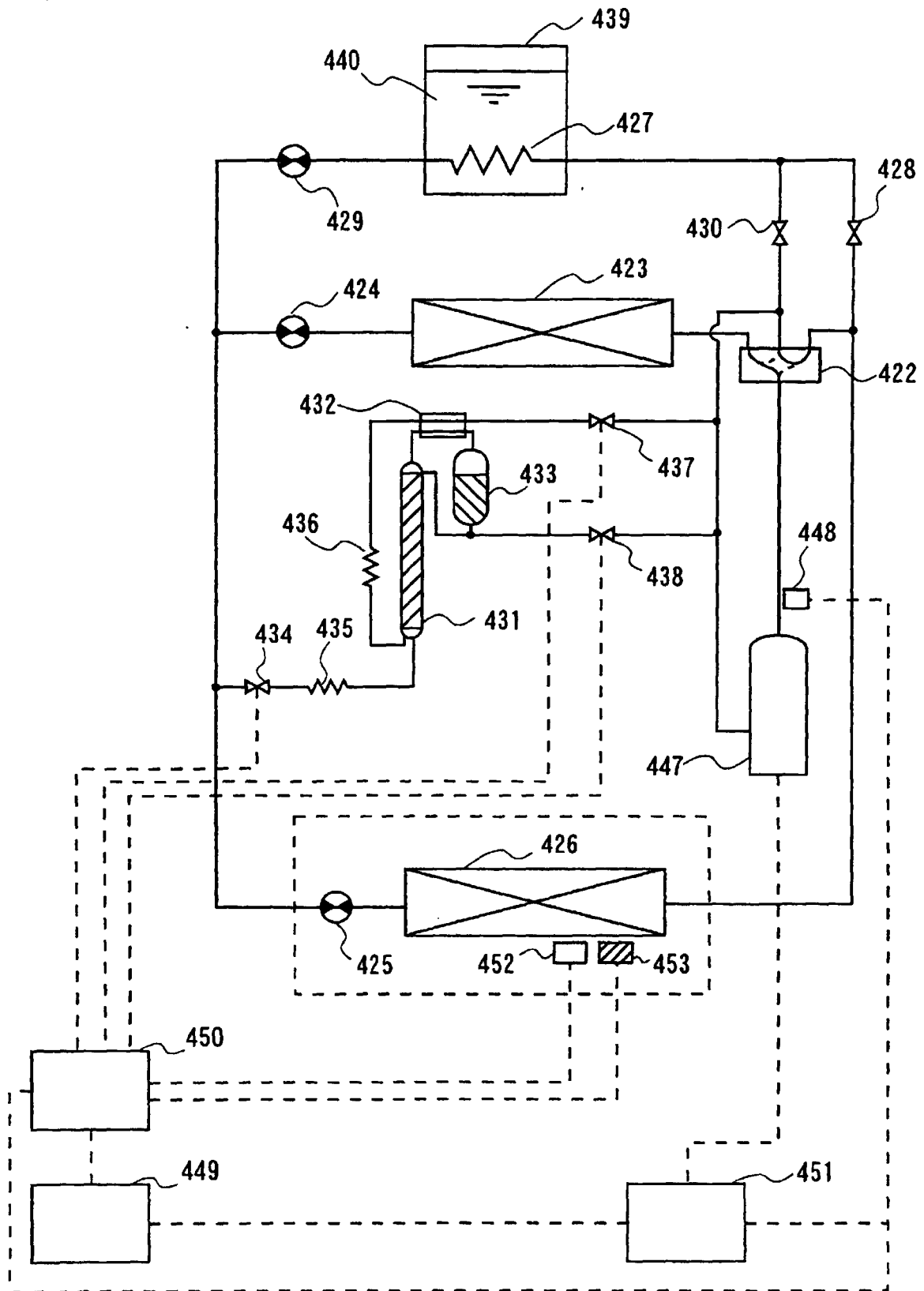


FIG. 36

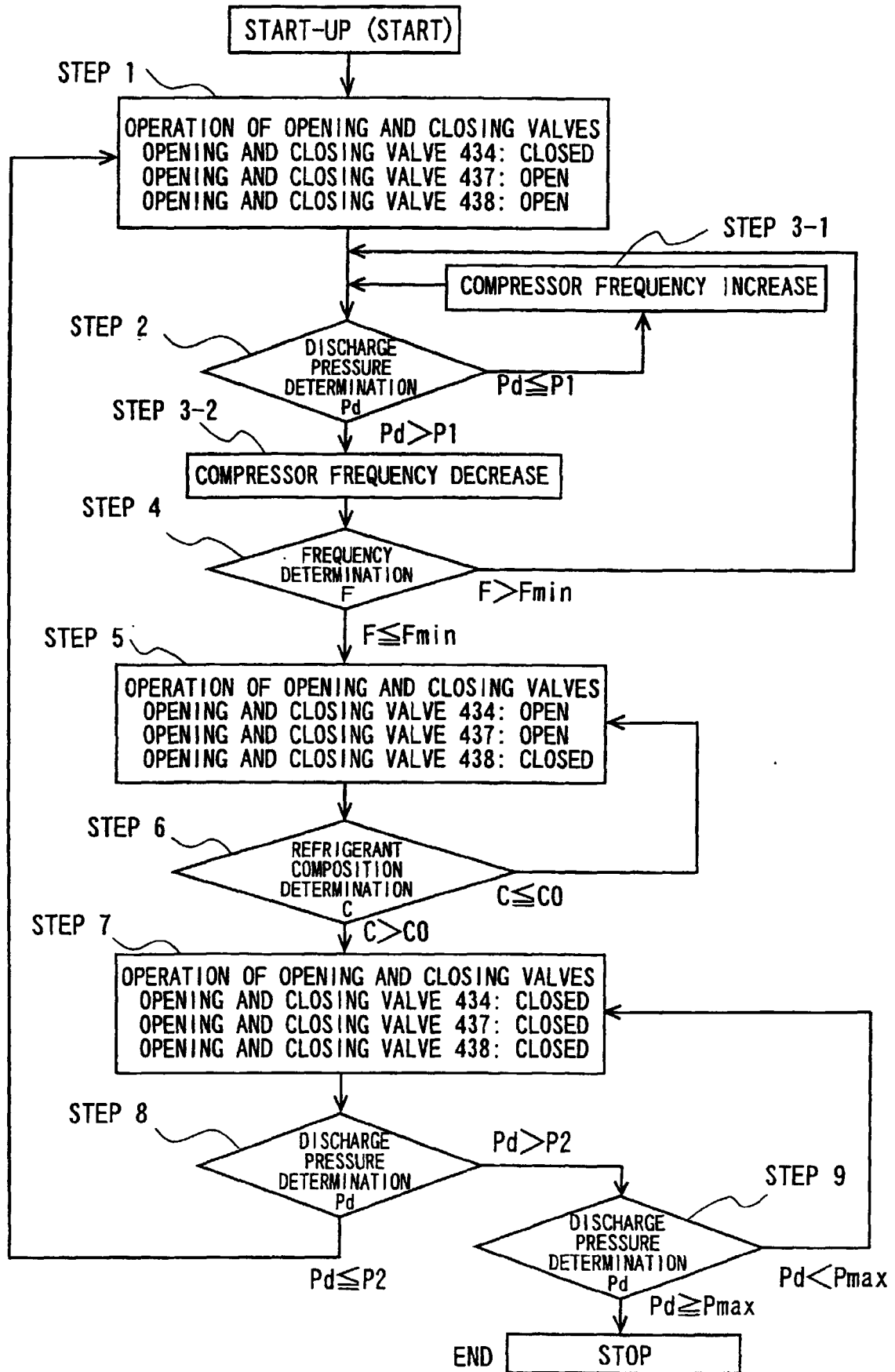


