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tube 18 is passed through a suction piping line 32 through which the refrigerant returning from the evaporator 13 to the compressor 14 flows, to constitute a double tube structure. Furthermore, the suction piping line 32 (a piping line 32A) formed in the double tube structure by passing the capillary tube 18 therethrough is surrounded with an insulating material 35.

[illegible]

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a refrigerating apparatus which condenses a refrigerant discharged from a compressor and then evaporates the refrigerant by an evaporator to exert a cooling function.

[0002] Heretofore, in a refrigerating apparatus for an ultralow temperature refrigerator used for storage of frozen food to be stored at a low temperature for a long period of time or storage of an anatomy, a specimen or the like at an ultralow temperature, a non-azeotropic mixed refrigerant including butane, ethylene and R14 (carbon tetrafluoride: CF_4) or a non-azeotropic mixed refrigerant including butane, ethane and R14 is introduced in a refrigerant circuit, to secure handleability of the refrigerant in the refrigerating apparatus owing to operability of butane having a high boiling point in such non-azeotropic mixed refrigerant gases, at ordinary temperature. Moreover, ethane or ethylene having a remarkably low boiling point is evaporated by the evaporator, thereby setting a temperature of the inside of a storage chamber to an ultralow temperature below -60°C .

[Prior Art Document]

[Patent Document]

[0003]

[Patent Document 1] Japanese Patent Application Laid-Open No. 2007-107858

SUMMARY OF THE INVENTION

[0004] However, to realize a desirable ultralow temperature, a compressor having a larger capability has to be selected. In such a case, a problem occurs to involve enlargement of an apparatus and steep rise of a cost. Moreover, with the increase of the capability of the used compressor, the increase of power consumption is incurred. Therefore, there has been desired the development of a refrigerating apparatus which can more efficiently cool the inside of a storage chamber to the ultralow temperature.

[0005] The present invention has been developed to solve a conventional technical problem, and an object thereof is to provide a refrigerating apparatus which can more efficiently cool the inside of a storage chamber to an ultralow temperature.

[0006] A refrigerating apparatus of the present invention of a first aspect condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube, and evaporates the refrigerant by an evaporator to exert a cooling function, **characterized in that** the capillary tube is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute a double tube structure.

orator to the compressor flows, to constitute a double tube structure.

[0007] A refrigerating apparatus of the present invention of a second aspect comprises a high temperature side refrigerant circuit and a low temperature side refrigerant circuit to constitute independent closed refrigerant circuits, each of which condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube and evaporates the refrigerant by an evaporator to exert a cooling function, the evaporator of the high temperature side refrigerant circuit and a condenser of the low temperature side refrigerant circuit constituting a cascade heat exchanger, the evaporator of the low temperature side refrigerant circuit being configured to exert a final cooling function, **characterized in that** the capillary tube of the low temperature side refrigerant circuit is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute a double tube structure.

[0008] A refrigerating apparatus of the present invention of a third aspect is a refrigerating apparatus which comprises a compressor, a condenser, an evaporator, a single or a plurality of intermediate heat exchangers connected so that a refrigerant returning from the evaporator circulates therethrough and a plurality of capillary tubes and into which a plurality of types of non-azeotropic mixed refrigerants are introduced and which allows a condensed refrigerant of the refrigerants flowing through the condenser to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools a non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having a lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert a cooling function, **characterized in that** the capillary tube of the final stage is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute a double tube structure.

[0009] A refrigerating apparatus of the present invention of a fourth aspect comprises a high temperature side refrigerant circuit and a low temperature side refrigerant circuit to constitute independent closed refrigerant circuits, each of which condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube and evaporates the refrigerant by an evaporator to exert a cooling function, the low temperature side refrigerant circuit comprising the compressor, a condenser, the evaporator, a single or a plurality of intermediate heat exchangers connected so that the refrigerant returning from the evaporator circulates therethrough and a plurality of capillary tubes, a plurality of types of non-azeotropic mixed refrigerants being introduced, the refrigerating apparatus having a constitution which allows a condensed refrigerant of the refrigerant flowing through the evaporator to join the refrigerants in

the intermediate heat exchangers through the capillary tubes, cools a non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having a lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert the cooling function, the evaporator of the high temperature side refrigerant circuit and the condenser of the low temperature side refrigerant circuit constituting a cascade heat exchanger, the evaporator of the low temperature side refrigerant circuit being configured to exert a final cooling function, **characterized in that** the capillary tube of the final stage of the low temperature side refrigerant circuit is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute a double tube structure.

[0010] A refrigerating apparatus of the present invention of a fifth aspect is **characterized in that** in the invention of the second or fourth aspect, the capillary tube of the high temperature side refrigerant circuit is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor of the high temperature side refrigerant circuit flows, to constitute the double tube structure.

[0011] A refrigerating apparatus of the present invention of a sixth aspect is **characterized in that** in the inventions of the above aspects, the suction piping line formed in the double tube structure by passing the capillary tube therethrough is surrounded with an insulating material.

[0012] A refrigerating apparatus of the present invention of a seventh aspect is **characterized in that** in the invention of the above aspects, a flow of the refrigerant through the capillary tube and a flow of the refrigerant through the suction piping line outside the capillary tube form a counter flow.

[0013] According to the present invention of the first aspect, in the refrigerating apparatus which condenses the refrigerant discharged from the compressor, reduces the pressure of the refrigerant by the capillary tube, and evaporates the refrigerant by the evaporator to exert the cooling function, the capillary tube is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute the double tube structure. Therefore, efficiency of the heat exchange between the refrigerant in the suction piping line and the refrigerant in the capillary tube can be enhanced to improve a performance of the refrigerating apparatus.

[0014] In particular, the capillary tube is passed through the suction piping line just exiting from the evaporator to constitute the double tube structure, thereby enabling the heat exchange by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube. According to this constitution, the refrigerant having the lowest boiling point is efficiently

cooled by the refrigerant returning from the evaporator, whereby the performance can remarkably be improved.

[0015] According to the invention of the second aspect, the refrigerating apparatus comprises the high temperature side refrigerant circuit and the low temperature side refrigerant circuit to constitute the independent closed refrigerant circuits, each of which condenses the refrigerant discharged from the compressor, reduces the pressure of the refrigerant by the capillary tube and evaporates the refrigerant by the evaporator to exert the cooling function. The evaporator of the high temperature side refrigerant circuit and the condenser of the low temperature side refrigerant circuit constitute the cascade heat exchanger. The evaporator of the low temperature side refrigerant circuit exerts the final cooling function. In this refrigerating apparatus, the capillary tube of the low temperature side refrigerant circuit is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute the double tube structure. Therefore, the efficiency of the heat exchange between the refrigerant in the suction piping line and the refrigerant in the capillary tube can be enhanced to improve the performance.

[0016] In particular, the capillary tube of the low temperature side refrigerant circuit is passed through the suction piping line just exiting from the evaporator to constitute the double tube structure, thereby enabling the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube. According to this constitution, the refrigerant having the lowest boiling point is efficiently cooled by the refrigerant returning from the evaporator of the low temperature side refrigerant circuit, whereby the performance can remarkably be improved.

[0017] According to the invention of the third aspect, the refrigerating apparatus comprises the compressor, the condenser, the evaporator, the single or the plurality of intermediate heat exchangers connected so that the refrigerant returning from this evaporator circulates therethrough, and the plurality of capillary tubes. Into the refrigerating apparatus, the plurality of types of non-azeotropic mixed refrigerants are introduced. The refrigerating apparatus allows the condensed refrigerant of the refrigerants flowing through the condenser to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools the non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having the lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert the cooling function. In the refrigerating apparatus, the capillary tube of the final stage is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute the double tube structure. Therefore, the efficiency of the heat exchange between the refrigerant in the suction piping line and the refrigerant

in the capillary tube can be enhanced to improve the performance.

[0018] In particular, the capillary tube is passed through the suction piping line just exiting from the evaporator to constitute the double tube structure, thereby enabling the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube. According to this constitution, the refrigerant having the lowest boiling point is efficiently cooled by the refrigerant returning from the evaporator, whereby the performance can remarkably be improved.

[0019] According to the present invention of the fourth aspect, the refrigerating apparatus comprises the high temperature side refrigerant circuit and the low temperature side refrigerant circuit to constitute the independent closed refrigerant circuits, each of which condenses the refrigerant discharged from the compressor, reduces the pressure of the refrigerant by the capillary tube and evaporates the refrigerant by the evaporator to exert the cooling function. This low temperature side refrigerant circuit comprises the compressor, the condenser, the evaporator, the single or the plurality of intermediate heat exchangers connected so that the refrigerant returning from this evaporator circulates therethrough and the plurality of capillary tubes. The plurality of types of non-azeotropic mixed refrigerants are introduced. The refrigerating apparatus has the constitution which allows the condensed refrigerant of the refrigerants flowing through the evaporator to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools the non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having the lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert the cooling function. The evaporator of the high temperature side refrigerant circuit and the condenser of the low temperature side refrigerant circuit constitute the cascade heat exchanger, and the evaporator of the low temperature side refrigerant circuit is configured to exert the final cooling function. In the refrigerating apparatus, the capillary tube of the final stage of the low temperature side refrigerant circuit is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute the double tube structure. Therefore, the efficiency of the heat exchange between the refrigerant in the suction piping line and the refrigerant in the capillary tube can be enhanced to improve the performance.

[0020] In particular, the capillary tube of the low temperature side refrigerant circuit is passed through the suction piping line just exiting from the evaporator to constitute the double tube structure, thereby enabling the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube. According to this constitution, the refrigerant having the lowest boiling point is efficiently cooled by the

refrigerant returning from the evaporator of the low temperature side refrigerant circuit, whereby the performance can remarkably be improved.

[0021] According to the invention of the fifth aspect, in the invention of the second or fourth aspect, the capillary tube of the high temperature side refrigerant circuit is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor of the high temperature side refrigerant circuit flows, to constitute the double tube structure. Therefore, also in the high temperature side refrigerant circuit, the efficiency of the heat exchange between the refrigerant in the suction piping line and the refrigerant in the capillary tube can further be enhanced to further improve the performance of the refrigerating apparatus.

[0022] Moreover, in the inventions of the respective aspects, as in the invention of the sixth aspect, the suction piping line formed in the double tube structure by passing the capillary tube therethrough is surrounded with the insulating material, which can further enhance the efficiency of the heat exchange.

[0023] Furthermore, in the inventions of the above aspects, as in the invention of the seventh aspect, the flow of the refrigerant through the capillary tube and the flow of the refrigerant through the suction piping line outside the capillary tube form the counter flow, which can further improve a heat exchange ability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

FIG. 1 is a side view of an ultralow temperature refrigerator to which a refrigerating apparatus is applied;

FIG. 2 is a refrigerant circuit diagram in an embodiment of the ultralow temperature refrigerator of FIG. 1;

FIG. 3 is a diagram for explaining a double tube structure of a heat exchanger obtained by passing a capillary tube through a suction piping line of the present invention shown in FIG. 2;

FIG. 4 is a graph concerning each data in a case where the weight of a mixed refrigerant of R245fa and R600 and the weight of R14 are set to be constant, while the weight of R23 is varied;

FIG. 5 is a graph concerning each data in a case where the weight of the mixed refrigerant of R245fa and R600 and the weight of R23 are set to be constant, while the weight of R14 is varied;

FIG. 6 is a refrigerant circuit diagram in a second embodiment (Embodiment 2);

FIG. 7 is a refrigerant circuit diagram in a third embodiment (Embodiment 3); and

FIG. 8 is a refrigerant circuit diagram in a fourth embodiment (Embodiment 4).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

[Embodiment 1]

[0026] FIG. 1 is a side view of an ultralow temperature refrigerator 1 to which a refrigerating apparatus of the present invention is applied. The ultralow temperature refrigerator 1 is used, for example, to store refrigerated food to be stored at a low temperature for a long period of time or to store an anatomy, a specimen or the like at an ultralow temperature. A main body of the refrigerator is constituted of an insulating box member 2 having an open upper surface, and a mechanical chamber (not shown) which is positioned in the lower part of the insulating box member 2 and in which a compressor 14 and the like are installed to constitute a refrigerant circuit of a refrigerating apparatus R1 of the present embodiment therein.

[0027] The insulating box member 2 is constituted of an outer box 3 and an inner box 4 both made of steel plates and having open upper surfaces; a breaker 5 made of a synthetic resin and connecting the upper ends of both the boxes 3 and 4 to each other; and a polyurethane resin insulating material 7 charged in a space surrounded by the outer box 3, the inner box 4 and the breaker 5 by an in-situ foaming system. The inside of the inner box 4 is a storage chamber 8 having an open upper surface.

[0028] In the present embodiment, to set a temperature in the storage chamber 8 (hereinafter referred to as the in-chamber temperature) to a target temperature below, for example, -80°C , the insulating box member 2, which insulates the inside of the storage chamber 8 from outside air, requires a larger insulating ability as compared with a low temperature refrigerator where the in-chamber temperature is set around 0°C . Therefore, when the insulating ability is acquired only by the polyurethane resin insulating material 7 described above, the material has to be formed with a considerable thickness, which causes a problem that the storage amount of the storage chamber 8 cannot sufficiently be acquired with a limited main body dimension. Consequently, in the insulating box member 2 of the present embodiment, a vacuum insulating material such as glass wool is disposed on the inner wall surface of the outer box 3, and the thickness of the polyurethane resin insulating material 7 is set to a small dimension in accordance with the insulating ability of the vacuum insulating material.

[0029] Moreover, the upper surface of the breaker 5 is formed in a staircase pattern, and an insulating door 9 is provided rotatably around one end thereof, i.e., the rear end in the present embodiment via a packing 11. In consequence, the upper surface opening of the storage chamber 8 is openably closed with the insulating door 9.

Moreover, the other end of the insulating door 9, i.e., the front end thereof in the present embodiment is provided with a grip portion 10, and the grip portion 10 is operated to open and close the insulating door 9. Furthermore, an evaporator (a refrigerant piping line) 13 constituting the refrigerant circuit of the refrigerating apparatus R1 is attached to the peripheral surface of the inner box 4 on an insulating material 7 side so as to perform heat exchange (in the heat exchange manner).

[0030] Next, the refrigerant circuit of the refrigerating apparatus R1 of the present embodiment will be described with reference to FIG. 2. The refrigerant circuit of the refrigerating apparatus R1 of the present embodiment has a constitution of a single unit/stage of a refrigerant circuit 12. The compressor 14 constituting the refrigerant circuit 12 is an electromotive compressor using a single phase or three phase alternator. The compressor 14 is connected to a disperse heater 20 in a constitution which once discharges a refrigerant compressed by the compressor 14 to the outside to radiate heat, returns the refrigerant into a shell of a sealed container and again discharges the refrigerant to a refrigerant discharge tube 31. The refrigerant discharge tube 31 connected to the compressor 14 on a discharge side thereof is connected to a preliminary condenser 21. The preliminary condenser 21 is connected to a frame pipe 22 for heating the opening edge of the storage chamber 8 to prevent dew condensation, and then connected to a condenser 15.

[0031] Moreover, the refrigerant piping line exiting from the condenser 15 is connected to a dry core 17 and a condensing pipe 23. The dry core 17 is water removal means for removing water from the refrigerant circuit 12. The condensing pipe 23 constitutes a heat exchanger 16 together with a part of a suction piping line 32 exiting from the evaporator 13 and returning to the compressor 14.

[0032] The refrigerant piping line exiting from the condensing pipe 23 is connected to the evaporator 13 via a capillary tube 18 as a pressure reducing unit. The capillary tube 18 is passed through a part (a piping line 32A) of the suction piping line 32 exiting from the evaporator 13 and returning to the compressor 14. Specifically, the capillary tube 18 is passed through the piping line 32A as a part of the suction piping line 32 positioned on a discharge side (the outlet side) of a header 26 provided on the discharge side of the evaporator 13 and on a suction side of the heat exchanger 16, to constitute a double tube structure as shown in FIG. 3. In such a double tube structure, it is possible to perform heat exchange between the refrigerant flowing through the capillary tube 18 inside a double tube 25 (hereinafter referred to as the double tube structure) and the refrigerant flowing from the evaporator 13 through the piping line 32A outside the capillary tube.

[0033] Here, a manufacturing method of the double tube structure 25 will be described. First, the linearly tubular capillary tube 18 is passed through the linearly tubular piping line 32A having a comparatively large diameter. Next, such a double tube is spirally wound as much

as a plurality of stages. At this time, the tube is wound so that the axial center of the piping line 32A coincides with the axial center of the capillary tube 18 as much as possible, to form the spiral double tube. In consequence, a gap is formed between the inner wall surface of the piping line 32A and the outer wall surface of the capillary tube 18 as consistently as possible. In this way, the double tube is spirally wound as much as the plurality of stages to form the spiral double tube structure, thereby enabling miniaturization while sufficiently acquiring the length of the capillary tube 18 and sufficiently acquiring such a heat exchange portion of the double tube structure.

[0034] Next, cap-like connection piping lines (not shown) having both end holes and side holes are attached to both ends of the piping line 32A, the ends of the capillary tube 18 are drawn from the side holes, respectively, and then the side holes are welded and sealed. Furthermore, one end of the connection piping line attached to the one end of the piping line 32A and a connecting portion of the piping line 32A are welded, the other end of the connection piping line is connected to the suction piping line 32 connected to the evaporator 13 on the discharge side thereof, and this connecting portion is welded. Similarly, one end of the connection piping line attached to the other end of the piping line 32A and a connecting portion of the piping line 32A are welded, the other end of the connection piping line is connected to the suction piping line 32 leading to the heat exchanger 16, and this connecting portion is welded. Moreover, the piping line 32A formed in such a double tube structure is surrounded with an insulating material 35, whereby the double tube structure 25 of the present embodiment can be obtained.

[0035] Additionally, in a conventional refrigerating apparatus formed so that heat exchange between the capillary tube and the suction piping line exiting from the evaporator can be performed, the capillary tube has been disposed along the outer peripheral surface of the suction piping line so that the outer wall of the capillary tube can come in contact with the outer wall of the suction piping line in the heat exchange manner. In this case, the suction piping line only linearly comes in contact with the capillary tube. Therefore, a heat exchange performance is so poor that the heat exchange cannot sufficiently be performed.

[0036] On the other hand, the capillary tube 18 is passed through the suction piping line 32 (the piping line 32A) to constitute the double tube structure as in the present invention, thereby performing the heat exchange between the refrigerant flowing through the capillary tube 18 and the refrigerant flowing through the suction piping line 32 by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 18. In consequence, a heat exchange performance can remarkably be improved as compared with a conventional structure. In particular, the whole outer periphery of the piping line 32A having the double tube structure is surrounded with the insulating material 35 as described

above, whereby the structure is not easily influenced by the heat from the outside. Moreover, it is possible to further improve the ability of the heat exchange between the refrigerant in the piping line 32A and the refrigerant in the capillary tube 18.

[0037] Furthermore, the refrigerant is allowed to flow through the capillary tube 18 inside the double tube structure and through the suction piping line 32 (the piping line 32A) outside the capillary tube 18 so as to form the counter flow of the refrigerant, whereby the heat exchange ability in the double tube structure 25 can further be improved.

[0038] The double tube structure 25 is disposed in the insulating material 7. Specifically, as shown in FIG. 1, the double tube structure is removably received in the insulating material 7 under the heat exchanger 16 on the back surface side of the inner box 4.

[0039] On the other hand, the suction piping line 32 exiting from the double tube structure 25 is connected to the compressor 14 on the suction side thereof successively through the heat exchanger 16, a check valve 27 and an accumulator 28. It is to be noted that in the present embodiment, the preliminary condenser 21 and the condenser 15 have a constitution of an integral condenser, and are cooled by a condensing fan 29 as a blower for the condenser.

[0040] In the present embodiment, a mixed refrigerant of R245fa and R600 and a non-azeotropic mixed refrigerant of R23 and R14 are charged in the refrigerant circuit 12. R245fa is 1,1,1,-3,3-pentafluoropropane ($\text{CF}_3\text{CH}_2\text{CHF}_2$) and has a boiling point of $+15.3^\circ\text{C}$. R600 is butane (C_4H_{10}) and has a boiling point of -0.5°C . R600 has a function of returning, to the compressor 14, a lubricant of the compressor 14 or mixed water which cannot be absorbed by the drier 17 in a state where the water is dissolved in R600. R600 is a combustible substance. However, when R600

is mixed with incombustible R245fa at a predetermined ratio of $\text{R245fa/R600} = 70/30$ in the present embodiment, whereby the substance can be treated as an incombustible substance. R23 is trifluoromethane (CHF_3) and has a boiling point of -82.1°C . R14 is tetrafluoromethane (CF_4) and has a boiling point of -127.9°C .

[0041] Moreover, a composition of these mixed refrigerants in the present embodiment includes 64% by weight of the mixed refrigerant of R245fa and R600, 24% by weight of R23 and 12% by weight of R14 in total.

[0042] It is to be noted that in FIG. 2, arrows show the flow of the refrigerant circulating through the refrigerant circuit 12. Specifically, a high temperature gaseous refrigerant discharged from the compressor 14 is once discharged from the sealed container to the disperse heater 20 through a refrigerant discharge tube on a disperse heater 20 side, radiates heat and again returns into the shell of the sealed container. In consequence, the inside of the sealed container can be cooled by the refrigerant which has radiated the heat in the disperse heater 20 to lower the temperature thereof. Moreover, such a high

temperature gaseous refrigerant is discharged from the sealed container through the refrigerant discharge tube 31, condensed by the preliminary condenser 21, the frame pipe 22 and the condenser 15 to radiate the heat, and is liquefied, followed by removing the water contained in the refrigerant by the dry core 17. Afterward, the refrigerant flows into the heat exchanger 16. In the heat exchanger 16, the heat exchange between the refrigerant from the condenser 15 and the low temperature refrigerant in the suction piping line 32 disposed in the heat exchange manner is performed, whereby the non-condensed refrigerant is cooled, condensed and liquefied. Afterward, the refrigerant flows into the capillary tube 18.

[0043] Here, the heat exchange between the refrigerant in the capillary tube 18 and the refrigerant flowing through the suction piping line 32 disposed around the whole periphery of the capillary tube 18 is performed by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 18. Afterward, the refrigerant having a pressure thereof reduced while lowering the temperature flows into the evaporator 13. Subsequently, in the evaporator 13, the refrigerants R14 and R23 take the heat from the ambient atmosphere to evaporate. At this time, the refrigerants R14 and R23 evaporate in the evaporator 13 to exert a cooling function, thereby cooling the ambient atmosphere of the evaporator 13 to an ultralow temperature of -85°C. In this case, the evaporator (the refrigerant piping line) 13 is wound along the inner box 4 on the insulating material 7 side in the heat exchange manner as described above, whereby the inside of the storage chamber 8 of the ultralow temperature refrigerator 1 can be set to an in-chamber temperature below -80°C by such cooling of the evaporator 13.