FIG. 37

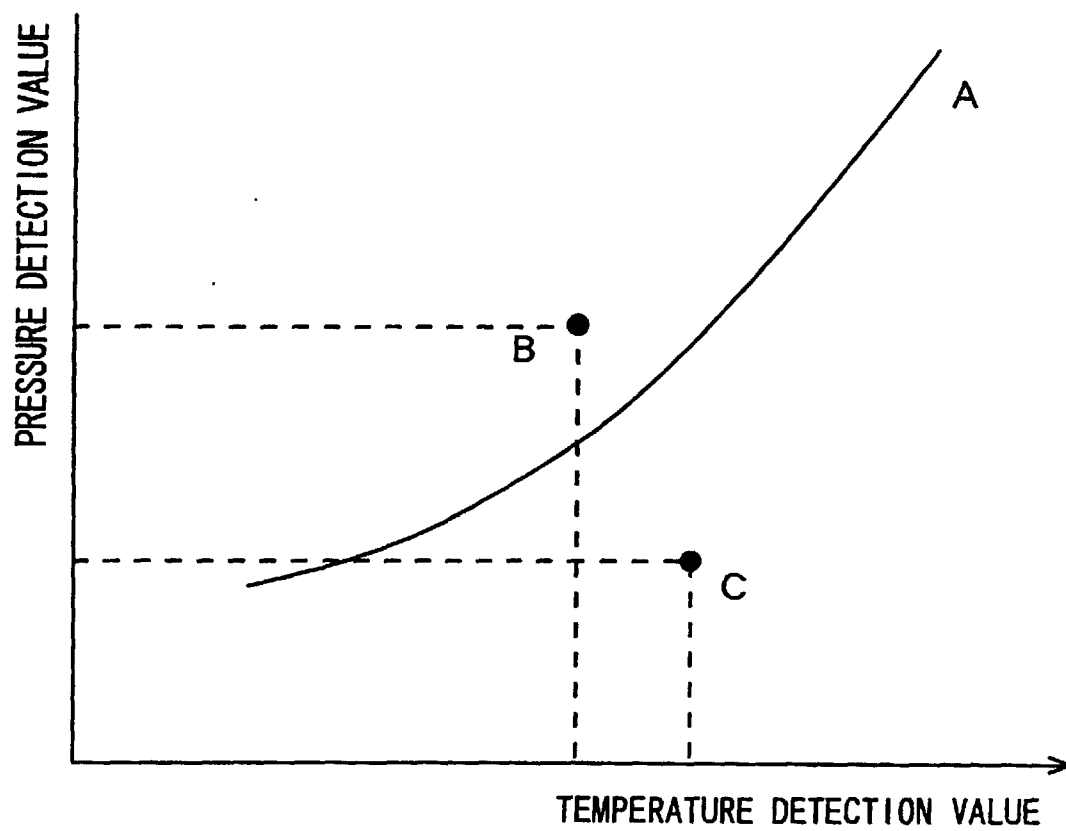


FIG. 38