[0044] Afterward, the refrigerant evaporated by the evaporator 13 exits from the evaporator 13 via the suction piping line 32 to return to the compressor 14 through the header 26, the double tube structure 25, the heat exchanger 16, the check valve 27 and the accumulator 28.

[0045] At this time, the finally reaching temperature of the evaporator 13 of the compressor 14 which is being operated is from -100°C to -60°C. At such a low temperature, R245fa in the refrigerant has a boiling point of +15.3°C, and R600 has a boiling point of -0.5°C. Therefore, the refrigerant does not evaporate but still has a liquid state in the evaporator 13, and hence the refrigerant hardly contributes to cooling. However, R600 has a function of returning, to the compressor 14, the lubricant of the compressor 14 or the mixed water which cannot be absorbed by the dry core 17 in the state where the water is dissolved in R600, and the liquid refrigerant also has a function of evaporating in the compressor 14 to lower the temperature of the compressor 14.

[0046] The evaporation temperature in the evaporator 13 varies in accordance with the composition ratio of the non-azeotropic mixed refrigerant introduced in the refrigerant circuit 12. Hereinafter, the evaporator temperature,

in-chamber temperature, high pressure side pressure and low pressure side pressure with respect to the composition ratio of each refrigerant will be described based on each experiment result in detail. FIG. 4 is a graph showing the evaporator inlet temperature, the in-chamber temperature, the high pressure side pressure and the low pressure side pressure in a case where the weight of the mixed refrigerant of R245fa and R600 and the weight of R14 are set to be constant, while the weight of R23 is varied. FIG. 5 is a graph showing the evaporator inlet temperature, the in-chamber temperature, the high pressure side pressure and the low pressure side pressure in a case where the weight of the mixed refrigerant of R245fa and R600 and the weight of R23 are set to be constant, while the weight of R14 is varied.

[0047] In the experiment result of FIG. 4, the weight ratio of R23 with respect to the total weight of the introduced refrigerants is increased from 20.0% by weight to 42.0% by weight. According to this result, with the 20.0% by weight regarded as the minimum amount in such an experiment, the inlet temperature of the evaporator 13 is -88.0°C, whereas the in-chamber temperature is -71.0°C. On the other hand, when the weight ratio of R23 is 21.3% by weight, the inlet temperature of the evaporator 13 rapidly lowers to -95.9°C, whereas the in-chamber temperature also lowers to -87.5°C. Afterward, with the increase of the weight ratio of R23 to 42.0% by weight, the temperature only slightly rises, and in either case, the in-chamber temperature can be set below about -85°C.

[0048] Moreover, in the experiment result of FIG. 5, the weight ratio of R14 with respect to the total weight of the introduced refrigerants is increased from 0.0% by weight to 14.1% by weight. According to this result, in the case of 0.0% by weight regarded as the minimum amount in such an experiment, i.e., in a case where R14 is not included, the inlet temperature of the evaporator 13 is -66.1°C, whereas the in-chamber temperature is -66.9°C. On the other hand, when the weight ratio of R14 is 1.8% by weight, the inlet temperature of the evaporator 13 rapidly lowers to -80.2°C, whereas the in-chamber temperature also lowers to -74.1°C. The weight ratio of R14 is gradually increased, and in the present experiment, at 14.1% by weight, the inlet temperature of the evaporator 13 lowers to -98.9°C, whereas the in-chamber temperature lowers to -90.0°C. R14 has a boiling point of -129.7°C. Therefore, it is then expected that when the weight ratio of R14 is increased, the temperature of the evaporator 13 and the in-chamber temperature further lower.

[0049] However, as seen from the graph of FIG. 5, the high pressure side pressure rises, as the weight ratio of R14 increases. In consequence, there occurs a problem that when the weight ratio of R14 is increased to 20% by weight or more, the high pressure side pressure excessively increases to, for example, 3 MPa or more. The rise of the high pressure side pressure causes a problem that an apparatus such as the compressor 14 is damaged or

a problem that the start properties of the compressor 14 deteriorate. Therefore, when the in-chamber temperature is preferably set to a target temperature below -75°C , the weight ratio of the R14 is preferably set to a range of 3% by weight to 20% by weight of the total weight.

[0050] It is to be noted that R23 has a boiling point of -82.1°C as described above. Therefore, only by R23, the temperature of the evaporator 13 cannot be set to a temperature which is not higher than the boiling point. However, as in the present invention, a predetermined amount, for example, about 5% or more by weight of R14 having a remarkably low boiling point is added, whereby the cooling function of R14 can constantly realize an ultralow temperature below -80°C as the evaporation temperature in the evaporator 13.

[0051] It is seen from the above experiment results that as to the non-azeotropic mixed refrigerant introduced in the refrigerant circuit 12, the total weight ratio of the mixed refrigerant of R245fa and R600 is from 40% by weight to 80% by weight with respect to the total weight, the weight ratio of R23 is from 15% by weight to 47% by weight, and the weight ratio of R14 is from 3% by weight to 20% by weight, whereby the incombustible non-azeotropic mixed refrigerant can realize the ultralow temperature so that the in-chamber temperature is below -70°C . In particular, as to the non-azeotropic mixed refrigerant introduced in the refrigerant circuit 12, the total weight ratio of the mixed refrigerant of R245fa and R600 is from 49% by weight to 70% by weight with respect to the total weight, the weight ratio of R23 is from 21% by weight to 42% by weight, and the weight ratio of R14 is from 9% by weight to 20% by weight, whereby the incombustible non-azeotropic mixed refrigerant can realize the ultralow temperature so that the in-chamber temperature is below -85°C .

[0052] In consequence, the storage of food, anatomy, specimen or the like for a long period of time can further be stabilized, and reliability can be improved. Moreover, since the non-azeotropic mixed refrigerant is incombustible, the refrigerant can safely be used, handling properties are improved, and it is possible to avoid a disadvantage that when the mixed refrigerant leaks owing to the damage of the refrigerant piping line or the like, the refrigerant is combusted.

[0053] In particular, when as to the composition ratio of each component of the non-azeotropic mixed refrigerant, the ratio of the mixed refrigerant of R245fa and R600 is 64% by weight, the ratio of R23 is 24% by weight and the ratio of R14 is 12% by weight, the ultralow temperature can be realized so that the in-chamber temperature is below -80°C . In consequence, the food, anatomy, specimen or the like can further stably be stored for a long period of time, and the reliability of the apparatus can be improved.

[0054] It is to be noted that the refrigerant is not limited to R23. For example, R116 (hexafluoroethane: CF_3CF_3), or R508A (R23/R116 = 39/61, a boiling point: -85.7°C) or R508B (R23/R116 = 46/54, a boiling point: -86.9°C) obtained by mixing R23 and R116 at a predetermined ratio

can produce a similar effect.

[0055] Moreover, when the non-azeotropic mixed refrigerant is used as in the present embodiment, the conventional refrigerant circuit hardly has to be changed in accordance with the change of the refrigerant composition, but the performance of the circuit can be maintained. Moreover, it is possible to cope with an environment problem such as depletion of ozone layer.

[0056] Furthermore, as in the present invention described above, the capillary tube 18 is passed through the suction piping line 32 (the piping line 32A) through which the refrigerant returning from the evaporator 13 to the compressor 14 flows, constitute the double tube structure, whereby the efficiency of the heat exchange between the refrigerant in the piping line 32A and the refrigerant in the capillary tube 18 can be enhanced to improve the performance. In particular, as in the present invention, the capillary tube 18 is passed through the piping line 32A of the suction piping line 32 just exiting from the evaporator 13, to constitute the double tube structure which enables the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 18.

In consequence, the refrigerant returning from the evaporator 13 can efficiently cool the refrigerant having the lowest boiling point, and hence the performance can remarkably be improved.

[0057] Furthermore, the piping line 32A formed in the double tube structure by passing the capillary tube 18 therethrough is surrounded with the insulating material 35, whereby the heat exchange efficiency can further be enhanced. In addition, the flow of the refrigerant through the capillary tube 18 and the flow of the refrigerant through the piping line 32A outside the capillary tube 18 form the counter flow, whereby the heat exchange ability can further be improved.

[0058] In consequence, energy saving of about 15% to 20% can be achieved as compared with a similarly used conventional refrigerating apparatus. Moreover, a lower temperature can be realized as the ambient temperature of the evaporator 13 as compared with the conventional apparatus. In consequence, even when the compressor is changed to a compressor having a smaller capability than a heretofore used compressor, a sufficient performance can be acquired. In consequence, further decrease of power consumption and miniaturization of the apparatus can be achieved.

[0059] Generally according to the present invention, a so-called multistage refrigerating system is not used, but the ultralow temperature can be realized by a single stage refrigerating system as in the present embodiment, whereby the apparatus can be simplified and costs can be decreased.

[0060] It is to be noted that the refrigerating apparatus of the present invention is not limited to the refrigerating apparatus R1 of the embodiment, and the present invention is effective as long as the refrigerant discharged from the compressor is condensed, has the pressure thereof

reduced by the capillary tube, and is evaporated by the evaporator to exert the cooling function. Moreover, when the heat exchanger 16 is not used in the present embodiment, the temperature of the compressed gas may be lowered to the above temperature range by use of another known cooling means, to proceed with a targeted condensing process.

[0061] Furthermore, in the present embodiment, it has been described that there is introduced, in the refrigerant circuit 12, the non-azeotropic mixed refrigerant including R245fa, R600, R23 and R14, the non-azeotropic mixed refrigerant including R245fa, R600, R116 and R14, the non-azeotropic mixed refrigerant including R245fa, R600, R508A and R14 or the non-azeotropic mixed refrigerant including R245fa, R600, R508B and R14. However, the present invention is not limited to this embodiment, and the present invention is also effective, when a single refrigerant is used.

[Embodiment 2]

[0062] Next, a refrigerating apparatus of another embodiment of the present invention will be described with reference to FIG. 6. FIG. 6 is a refrigerant circuit diagram of the embodiment having a constitution of the refrigerating apparatus for the ultralow temperature refrigerator 1 of FIG. 1. In this case, compressors 54 and 84 and the like constituting the refrigerant circuit of a refrigerating apparatus R2 are installed in a mechanical chamber (not shown) positioned in the lower part of an insulating box member 2 of the ultralow temperature refrigerator 1, and an evaporator (a refrigerant piping line) 83 is attached to the peripheral surface of an inner box 4 on an insulating material 7 side in a heat exchange manner, similarly to the evaporator 13 of Embodiment 1 described above.

[0063] The refrigerant circuit of the refrigerating apparatus R2 of the present embodiment is a multiunit (two units) single stage refrigerant circuit constituted of a high temperature side refrigerant circuit 52 and a low temperature side refrigerant circuit 82 constituting independent closed refrigerant circuits, respectively. The compressor 54 constituting the high temperature side refrigerant circuit 52 is an electromotive compressor using a single phase or three phase alternator. The compressor 54 is connected to a disperse heater 60, and has a constitution which once discharges a refrigerant compressed by the compressor 54 to the outside to radiate heat, returns the refrigerant into a shell of a sealed container and again discharges the refrigerant to a refrigerant discharge tube 71. The refrigerant discharge tube 71 connected to the compressor 54 on a discharge side thereof is connected to a preliminary condenser 61. The preliminary condenser 61 is connected to a frame pipe 62 for heating the opening edge of a storage chamber 8 to prevent dew condensation. The refrigerant piping line exiting from the frame pipe 62 is connected to an oil cooler 84C of the compressor 84 constituting the low temperature side refrigerant circuit 82, and is then connected to a condenser

55.

[0064] Moreover, the refrigerant piping line exiting from the condenser 55 is connected to a high temperature side dehydrator (a dry core) 57 and a capillary tube 58. The dehydrator 57 is water removal means for removing water from the high temperature side refrigerant circuit 52. Moreover, the capillary tube 58 is passed through a part (72A) of a suction piping line 72 exiting from a high temperature side evaporator 59 of a cascade heat exchanger 56 and returning to the compressor 54.