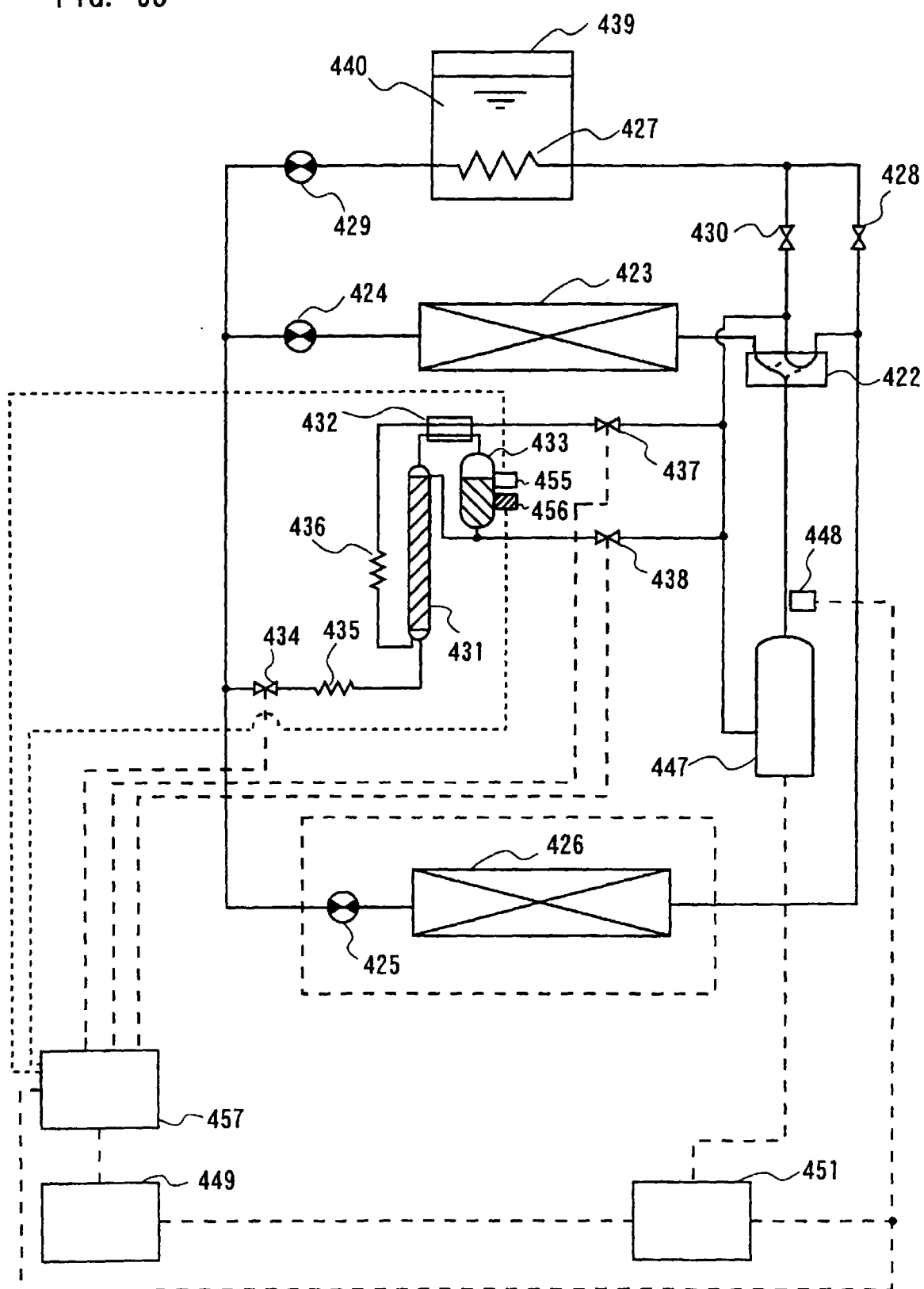


FIG. 39

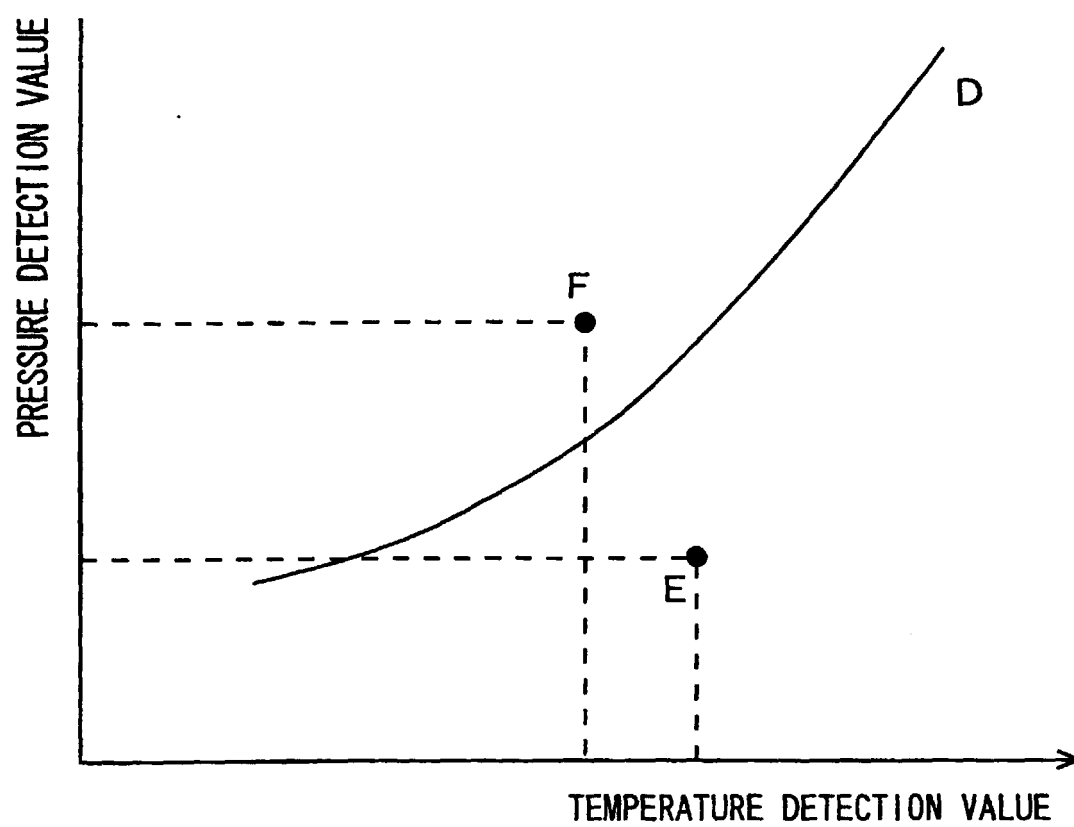


FIG. 40

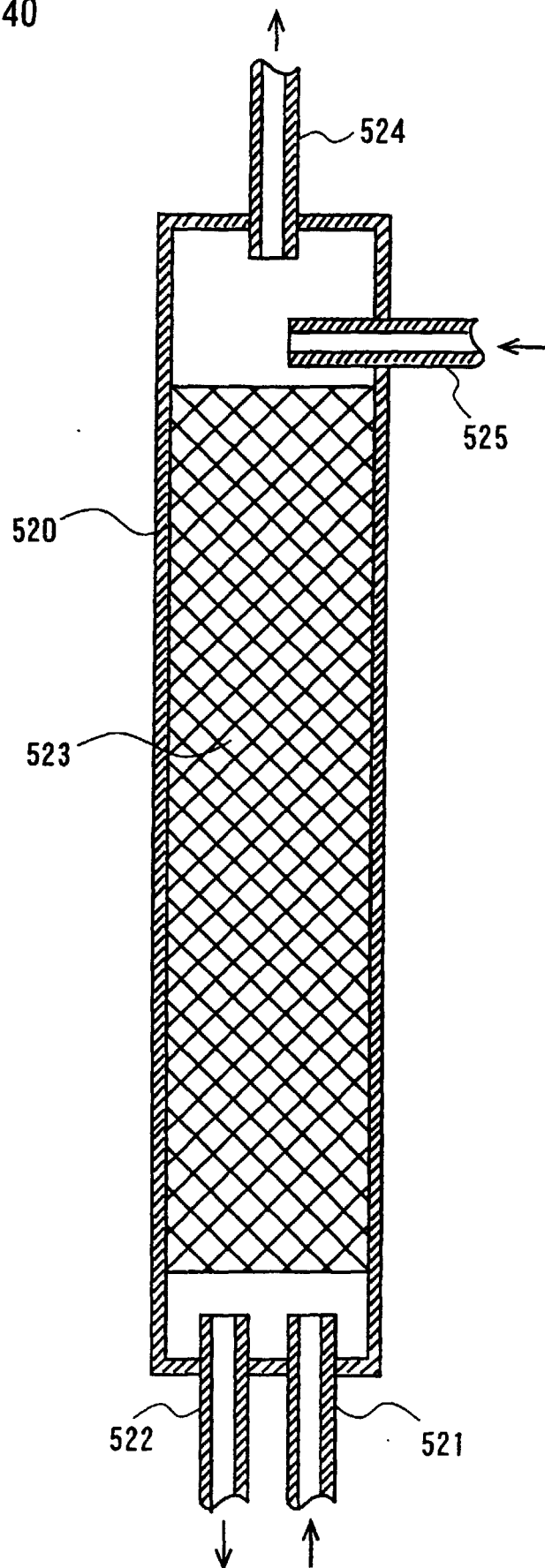


FIG. 41