[0065] Specifically, the capillary tube 58 is passed through the piping line 72A as a part of the suction piping line 72 positioned on the discharge side of the evaporator 59 and on the suction side of an accumulator 68, to constitute a double tube structure as shown in FIG. 3. According to such a double tube structure, it is possible to perform heat exchange between the refrigerant flowing through the capillary tube 58 inside a double tube 67 (hereinafter referred to as the double tube structure) and the refrigerant flowing from the evaporator 83 through the piping line 72A outside the capillary tube.

[0066] The double tube structure 67 is manufactured by a method similar to that of the double tube structure 25 described above in Embodiment 1. That is, first, the linearly tubular capillary tube 58 is passed through the linearly tubular piping line 72A having a comparatively large diameter. Next, such a double tube is spirally wound as much as a plurality of stages. At this time, the tube is wound so that the axial center of the piping line 72A coincides with the axial center of the capillary tube 58 as much as possible, to form the spiral double tube. In consequence, a gap is formed between the inner wall surface of the piping line 72A and the outer wall surface of the capillary tube 58 as consistently as possible. In this way, the double tube is spirally wound as much as the plurality of stages to form the spiral double tube structure, thereby enabling miniaturization while sufficiently acquiring the length of the capillary tube 58 and sufficiently acquiring such a heat exchange portion of the double tube structure.

[0067] Next, cap-like connection piping lines (not shown) having both end holes and side holes are attached to both ends of the piping line 72A, the ends of the capillary tube 58 are drawn from the side holes, respectively, and then the side holes are welded and sealed. Furthermore, one end of the connection piping line attached to the one end of the piping line 72A and a connecting portion of the piping line 72A are welded, the other end of the connection piping line is connected to the suction piping line 72 connected to the evaporator 59 on the discharge side thereof, and this connecting portion is welded. Similarly, one end of the connection piping line attached to the other end of the piping line 72A and a connecting portion of the piping line 72A are welded, the other end of the connection piping line is connected to the suction piping line 72 leading to the accumulator 68, and this connecting portion is welded. Moreover, the outer periphery of the piping line 72A formed in such a double

tube structure is surrounded with an insulating material (not shown), whereby the double tube structure 67 of the present embodiment can be obtained.

[0068] In this way, the capillary tube 58 is passed through the suction piping line 72 (the piping line 72A) to constitute the double tube structure, thereby performing heat exchange between the refrigerant flowing through the capillary tube 58 and the refrigerant flowing through the suction piping line 72 (the piping line 72A) by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 58.

In consequence, a heat exchange performance can remarkably be improved as compared with a conventional structure in which a capillary tube is attached to the outer peripheral surface of a suction piping line.

[0069] Furthermore, the whole outer periphery of the piping line 72A having the double tube structure is surrounded with the insulating material as described above, whereby the structure is not easily influenced by the heat from the outside. Moreover, it is possible to further improve the ability of the heat exchange between the refrigerant in the piping line 72A and the refrigerant in the capillary tube 58. Furthermore, the refrigerant is allowed to flow through the capillary tube 58 inside the double tube structure and through the suction piping line 72 (the piping line 72A) outside the capillary tube 58 so as to form the counter flow of the refrigerant, whereby the heat exchange ability in the double tube structure 67 can further be improved.

[0070] Moreover, the refrigerant piping line exiting from the capillary tube 58 is connected to the high temperature side evaporator 59 disposed in a heat exchange manner with respect to an evaporator 85 of the low temperature side refrigerant circuit 82. The high temperature side evaporator 59 constitutes the cascade heat exchanger 56 together with the evaporator 85 of the low temperature side refrigerant circuit 82.

[0071] The suction piping line 72 exiting from the high temperature side evaporator 59 is connected to the compressor 54 on the suction side successively through a high temperature side header 66, the double tube structure 67, the accumulator 68 and a check valve 69.

[0072] In the high temperature side refrigerant circuit 52, R404A is introduced as the refrigerant. R404A comprises R125 (pentafluoroethane: CHF_2CF_3), R143a (1,1,1-trifluoroethane: CH_3CF_3) and R134a (1,1,1,2-tetrafluoroethane: CH_2FCF_3), and a composition thereof includes 44% by weight of R125, 52% by weight of R143a and 4% by weight of R134a. This mixed refrigerant has a boiling point of -46.5°C .

[0073] It is to be noted that the refrigerant introduced in the high temperature side refrigerant circuit 52 is not limited to R404A described above. For example, also when R407C as a mixed refrigerant of three types R134a, R32 (difluoromethane: CH_2F_2) and R125 is introduced as the refrigerant, the present invention is effective.

[0074] In FIG. 6, broken-line arrows show the flow of the refrigerant circulating through the high temperature

side refrigerant circuit 52. That is, a high temperature gaseous refrigerant discharged from the compressor 54 is once discharged from the sealed container to the disperse heater 60 through a refrigerant discharge tube on a disperse heater 60 side, radiates heat and again returns into the shell of the sealed container. In consequence, the inside of the sealed container can be cooled by the refrigerant which has radiated the heat in the disperse heater 60 to lower the temperature thereof. Moreover, such a high temperature gaseous refrigerant is discharged from the sealed container through the refrigerant discharge tube 71, condensed by the preliminary condenser 61, the frame pipe 62, the oil cooler 84C of the compressor 84 of the low temperature side refrigerant circuit 82 and the condenser 55 to radiate the heat, and is liquefied, followed by removing the water contained in the refrigerant by the dehydrator 57. Afterward, the refrigerant flows into the capillary tube 58 of the double tube structure 67.

[0075] Here, the heat exchange between the refrigerant in the capillary tube 58 and the refrigerant flowing through the suction piping line 72 (the piping line 72A) disposed along the whole periphery of the capillary tube 58 is performed by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 58. Furthermore, the refrigerant has a pressure thereof reduced while lowering the temperature, and flows into the evaporator 59. Subsequently, in the evaporator 59, the refrigerant R404A absorbs the heat from the refrigerant flowing through the evaporator 85 of the cascade heat exchanger 56 to evaporate. At this time, the refrigerant R404A evaporates to cool the refrigerant flowing through the evaporator 85.

[0076] Afterward, the refrigerant which has evaporated in the evaporator 59 exits from the high temperature side evaporator 59 through the suction piping line 72, flows into the double tube structure 67 through the high temperature side header 66, and performs heat exchange between the refrigerant and the refrigerant flowing through the capillary tube 58. Then, the refrigerant returns to the compressor 54 through the accumulator 68 and the check valve 69.

[0077] On the other hand, the compressor 84 constituting the low temperature side refrigerant circuit 82 is an electromotive compressor using a single phase or three phase alternator in the same manner as in the compressor 54 of the high temperature side refrigerant circuit 52. The compressor 84 is connected to a disperse heater 90, and has a constitution which once discharges the refrigerant compressed by the compressor 84 to the outside to radiate the heat, then returns the refrigerant into the shell of the sealed container and again discharges the refrigerant to a refrigerant discharge tube 101. The refrigerant discharge tube 101 connected to the compressor 84 on the discharge side is connected to a preliminary condenser 91. The refrigerant piping line exiting from the preliminary condenser 91 is connected to an oil separator 92. The oil separator 92 is connected to an oil

return tube 103 returning to the compressor 84.

[0078] The refrigerant piping line exiting from the oil separator 92 leads to an inner heat exchanger 93. The inner heat exchanger 93 is a heat exchanger for performing heat exchange between the high pressure side refrigerant compressed by the compressor 84 and flowing toward a capillary tube 88 and the low pressure side refrigerant evaporated in the evaporator 83 and returning to the compressor 84.

[0079] The high pressure side refrigerant piping line passing through the inner heat exchanger 93 is connected to the evaporator 85. The evaporator 85 constitutes the cascade heat exchanger 56 together with the high pressure side evaporator 59 of the high temperature side refrigerant circuit 52 as described above. The refrigerant piping line exiting from the evaporator 85 is connected to a low temperature side dehydrator (a dry core) 87 and the capillary tube 88. The dehydrator 87 is water removal means for removing water from the low temperature side refrigerant circuit 82. Moreover, the capillary tube 88 is passed through a part (a piping line 102A) of a suction piping line 102 exiting from the evaporator 83 and returning to the compressor 84.

[0080] Specifically, the capillary tube 88 is passed through the piping line 102A as a part of the suction piping line 102 positioned on the discharge side of the evaporator 83 and on the suction side of the inner heat exchanger 93, to constitute the double tube structure as shown in FIG. 3. In such a double tube structure, it is possible to perform heat exchange between the refrigerant flowing through the capillary tube 88 inside a double tube 95 (hereinafter referred to as the double tube structure) and the refrigerant flowing from the evaporator 83 through the piping line 102A outside the capillary tube.

[0081] The double tube structure 95 is manufactured by a method similar to that of the double tube structure 25 described above in Embodiment 1. That is, first, the linearly tubular capillary tube 88 is passed through the linearly tubular piping line 102A having a comparatively large diameter. Next, such a double tube is spirally wound as much as a plurality of stages. At this time, the tube is wound so that the axial center of the piping line 102A coincides with the axial center of the capillary tube 88 as much as possible, to form the spiral double tube. In consequence, a gap is formed between the inner wall surface of the piping line 102A and the outer wall surface of the capillary tube 88 as consistently as possible. In this way, the double tube is spirally wound as much as the plurality of stages to form the spiral double tube structure, thereby enabling miniaturization while sufficiently acquiring the length of the capillary tube 88 and sufficiently acquiring such a heat exchange portion of the double tube structure.

[0082] Next, cap-like connection piping lines (not shown) having both end holes and side holes are attached to both ends of the piping line 102A, the ends of the capillary tube 88 are drawn from the side holes, respectively, and then the side holes are welded and

sealed. Furthermore, one end of the connection piping line attached to the one end of the piping line 102A and a connecting portion of the piping line 102A are welded, the other end of the connection piping line is connected to the suction piping line 102 connected to the evaporator 83 on the discharge side thereof, and this connecting portion is welded. Similarly, one end of the connection piping line attached to the other end of the piping line 102A and a connecting portion of the piping line 102A are welded, the other end of the connection piping line is connected to the suction piping line 102 leading to the inner heat exchanger 93, and this connecting portion is welded. Moreover, the outer periphery of the piping line 102A formed in such a double tube structure is surrounded with an insulating material 105, whereby the double tube structure 95 of the present embodiment can be obtained.

[0083] In this way, the capillary tube 88 is passed through the suction piping line 102 (the piping line 102A) to constitute the double tube structure, thereby performing heat exchange between the refrigerant flowing through the capillary tube 88 and the refrigerant flowing through the suction piping line 102 (the piping line 102A) by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 88. In consequence, a heat exchange performance can remarkably be improved as compared with a conventional structure in which the capillary tube is attached to the outer peripheral surface of the suction piping line.

[0084] Furthermore, the whole outer periphery of the piping line 102A having the double tube structure is surrounded with the insulating material 105 as described above, whereby the structure is not easily influenced by the heat from the outside. Moreover, it is possible to further improve the ability of the heat exchange between the refrigerant in the piping line 102A and the refrigerant in the capillary tube 88. Furthermore, the refrigerant is allowed to flow through the capillary tube 88 inside the double tube structure and through the suction piping line 102 (the piping line 102A) outside the capillary tube 88 so as to form the counter flow of the refrigerant, whereby the heat exchange ability in the double tube structure 95 can further be improved.

[0085] The double tube structure 95 is removably received in the insulating material 7 under the inner box 4 on the back surface side thereof in the same manner as in the double tube structure 25 of Embodiment 1.

[0086] On the other hand, the refrigerant piping line 102 exiting from the capillary tube 95 is connected to the compressor 84 on the suction side through the inner heat exchanger 93. The compressor 84 is further connected to a refrigerant piping line 106, and the refrigerant piping line 106 is connected to expansion tanks 107 in which the refrigerant is stored at the stop of the compressor 84 through a capillary tube 108 as a pressure reducing unit.

[0087] On the other hand, in the low temperature side refrigerant circuit 82, R508A is introduced as the refrigerant. R508A comprises R23 (trifluoromethane: CHF_3)

and R116 (hexafluoroethane: CF_3CF_3), and a composition thereof includes 39% by weight of R23 and 61% by weight of R116. This mixed refrigerant has a boiling point of -85.7°C .

[0088] It is to be noted that the refrigerant introduced in the low temperature side refrigerant circuit 82 is not limited to R508A described in the present embodiment. For example, also when R508B (R23/R116:46/54) having a different mixture ratio of R23 and R116 is used in place of R508A, the present invention is effective.

[0089] In FIG. 6, solid-line arrows show the flow of the refrigerant circulating through the low temperature side refrigerant circuit 82. The flow of the refrigerant in the low temperature side refrigerant circuit 82 will specifically be described. The high temperature gaseous refrigerant discharged from the compressor 84 is once discharged from the sealed container to the disperse heater 90 through a refrigerant discharge tube on a disperse heater 90 side, radiates heat and again returns into the shell of the sealed container. In consequence, the inside of the sealed container can be cooled by the refrigerant which has radiated the heat in the disperse heater 90 to lower the temperature thereof. Moreover, such a high temperature gaseous refrigerant is discharged from the sealed container through the refrigerant discharge tube 101, radiates the heat in the preliminary condenser 91, and flows into the oil separator 92.

[0090] A large part of the lubricant oil of the compressor 84 mixed with the refrigerant in the oil separator 92 and a part of the refrigerant condensed and liquefied in the preliminary condenser 91 are returned to the compressor 84 through the oil return tube 103. On the other hand, the refrigerant discharged from the oil separator 92 is condensed to radiate the heat and is liquefied by the inner heat exchanger 93 and the evaporator 85. Afterward, the water contained in the refrigerant is removed by the low temperature side dehydrator 87, and the refrigerant flows into the capillary tube 88.

[0091] Here, the heat exchange between the refrigerant in the capillary tube 88 and the refrigerant flowing through the suction piping line 102 (the piping line 102A) disposed along the whole periphery of the capillary tube 88 is performed by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 88. Furthermore, the refrigerant has a pressure thereof reduced while lowering the temperature, and flows into the evaporator 83. Subsequently, in the evaporator 83, the refrigerant R508A absorbs the heat from the ambient atmosphere to evaporate. At this time, the refrigerant R508A evaporates in the evaporator 83 to exert a cooling function, thereby cool the periphery of the evaporator 83 to an ultralow temperature in a range of -86°C to -87°C . In this case, the evaporator (the refrigerant piping line) 83 is wound along the inner box 4 on the insulating material 7 side in the heat exchange manner as described above, whereby the inside of the storage chamber 8 of the ultralow temperature refrigerator 1 is set to an in-chamber temperature below -80°C by such

cooling of the evaporator 83.

[0092] Afterward, the refrigerant evaporated in the evaporator 83 is discharged from the evaporator 83 through the suction piping line 102, and returns to the compressor 84 through the double tube structure 95 and the inner heat exchanger 93 as described above.

[0093] On the other hand, the ON-OFF control of the compressor 84 constituting the low temperature side refrigerant circuit 82 is performed by a control apparatus (not shown) based on the in-chamber temperature of the storage chamber 8. In this case, when the operation of the compressor 84 is stopped by the control apparatus, the mixed refrigerant in the low temperature side refrigerant circuit 82 is collected in the expansion tanks 107 through the refrigerant piping line 106 and the capillary tube 108.

[0094] In consequence, the pressure in the refrigerant circuit 82 can be prevented from rising. Moreover, when the compressor 84 is started by the control apparatus, the refrigerant is gradually returned from the expansion tanks 107 into the compressor 84, which can alleviate a start load on the compressor 84.

[0095] As described above in detail, the capillary tube 88 is passed through the suction piping line 102 (the piping line 102A) through which the refrigerant returning from the evaporator 83 to the compressor 84 flows, to constitute the double tube structure, whereby the efficiency of the heat exchange between the refrigerant in the piping line 102A and the refrigerant in the capillary tube 88 can be enhanced to improve the performance.

[0096] In particular, as in the present invention, the capillary tube 88 is passed through the piping line 102A of the suction piping line 102 just exiting from the evaporator 83, to constitute the double tube structure which enables the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 88.

In consequence, the refrigerant returning from the evaporator 83 can efficiently cool the refrigerant having the lowest boiling point, and hence the performance can remarkably be improved. Therefore, the present invention is especially effective in the ultralow temperature refrigerator 1 of the present embodiment.

[0097] Furthermore, the piping line 102A formed in the double tube structure by passing the capillary tube 88 therethrough is surrounded with the insulating material 105, whereby the heat exchange efficiency can further be enhanced. In addition, the flow of the refrigerant through the capillary tube 88 and the flow of the refrigerant through the piping line 102A outside the capillary tube 88 form the counter flow, whereby the heat exchange ability can further be improved.

[0098] Additionally, in the present embodiment, the capillary tube 58 as pressure reducing means of the high temperature side refrigerant circuit 52 is also formed in the double tube structure in the same manner as in capillary tube 88 of the low temperature side refrigerant circuit 82, and the piping line 72A having such a double

tube structure is surrounded with the insulating material. Furthermore, the flow of the refrigerant becomes the counter flow in the capillary tube 58 inside the double tube structure and the suction piping line 72 (the piping line 72A) outside the capillary tube 58. In consequence, the refrigerant returning from the evaporator 59 can efficiently cool the refrigerant in the capillary tube 58. Consequently, the heat exchange efficiency can further be enhanced to further improve the performance.

[0099] Generally according to the present invention, it is possible to realize the ultralow temperature refrigerator 1 in which the inside of the storage chamber 8 can more efficiently be cooled to a desirable ultralow temperature. In particular, according to the present invention, energy saving of about 15% to 20% can be achieved as compared with a similarly used conventional refrigerating apparatus. Moreover, the ambient temperature of the evaporator 13 has heretofore been about -83°C, but according to the above structure of the present invention, a lower temperature in a range of -86°C to -87°C can be realized. In consequence, even when a compressor having a 200 V specification and heretofore used as the compressor of the low temperature side refrigerant circuit 82 is changed to a compressor having a smaller capability and having 115 V specification, a sufficient performance can be acquired. In consequence, further decrease of power consumption and miniaturization of the apparatus can be achieved.

[Embodiment 3]

[0100] Next, a refrigerating apparatus of a further embodiment of the present invention will be described with reference to FIG. 7. FIG. 7 is a refrigerant circuit diagram of the embodiment having a constitution of the refrigerating apparatus for the ultralow temperature refrigerator 1 of FIG. 1. In this case, a compressor 114 and the like constituting the refrigerant circuit of a refrigerating apparatus R3 are installed in a mechanical chamber (not shown) positioned in the lower part of an insulating box member 2 of the ultralow temperature refrigerator 1, and an evaporator (a refrigerant piping line) 113 is attached to the peripheral surface of an inner box 4 on an insulating material 7 side in a heat exchange manner.

[0101] The refrigerant circuit of the refrigerating apparatus R3 of the present embodiment is constituted of a single unit multistage (two stages) refrigerant circuit 112 comprising the compressor 114, a condenser 115, an evaporator 113, a single intermediate heat exchanger 116 connected so that a refrigerant returning from the evaporator 113 circulates therethrough and a plurality of capillary tubes 118 and 135. The compressor 114 constituting the refrigerant circuit 112 is an electromotive compressor using a single phase or three phase alternator in the same manner as in the above embodiments. A refrigerant discharge tube 131 connected to the compressor 114 on a discharge side thereof is connected to a preliminary condenser 121. The preliminary condenser

121 is connected to a frame pipe 122 for heating the opening edge of the storage chamber 8 to prevent dew condensation, an oil cooler 114C of the compressor 114, and then the condenser 115. It is to be noted that in the present embodiment, the preliminary condenser 121 and the condenser 115 have an constitution of an integral condenser, and are cooled by a condensing fan 129 as a blower for the condenser.

[0102] Moreover, the refrigerant piping line exiting from the condenser 115 is connected to a flow diverter 130 via a dehydrator (a dry core) 117. The dehydrator 117 is water removal means for removing water from the refrigerant circuit 112. The flow diverter 130 is a gas-liquid separator for separating a refrigerant condensed and liquefied while flowing through the preliminary condenser 121, the frame pipe 122 and the condenser 115 from a refrigerant which is not condensed yet and still has a liquid state. A gas phase piping line 133 connected to the flow diverter 130 on a suction side (an outlet side) thereof to take a gas phase refrigerant (the non-condensed refrigerant) separated by the flow diverter 130 is connected to a condensing pipe 123.

[0103] The condensing pipe 123 constitutes the intermediate heat exchanger 116 together with a preliminary evaporator 136. The intermediate heat exchanger 116 reduces, by the capillary tube 135, a pressure of the liquid phase refrigerant (the condensed refrigerant) separated by the flow diverter 130, and allows the refrigerant to flow through the preliminary evaporator 136 of the intermediate heat exchanger 116 to evaporate the refrigerant therein, thereby cooling the gas phase refrigerant (the non-condensed refrigerant) flowing through the condensing pipe 123 to condense the refrigerant. The refrigerant piping line exiting from the condensing pipe 123 is connected to the evaporator 113 via the capillary tube (the capillary tube of the final stage) 118.

[0104] The capillary tube 118 is passed through a part (a piping line 132A) of a suction piping line 132 exiting from the evaporator 113 to return to the compressor 114. Specifically, the capillary tube 118 is passed through the piping line 132A as a part of the suction piping line 132 positioned on the discharge side of the evaporator 113 and on the suction side of the intermediate heat exchanger 116, to constitute the double tube structure as shown in FIG. 3. Such a double tube structure has a constitution which can perform heat exchange between the refrigerant flowing through the capillary tube 118 inside a double tube 125 (hereinafter referred to as the double tube structure) and the refrigerant flowing from the evaporator 113 through the piping line 132A outside the capillary tube.

[0105] The double tube structure 125 is manufactured by a method similar to that of the double tube structure 25 described above in Embodiment 1. That is, first, the linearly tubular capillary tube 118 is passed through the linearly tubular piping line 132A having a comparatively large diameter. Next, such a double tube is spirally wound as much as a plurality of stages. At this time, the tube is wound so that the axial center of the piping line 132A

coincides with the axial center of the capillary tube 118 as much as possible, to form the spiral double tube. In consequence, a gap is formed between the inner wall surface of the piping line 132A and the outer wall surface of the capillary tube 118 as consistently as possible. In this way, the double tube is spirally wound as much as the plurality of stages to form the spiral double tube structure, thereby enabling miniaturization while sufficiently acquiring the length of the capillary tube 118 and sufficiently acquiring such a heat exchange portion of the double tube structure.