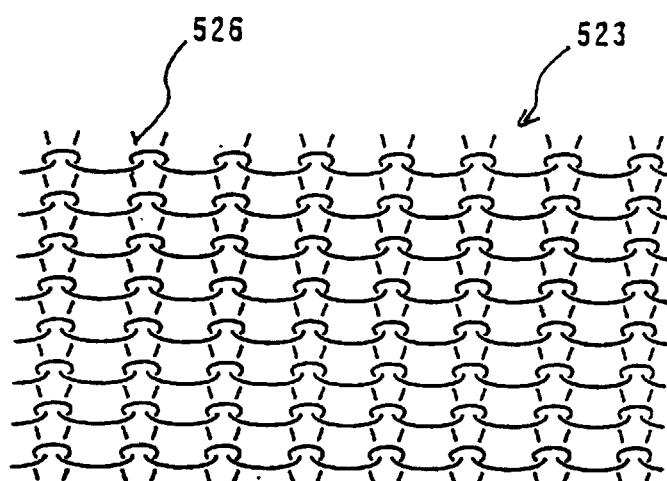


FIG. 42

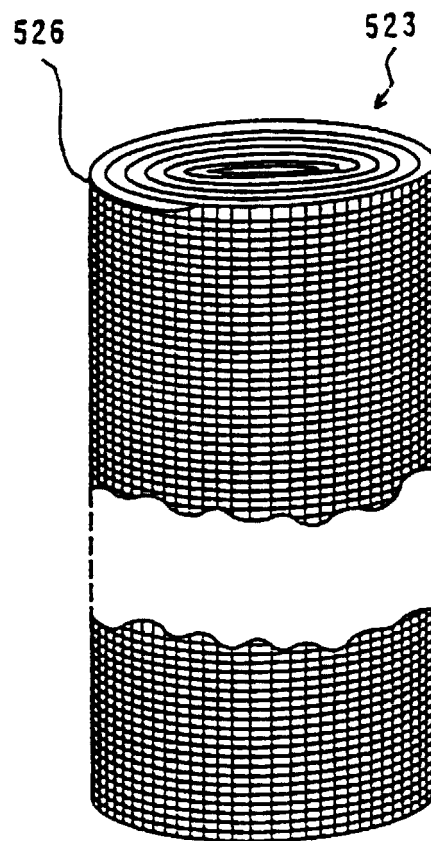