[0106] Next, cap-like connection piping lines (not shown) having both end holes and side holes are attached to both ends of the piping line 132A, the ends of the capillary tube 118 are drawn from the side holes, respectively, and then the side holes are welded and sealed. Furthermore, one end of the connection piping line attached to the one end of the piping line 132A and a connecting portion of the piping line 132A are welded, the other end of the connection piping line is connected to the suction piping line 102 connected to the evaporator 113 on the discharge side thereof, and this connecting portion is welded. Similarly, one end of the connection piping line attached to the other end of the piping line 132A and a connecting portion of the piping line 132A are welded, the other end of the connection piping line is connected to the suction piping line 102 leading to the intermediate heat exchanger 116, and this connecting portion is welded. Moreover, the outer periphery of the piping line 132A formed in such a double tube structure is surrounded with an insulating material 140, whereby the double tube structure 125 of the present embodiment can be obtained.

[0107] In this way, the capillary tube 118 is passed through the suction piping line 132 to constitute the double tube structure, thereby performing heat exchange between the refrigerant flowing through the capillary tube 118 and the refrigerant flowing through the suction piping line 132 by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 118. In consequence, a heat exchange performance can remarkably be improved as compared with a conventional structure in which the capillary tube is attached to the outer peripheral surface of the suction piping line.

[0108] Furthermore, the whole outer periphery of the piping line 132A having the double tube structure is surrounded with the insulating material 140 as described above, whereby the structure is not easily influenced by the heat from the outside. Moreover, it is possible to further improve the ability of the heat exchange between the refrigerant in the piping line 132A and the refrigerant in the capillary tube 118. In addition, the refrigerant is allowed to flow through the capillary tube 118 inside the double tube structure and through the suction piping line 132 (the piping line 132A) outside the capillary tube 118 so as to form the counter flow of the refrigerant, whereby the heat exchange ability in the double tube structure 125 can further be improved.

[0109] The double tube structure 125 is removably received in the insulating material 7 under the inner box 4 on the back surface side thereof in the same manner as in the double tube structures 25 and 95 of the above embodiments.

[0110] On the other hand, the suction piping line 132 exiting from the evaporator 113 is connected to the preliminary evaporator 136 through the piping line 132A of the double tube structure 125. Moreover, the suction piping line 132 exiting from the preliminary evaporator 136 is connected to the compressor 114 on the suction side thereof. Furthermore, an expansion tank 137 for storing the refrigerant at the stop of the compressor 114 is interposed between the compressor 114 and the preliminary evaporator 136 along the suction piping line 132 via a capillary tube 138 as a pressure reducing unit.

[0111] Moreover, a non-azeotropic mixed refrigerant constituted of a plurality of types of mixed refrigerants having different boiling points is introduced as a refrigerant in the refrigerant circuit 112. In the present embodiment, a non-azeotropic mixed refrigerant comprising R245fa (1,1,1,-3,3-pentafluoropropane: $\text{CF}_3\text{CH}_2\text{CHF}_2$), R600 (butane: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$), R23 (trifluoromethane: CHF_3) and R14 (tetrafluoromethane: CF_4) is introduced in the same manner as in Embodiment 1.

[0112] It is to be noted that the refrigerant introduced in the refrigerant circuit 112 is not limited to the above non-azeotropic mixed refrigerant including R245fa, R600, R23 and R14. For example, a non-azeotropic mixed refrigerant including R245fa, R600, R116 and R14, a non-azeotropic mixed refrigerant including R245fa, R600, R508A and R14 or a non-azeotropic mixed refrigerant including R245fa, R600, R508B and R14 may be introduced. Also when another refrigerant is used, the present invention is effective.

[0113] In FIG. 7, arrows show the flow of the refrigerant circulating through the refrigerant circuit 112. This will specifically be described. A high temperature gaseous refrigerant discharged from the compressor 114 is discharged from the sealed container through the refrigerant discharge tube 131, and successively flows through the preliminary condenser 121, the frame pipe 122, the oil cooler 114C of the compressor 114 and the condenser 115. The high temperature gaseous refrigerant discharged from the compressor 114 radiates heat while flowing through the preliminary condenser 121, the frame pipe 122, the oil cooler 114C and the condenser 115, and the refrigerants (R245fa and R600) having a high boiling point in the mixed refrigerant is condensed and liquefied.

[0114] Subsequently, the water contained in the mixed refrigerant discharged from the condenser 115 is removed by the dehydrator 117, and the refrigerant flows into the flow diverter 130. At this time, R23 and R14 in the mixed refrigerant, having a remarkably low boiling point, are not condensed yet and have a gas state, and R245fa and R600 having a high boiling point are condensed and liquefied. Therefore, R23 and R14 are al-

lowed to flow through the gas phase piping line 133, and R245fa and R600 are separately allowed to flow through a liquid phase piping line 134. The refrigerant mixture which has flowed into the gas phase piping line 133 flows into the condensing pipe 123 constituting the intermediate heat exchanger 116.

[0115] Moreover, the mixed refrigerant which has flowed into the liquid phase piping line 134 has a pressure thereof reduced by the capillary tube 135, and flows into the preliminary evaporator 136 constituting the intermediate heat exchanger 116 together with the condensing pipe 123, to cool R23 and R14 flowing through the condensing pipe 123 together with the low temperature refrigerant returning from the evaporator 113. In consequence, R23 and R14 flowing through the condensing pipe 123 are condensed and liquefied. Subsequently, in the intermediate heat exchanger 116, condensed R23 and R14 then exit from the condensing pipe 123 to flow into the capillary tube 118.

[0116] Here, heat exchange between the refrigerant in the capillary tube 118 and the refrigerant flowing through the suction piping line 132 (the piping line 132A) disposed along the whole periphery of the capillary tube 118 is performed by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 118. Furthermore, the refrigerant has a pressure thereof reduced while further lowering the temperature, and flows into the evaporator 113. Subsequently, in the evaporator 113, the refrigerants R14 and R23 take the heat from the ambient atmosphere to evaporate. At this time, the refrigerants R14 and R23 evaporate in the evaporator 113 to exert a cooling function, thereby cooling the periphery of the evaporator 113 to an ultralow temperature of - 85°C. In this case, the evaporator (the refrigerant piping line) 113 is wound along the inner box 4 on the insulating material 7 side in the heat exchange manner, whereby the inside of the storage chamber 8 of the ultralow temperature refrigerator 1 can be set to an in-chamber temperature below -80°C by such cooling of the evaporator 113.

[0117] Subsequently, the refrigerant evaporated in the evaporator 113 exits from the evaporator 113 through the suction piping line 132, flows into the preliminary evaporator 136 of the intermediate heat exchanger 116 through the double tube structure 125 described above, and then joins the refrigerants (R245fa and R600) evaporated in the preliminary evaporator 136 and having a high boiling point. Afterward, the refrigerant exits from the preliminary evaporator 136 to return to the compressor 114.

[0118] On the other hand, ON-OFF control of the compressor 114 constituting the refrigerant circuit 112 is performed by a control apparatus (not shown) based on the in-chamber temperature of the storage chamber 8. In this case, when the operation of the compressor 114 is stopped by the control apparatus, the mixed refrigerant in the low temperature side refrigerant circuit 112 is collected in the expansion tank 137 through the capillary

tube 138.

[0119] In consequence, the pressure in the refrigerant circuit 112 can be prevented from rising. Moreover, when the compressor 114 is started by the control apparatus, the refrigerant is gradually returned from the expansion tank 137 into the refrigerant circuit 112 through the capillary tube 138, which can alleviate a start load on the compressor 114.

[0120] As in the present embodiment described above in detail, the capillary tube 118 is passed through the suction piping line 132 (the piping line 132A) through which the refrigerant returning from the evaporator 113 to the compressor 114 flows, to constitute the double tube structure, whereby the efficiency of the heat exchange between the refrigerant in the piping line 132A and the refrigerant in the capillary tube 118 can be enhanced to improve the performance. In particular, as in the present invention, the capillary tube 118 is passed through the piping line 132A of the suction piping line 132 just exiting from the evaporator 113, to constitute the double tube structure which enables the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 118. In consequence, the refrigerant returning from the evaporator 113 can efficiently cool the refrigerant having the lowest boiling point, and hence the performance can remarkably be improved. Therefore, the present invention is especially effective in the ultralow temperature refrigerator 1 of the present embodiment.

[0121] Furthermore, the piping line 132A formed in the double tube structure by passing the capillary tube 118 therethrough is surrounded with the insulating material 140, whereby the heat exchange efficiency can further be enhanced. In addition, the flow of the refrigerant through the capillary tube 118 and the flow of the refrigerant through the suction piping line 132A outside the capillary tube 118 form the counter flow, whereby the heat exchange ability can further be improved.

[0122] Generally according to the present invention, it is possible to realize the ultralow temperature refrigerator 1 in which the inside of the storage chamber 8 can more efficiently be cooled to a desirable ultralow temperature. In particular, according to the present invention, energy saving of about 15% to 20% can be achieved as compared with a similarly used conventional refrigerating apparatus. Moreover, the ambient temperature of the evaporator 113 can be set to a low temperature as compared with the conventional apparatus. In consequence, even when the compressor is changed to a compressor having a smaller capability than the conventional compressor, a sufficient performance can be acquired. In consequence, further decrease of power consumption and miniaturization of the apparatus can be achieved.

[0123] It is to be noted that in the present embodiment, the only refrigerant circuit 112 described above may constitute the refrigerating apparatus R3 of the ultralow temperature refrigerator 1, but as shown in FIG. 7, in addition to the refrigerant circuit 112, a refrigerant circuit 152 hav-

ing a circuit constitution similar to the refrigerant circuit 112 may be disposed in parallel, and the two refrigerant circuits 112 and 152 may constitute the refrigerating apparatus R3 of the ultralow temperature refrigerator 1. The circuit constitution and refrigerant flow of the refrigerant circuit 152 are similar to those of the refrigerant circuit 112 described above, and hence the constitution is denoted with the same reference numerals as those of the members constituting the refrigerant circuit 112. That is, the members denoted with the same reference numerals as those of the refrigerant circuit 112 produce the same or similar effect or function, and hence description thereof is omitted here.

[0124] A compressor 114 and the like constituting the refrigerant circuit 152 are installed in a mechanical chamber (not shown) positioned in the lower part of the insulating box member 2 of the ultralow temperature refrigerator 1 in the same manner as in the compressor 114 of the refrigerant circuit 112, and an evaporator 113 of the refrigerant circuit 152 is also attached to the peripheral surface of the inner box 4 on the insulating material 7 side in the heat exchange manner, similarly to the evaporator 113 of the refrigerant circuit 112. Furthermore, refrigerants introduced in the refrigerant circuit 152 and circulation of the refrigerants are similar to those of the refrigerant circuit 112 described above, and hence description thereof is omitted here.

[0125] In this way, in a case where the refrigerating apparatus R3 of the ultralow temperature refrigerator 1 has a constitution in which two independent refrigerant circuits 112 and 152 having substantially the same performance are arranged side by side, when one of the refrigerant circuits breaks down, the other refrigerant circuit can be used as a backup. That is, for example, even when the refrigerant circuit 112 breaks down, the refrigerant circuit 152 is operated without any trouble, and the evaporator 113 of the refrigerant circuit 152 can keep the inside of the storage chamber 8 at the ultralow temperature. In consequence, reliability of the ultralow temperature refrigerator 1 can be enhanced.

[0126] It is to be noted that in the present embodiment, each refrigerant circuit constituting the refrigerating apparatus is described as the refrigerant circuit for the single unit two stage system refrigerating apparatus R3, comprising the compressor 114, the condenser 115, the evaporator 113, the single intermediate heat exchanger 116 connected so that the refrigerant returning from the evaporator 113 circulates therethrough and the plurality of, specifically, two capillary tubes 135 and 118. The plurality of types of non-azeotropic mixed refrigerants are introduced, the condensed refrigerant of the refrigerants passed through the condenser 115 is allowed to join the intermediate heat exchanger 116 through the capillary tube 135, and the non-condensed refrigerant of the refrigerants is cooled in the intermediate heat exchanger 116, whereby the refrigerant having a lower boiling point is condensed, and the refrigerant having the lowest boiling point is evaporated by the evaporator 113 through

the capillary tube 118 of the final stage to exert the cooling function. However, the present invention is not limited to this embodiment, and, for example, a plurality of intermediate heat exchangers may be connected in series to constitute the circuit.