FIG. 43

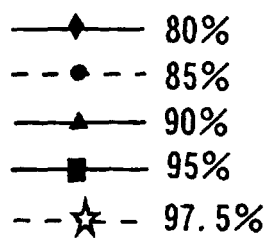
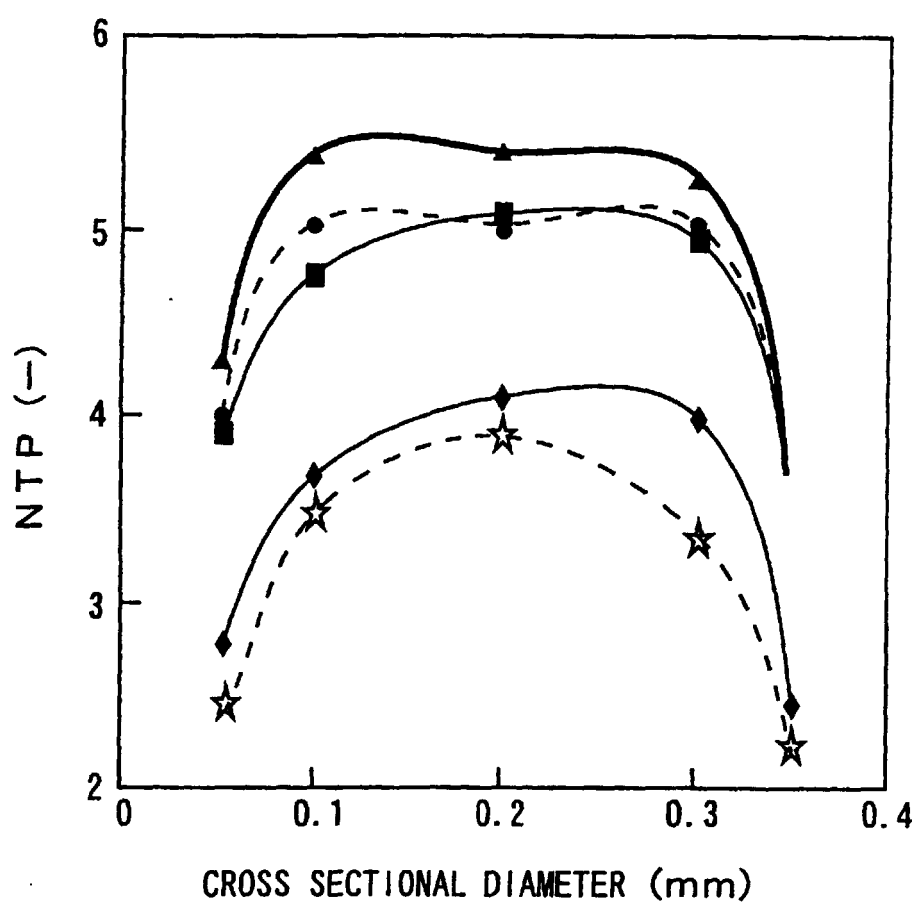
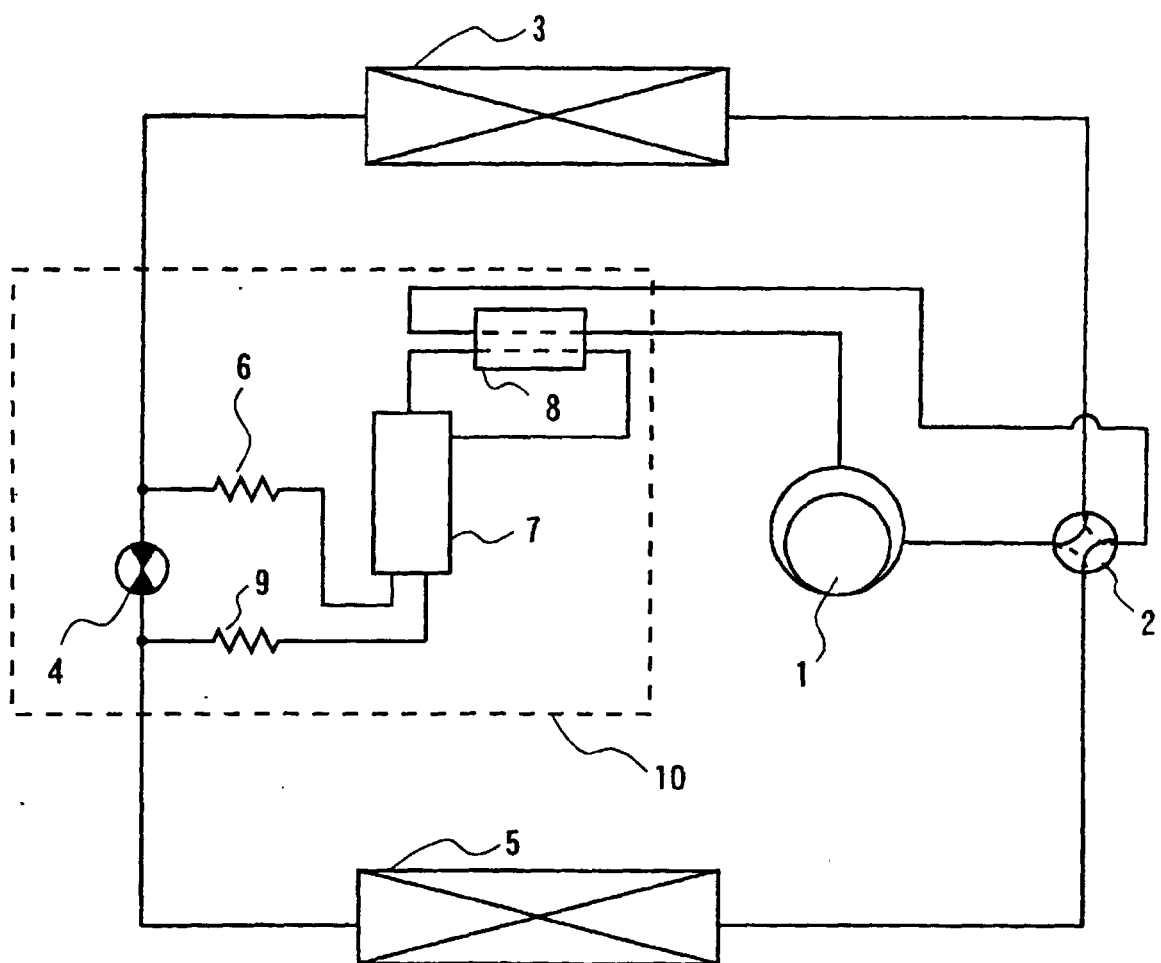