[Embodiment 4]

[0127] Next, a refrigerating apparatus of a still further embodiment of the present invention will be described with reference to FIG. 8. FIG. 8 is a refrigerant circuit diagram of the embodiment having a constitution of the refrigerating apparatus for the ultralow temperature refrigerator 1 of FIG. 1. In this case, compressors 214 and 254 and the like constituting the refrigerant circuit of a refrigerating apparatus R4 are installed in a mechanical chamber (not shown) positioned in the lower part of an insulating box member 2 of the ultralow temperature refrigerator 1, and an evaporator (a refrigerant piping line) 253 is attached to the peripheral surface of an inner box 4 on an insulating material 7 side in a heat exchange manner, similarly to the evaporators 13, 83 and 113 of the above embodiments.

[0128] The refrigerant circuit of the refrigerating apparatus R4 of the present embodiment is a multiunit multi-stage refrigerant circuit, i.e., a two-unit two-stage refrigerant circuit comprising a high temperature side refrigerant circuit 212 and a low temperature side refrigerant circuit 252 constituting independent refrigerant closed circuits, respectively. The compressor 214 constituting the high temperature side refrigerant circuit 212 is an electromotive compressor using a single phase or three phase alternator. A refrigerant discharge tube 231 connected to the compressor 214 on a discharge side thereof is connected to a preliminary condenser 221. The preliminary condenser 221 is connected to a frame pipe 222 for heating the opening edge of a storage chamber 8 to prevent dew condensation.

[0129] The frame pipe 222 is connected to an oil cooler 214C of the compressor 214, and is then connected to a condenser 215. Moreover, the refrigerant piping line exiting from the condenser 215 is connected to an oil cooler 254C constituting the low temperature side refrigerant circuit 252, and is then connected to a condenser 223. The refrigerant piping line exiting from the condenser 223 is connected to a high temperature side evaporator 213 as an evaporator portion constituting the evaporator of the high temperature side refrigerant circuit 212 successively via a drier (a dry core) 217 and a capillary tube 218 as a pressure reducing unit.

[0130] The high temperature side evaporator 213 constitutes a cascade heat exchanger 216 together with a condensing pipe 255 as a condenser of the low temperature side refrigerant circuit 252. A suction piping line 232 exiting from the preliminary evaporator 213 is connected to an accumulator 228 as a refrigerant liquid storage, and the suction piping line 232 exiting from the accumulator 228 is connected to the oil cooler 214C on the

suction side. It is to be noted that in the present embodiment, the preliminary condenser 221 and the condensers 215 and 223 have a constitution of an integral condenser, and are cooled by a condensing fan 229 as a blower for the condensers.

[0131] A refrigerant comprising R407D and n-pentane is charged as a non-azeotropic refrigerant in the high temperature side refrigerant circuit 212. R407D comprises R32 (difluoromethane: CH_2F_2), R125 (pentafluoroethane: CHF_2CF_3) and R134a (1,1,1,2-tetrafluoroethane: CH_2FCF_3), and a composition of the refrigerant includes 15% by weight of R32, 15% by weight of R125 and 70% by weight of R134a. As to boiling points of the refrigerants, R32 has -51.8°C , R125 has -48.57°C and R134a has -26.16°C . Moreover, n-pentane has a boiling point of $+36.1^\circ\text{C}$.

[0132] In such a constitution, a high temperature gaseous refrigerant discharged from the compressor 214 is condensed, radiates heat and is liquefied by the preliminary condenser 221, the frame pipe 222, the oil cooler 214C, the condenser 215, the oil cooler 254C of the compressor 254 of the low temperature side refrigerant circuit 252 and the condenser 223, water contained in the refrigerant is removed by the drier 217, and then the refrigerant flows into the capillary tube 218. Subsequently, the refrigerant having the pressure thereof reduced by the capillary tube 218 flows into the high temperature side evaporator 213 constituting the cascade heat exchanger 216. In the high temperature side evaporator 213, the refrigerants R32, R125 and R134a absorb the heat from the refrigerant flowing through the condensing pipe 255 to evaporate. At this time, in the cascade heat exchanger 216, the refrigerant of the high temperature side evaporator 213 of the high temperature side refrigerant circuit 212 evaporates, thereby cooling the refrigerant flowing through the condensing pipe 255 in the low temperature side refrigerant circuit 252.

[0133] Subsequently, the refrigerant evaporated by the high temperature side evaporator 213 exits from the evaporator 213 through the suction piping line 232, and then returns to the compressor 214 through the accumulator 228.

[0134] At this time, the compressor 214 has a capability of, for example, 1.5 HP, and the finally reaching temperature of the high temperature side evaporator 213 which is being operated is in a range of -27°C to -35°C . At such a low temperature, the boiling point of n-pentane in the refrigerant is $+36.1^\circ\text{C}$, and hence the refrigerant does not evaporate and still has a liquid state in the high temperature side evaporator 213. Therefore, the refrigerant hardly contributes to the cooling. However, the refrigerant has a function of returning, to the compressor 214, a lubricant of the compressor 214 or mixed water which cannot be absorbed by the drier 217 in a state where the water is dissolved in the refrigerant, and the liquid refrigerant has a function of evaporating in the compressor 214 to lower the temperature of the compressor 214.

[0135] On the other hand, the low temperature side refrigerant circuit 252 comprises the compressor 254, the condensing pipe (the condenser) 255, the evaporator 253, a plurality of intermediate heat exchanges 262, 266, 270 and 272 connected so that the refrigerant returning from the evaporator 253 circulates therethrough, and a plurality of capillary tubes 264, 268 and 258. Specifically, the compressor 254 constituting the low temperature side refrigerant circuit 252 is an electromotive compressor using a single phase or three phase alternator in the same manner as in the compressor 214, and a refrigerant discharge tube 281 connected to the compressor 254 on the discharge side is connected to an oil separator 260 via a radiator 259 made of a wire condenser. The oil separator 260 is connected to an oil return tube 287 returning to the compressor 254. The refrigerant piping line connected to the oil separator 260 on the discharge side is connected to the condensing pipe 255 as a condenser constituting the cascade heat exchanger 216 together with the high temperature side evaporator 213.

[0136] Moreover, the refrigerant piping line connected to the condensing pipe 255 on the discharge side is connected to a first gas-liquid separator 261 via a drier (a dry core) 257. The gas phase refrigerant (the non-condensed refrigerant) separated by the first gas-liquid separator 261 flows through the first intermediate heat exchange 262 via a gas phase piping line 283, and flows into a second gas-liquid separator 265. On the other hand, the liquid phase refrigerant (the condensed refrigerant) separated by the first gas-liquid separator 261 flows into the first intermediate heat exchange 262 via a liquid phase piping line 284 through a drier 263 and the capillary tube 268 as a pressure reducing unit. The first intermediate heat exchange 262 allows the liquid phase refrigerant (the condensed refrigerant) separated by the first gas-liquid separator 261 to join the intermediate heat exchange 262 through the capillary tube 264. In the heat exchanger, the gas phase refrigerant (the non-condensed refrigerant) flowing through the gas phase piping line 283 is cooled, thereby condensing the refrigerant having a lower boiling point.

[0137] The liquid phase refrigerant separated by the second gas-liquid separator 265 flows through a drier 267 via a liquid phase piping line 286, and then flows into the second intermediate heat exchanger 266 through the capillary tube 268 as a pressure reducing unit. Moreover, the gas phase refrigerant separated by the second gas-liquid separator 265 flows through the second intermediate heat exchanger 266 through a gas phase piping line 285. The second intermediate heat exchanger 266 allows the liquid phase refrigerant (the condensed refrigerant) separated by the second gas-liquid separator 265 to join the intermediate heat exchanger 266 through the capillary tube 268. In the heat exchanger, the gas phase refrigerant (the non-condensed refrigerant) flowing through the gas phase piping line 285 is cooled, thereby condensing the refrigerant having a lower boiling point.

[0138] Next, the gas phase piping line 285 which has

flowed through the second intermediate heat exchanger 266 flows into the capillary tube 258 as a pressure reducing unit through the third intermediate heat exchanger 270, the fourth intermediate heat exchanger 272 and a drier 274.

[0139] The capillary tube 258 is passed through a part (a piping line 282A) of a suction piping line 282 exiting from the evaporator 253 and returning to the compressor 254. Specifically, the capillary tube 258 is passed through the piping line 282A as a part of the suction piping line 282 positioned on a discharge side of the evaporator 253 and on a suction side of the fourth intermediate heat exchanger 272, to constitute a double tube structure as shown in FIG. 3. In such a double tube structure, it is possible to perform heat exchange between the refrigerant flowing through the capillary tube 258 inside a double tube 295 (hereinafter referred to as the double tube structure) and the refrigerant flowing from the evaporator 253 through the piping line 282A outside the capillary tube.

[0140] The double tube structure 295 is manufactured by a method similar to that of the double tube structure 25 described above in Embodiment 1. That is, first, the linearly tubular capillary tube 258 is passed through the linearly tubular piping line 282A having a comparatively large diameter. Next, such a double tube is spirally wound as much as a plurality of stages. At this time, the tube is wound so that the axial center of the piping line 282A coincides with the axial center of the capillary tube 258 as much as possible, to form the spiral double tube. In consequence, a gap is formed between the inner wall surface of the piping line 282A and the outer wall surface of the capillary tube 258 as consistently as possible. In this way, the double tube is spirally wound as much as the plurality of stages to form the spiral double tube structure, thereby enabling miniaturization while sufficiently acquiring the length of the capillary tube 258 and sufficiently acquiring such a heat exchange portion of the double tube structure.

[0141] Next, cap-like connection piping lines (not shown) having both end holes and side holes are attached to both ends of the piping line 282A, the ends of the capillary tube 258 are drawn from the side holes, respectively, and then the side holes are welded and sealed. Furthermore, one end of the connection piping line attached to the one end of the piping line 282A and a connecting portion of the piping line 282A are welded, the other end of the connection piping line is connected to the suction piping line 282 connected to the evaporator 253 on the discharge side thereof, and this connecting portion is welded. Similarly, one end of the connection piping line attached to the other end of the piping line 282A and a connecting portion of the piping line 282A are welded, the other end of the connection piping line is connected to the suction piping line 282 leading to the fourth intermediate heat exchanger 272, and this connecting portion is welded. Moreover, the piping line 282A formed in such a double tube structure is surrounded with an insulating material 297, whereby the double tube

structure 295 of the present embodiment can be obtained.

[0142] In this way, the capillary tube 258 is passed through the suction piping line 282 to constitute the double tube structure, thereby performing heat exchange between the refrigerant flowing through the capillary tube 258 and the refrigerant flowing through the suction piping line 282 by conduction of heat transmitted along the wall surface of the whole periphery of the capillary tube 258. In consequence, a heat exchange performance can remarkably be improved as compared with a conventional structure in which a capillary tube is attached to the outer peripheral surface of the suction piping line.

[0143] Furthermore, the whole outer periphery of the piping line 282A having the double tube structure is surrounded with the insulating material 297 as described above, whereby the structure is not easily influenced by the heat from the outside. Moreover, it is possible to further improve the ability of the heat exchange between the refrigerant in the piping line 282A and the refrigerant in the capillary tube 258. In addition, the refrigerant is allowed to flow through the capillary tube 258 inside the double tube structure and through the suction piping line 282 (the piping line 282A) outside the capillary tube 258 so as to form the counter flow of the refrigerant, whereby the heat exchange ability in the double tube structure 295 can further be improved.