FIG. 44



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/01885

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl.⁷ F25B1/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.⁷ F25B1/00

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

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsuyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, 4913714, A1 (Ogura et al.),	1-3
Y	03 April, 1990 (03.04.90)	4-16
A	& JP, 62-193911, A & JP, 62-218547, A	17-44
Y	JP, 1-14557, A (Matsushita Electric Ind. Co., Ltd.), 18 January, 1989 (18.01.89) (Family: none)	4, 16, 25-28
Y	JP, 5-44582, B2 (Matsushita Electric Ind. Co., Ltd.), 06 July, 1993 (06.07.93) (Family: none)	5-13
Y	JP, 8-178451, A (Mitsubishi Heavy Industries, Ltd.), 12 July, 1996 (12.07.96) (Family: none)	10, 11, 14-16, 21-31
Y	JP, 4-61260, B2 (Matsushita Electric Ind. Co., Ltd.), 30 September, 1992 (30.09.92) (Family: none)	12-16, 21-28
A	JP, 10-9704, A (Matsushita Refrig. co., Ltd.), 16 January, 1998 (16.01.98) (Family: none)	28, 31, 40-43
Y	JP, 9-159296, A (Matsushita Electric Ind. Co., Ltd.),	32, 33
A	20 June, 1997 (20.06.97) (Family: none)	34-44

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
20 June, 2000 (20.06.00)Date of mailing of the international search report
04 July, 2000 (04.07.00)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/01885

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP, 6-281282, A (Toshiba Corporation), 07 October, 1994 (07.10.94) (Family: none)	37, 38, 40 39, 41-43

Form PCT/ISA/210 (continuation of second sheet) (July 1992)