[0144] The double tube structure 295 is removably received in the insulating material 7 under the inner box 4 on the back surface side thereof in the same manner as in the double tube structure 25 of Embodiment 1 described above.

[0145] On the other hand, the suction piping line 282 exiting from the double tube structure 295 is successively connected to the fourth intermediate heat exchanger 272, the third intermediate heat exchanger 270, the second intermediate heat exchanger 266 and the first intermediate heat exchange 262, and is then connected to the compressor 254 on the suction side. Furthermore, expansion tanks 288 for storing the refrigerant at the stop of the compressor 254 are interposed between the compressor 254 and the first intermediate heat exchange 262 along the suction piping line 282, via a capillary tube 289 as a pressure reducing unit. Moreover, the capillary tube 289 is connected to a check valve 290 so that the direction of the expansion tanks 288 is a forward direction.

[0146] On the other hand, in the low temperature side refrigerant circuit 252, a non-azeotropic mixed refrigerant including R245fa, R600, R404A, R508, R14, R50 and R740 is introduced as a mixed refrigerant of seven types of refrigerants having different boiling points. R245fa is 1,1,1,3,3-pentafluoropropane ($\text{CF}_3\text{CH}_2\text{CHF}_2$) and R600 is butane ($\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$). R245fa has a boiling point of +15.3°C and R600 has a boiling point of -0.5°C. Therefore, when these refrigerants are mixed at a predetermined ratio, the refrigerant can be used in place of heretofore used R21 having a boiling point of +8.9°C.

[0147] It is to be noted that R600 is a combustible sub-

stance. Therefore, when the substance is mixed with incombustible R245fa at a predetermined ratio, i.e., R245fa/R600 = 70/30 in the present embodiment, the substance can be introduced as an incombustible substance in the refrigerant circuit 252. It is to be noted that in the present embodiment, the weight ratio of R245fa is 70% by weight with respect to the total weight of R245fa and R600, but if the weight ratio is above this value, the refrigerant becomes incombustible. Therefore, the weight ratio may be above the value.

[0148] R404A comprises R125 (pentafluoroethane: CHF_2CF_3), R143a (1,1,1-trifluoroethane: CH_3CF_3) and R134a (1,1,1,2-tetrafluoroethane: CH_2FCF_3), and a composition thereof includes 44% by weight of R125, 52% by weight of R143a and 4% by weight of R134a. The mixed refrigerant has a boiling point of -46.48°C . Therefore, the refrigerant can be used in place of heretofore used R22 having a boiling point of -40.8°C .

[0149] R508 comprises R23 (trifluoromethane: CHF_3) and R116 (hexafluoroethane: CF_3CF_3), and a composition thereof includes 39% by weight of R23 and 61% by weight of R116. The mixed refrigerant has a boiling point of -88.64°C .

[0150] Moreover, R14 is tetrafluoromethane (carbon tetrafluoride: CF_4), R50 is methane (CH_4) and R740 is argon (Ar). As to boiling points of these refrigerants, R14 has -127.9°C , R50 has -161.5°C and R740 has -185.86°C . It is to be noted that R50 might combine with oxygen to be in danger of exploding. However, the refrigerant is mixed with R14, the danger of the exploding is eliminated. Therefore, even if a leak accident of the mixed refrigerant occurs, any explosion is not caused.

[0151] It is to be noted that as to these refrigerants, R245fa and R600 and R14 and R50 are once mixed beforehand to obtain an incombustible state. Afterward, the mixed refrigerant of R245fa and R600, R404A, R508A, the mixed refrigerant of R14 and R50, and R740 are beforehand mixed, and then introduced in the refrigerant circuit 252. Alternatively, R245fa and R600, next R404A, R508A, R14 and R50 and finally R740 are introduced in order from a higher boiling point. The composition of the respective refrigerants includes, for example, 10.3% by weight of the mixed refrigerant of R245fa and R600, 28% by weight of R404A, 29.2% by weight of R508A, 26.4% by weight of the mixed refrigerant of R14 and R50 and 5.1% by weight of R740.

[0152] It is to be noted that in the present embodiment, 4% by weight of n-pentane may be added to R404A (in a range of 0.5 to 2% by weight with respect to the total weight of the non-azeotropic refrigerants).

[0153] Next, the circulation of the refrigerant through the low temperature side refrigerant circuit 252 will be described. A high temperature high pressure gaseous mixed refrigerant discharged from the compressor 254 flows into the radiator 259 through the refrigerant discharge tube 281, and radiates heat in the radiator, whereby a part of n-pentane or R600 as an oil carrier refrigerant having a high boiling point in the mixed refrigerant and

having a satisfactory solubility in oil is condensed and liquefied.

[0154] The mixed refrigerant discharged from the radiator 259 flows into the oil separator 260, and a large part of lubricant oil of the compressor 254 mixed with the refrigerant and a part of the refrigerant condensed and liquefied in the radiator 259 (a part of n-pentane or R600) are returned to the compressor 254 through the oil return tube 287. In consequence, a low boiling point refrigerant having a higher purity flows through the refrigerant circuit 252 behind the cascade heat exchanger 216, whereby an ultralow temperature can efficiently be obtained. Consequently, even when the compressors 214 and 254 have the same capability, the inside of the storage chamber 8 as a cooling target having a larger capacity can be cooled to a predetermined ultralow temperature, which enables the increase of a storage capacity without enlarging the whole refrigerating apparatus R.

[0155] Here, in the present embodiment, the refrigerant which has flowed into the oil separator 260 is once cooled in the radiator 259, and hence the temperature of the refrigerant flowing into the cascade heat exchanger 216 can be lowered. Specifically, heretofore, the temperature of the refrigerant flowing into the cascade heat exchanger 216 has been about $+65^\circ\text{C}$, but in the present embodiment, the temperature can be lowered to about $+45^\circ\text{C}$.

[0156] Therefore, in the cascade heat exchanger 216, it is possible to alleviate a load added to the compressor 214 of the high temperature side refrigerant circuit 212 for cooling the refrigerant in the low temperature side refrigerant circuit 252. Moreover, the refrigerant in the low temperature side refrigerant circuit 252 can effectively be cooled, and hence it is possible to alleviate a load added to the compressor 254 constituting the low temperature side refrigerant circuit 252. In consequence, the operation efficiency of the whole refrigerating apparatus R4 can be enhanced.

[0157] As to the other mixed refrigerants themselves, in the cascade heat exchanger 216, a part of the refrigerant (a part of R245fa, R600, R404A or R508) discharged from the high temperature side evaporator 213, cooled to about -40°C to -30°C and having a high boiling point in the mixed refrigerant is condensed and liquefied. Subsequently, the mixed refrigerant discharged from the condensing pipe 255 flows into the first gas-liquid separator 261 through the drier 257. At this time, R14, R50 and R740 in the mixed refrigerant have a remarkably low boiling point, are not condensed yet and still have a gas state, and an only part of R245fa, R600, R404A or R508 is condensed and liquefied, whereby R14, R50 and R740 are diverted to the gas phase piping line 283, and R245fa, R600, R404A and R508A are diverted to the liquid phase piping line 284.

[0158] The refrigerant mixture which has flowed into the gas phase piping line 283 is condensed by heat exchange between the mixture and the first intermediate heat exchange 262, and then reaches the second gas-

liquid separator 265. In this separator, the low temperature refrigerant returning from the evaporator (the refrigerant piping line) 253 flows into the first intermediate heat exchange 262, and the liquid refrigerant which has flowed into the liquid phase piping line 284 has a pressure thereof reduced by the capillary tube 264 through the drier 263. Afterward, the refrigerant flows into the first intermediate heat exchange 262 to evaporate therein, and hence contributes to the cooling. Therefore, a part of non-condensed R14, R50, R740 or R508 is cooled, with the result that an intermediate temperature of the first intermediate heat exchange 262 becomes about -60°C . Therefore, R508 in the mixed refrigerant flowing through the gas phase piping line 283 is completely condensed and liquefied, and diverted to the second gas-liquid separator 265. R14, R50 and R740 further have a low boiling point and still have the gas state.

[0159] In the second intermediate heat exchanger 266, R508 separated by the second gas-liquid separator 265 has water therein removed by the drier 267, has a pressure thereof reduced by the capillary tube 268, flows into the second intermediate heat exchanger 266, and then cools R14, R50 and R740 in the gas phase piping line 285 together with the low temperature refrigerant returning from the evaporator 253, to condense R14 having the highest evaporation temperature in these refrigerants. In consequence, the intermediate temperature of the second intermediate heat exchanger 266 becomes about -90°C .

[0160] The gas phase piping line 285 passing through the second intermediate heat exchanger 266 subsequently passes through the third intermediate heat exchanger 270 and the fourth intermediate heat exchanger 272. Here, the refrigerant just discharged from the evaporator 253 through the double tube structure 295 is returned to the fourth intermediate heat exchanger 272. According to an experiment, the intermediate temperature of the fourth intermediate heat exchanger 272 reaches a considerably low temperature of about -130°C .

[0161] Here, heat exchange between the refrigerant in the capillary tube 258 and the refrigerant flowing through the suction piping line 282 (the piping line 282A) disposed along the whole periphery of the capillary tube 258 is performed by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 258, and the refrigerant further has a pressure thereof reduced while lowering the temperature thereof, to flow into the evaporator 253. Subsequently, in the evaporator 253, the refrigerant takes the heat from the ambient atmosphere to evaporate. According to the experiment, at this time, the ambient temperature of the evaporator 253 is an ultralow temperature in a range of -160.3°C to -157.3°C .

[0162] In this way, the refrigerant still having a gas phase state is successively condensed in the intermediate heat exchanges 262, 266, 270 and 272 by use of each refrigerant evaporation temperature difference in the low temperature side refrigerant circuit 252, whereby

an ultralow temperature below -150°C can be acquired in the evaporator 253 of the final stage. Consequently, in a constitution in which the evaporator 253 is wound along the inner box 4 on the insulating material 7 side in the heat exchange manner, the inside of the storage chamber 8 can realize an in-chamber temperature below -152°C .

[0163] Afterward, the refrigerant evaporated in the evaporator 253 is discharged from the evaporator 253 through the suction piping line 282, successively flows into the double tube structure 295, the fourth intermediate heat exchanger 272, the third intermediate heat exchanger 270, the second intermediate heat exchanger 266 and the first intermediate heat exchange 262, joins the refrigerant evaporated in each heat exchanger, and returns to the compressor 254.

[0164] The oil mixed in the refrigerant and discharged from the compressor 254 has a large part thereof separated by the oil separator 260 and is returned to the compressor 254, but mist-like oil discharged from the oil separator 260 together with the refrigerant is returned to the compressor 254 in a state where the oil is dissolved in R600 having a high solubility in the oil. This can prevent the compressor 254 from causing defective lubrication or locking. Moreover, R600 still having the liquid state returns to the compressor 254 to evaporate in the compressor 254, whereby the discharge temperature of the compressor 254 can be lowered.

[0165] It is to be noted that ON-OFF control of the compressor 254 constituting the low temperature side refrigerant circuit 252 is performed by a control apparatus (not shown) based on the in-chamber temperature of the storage chamber 8. In this case, when the operation of the compressor 254 is stopped by the control apparatus, the mixed refrigerant in the low temperature side refrigerant circuit 252 is collected in the expansion tanks 288 through the check valve 290 so that the direction of the expansion tanks 288 is a forward direction.

[0166] Therefore, it is possible to remarkably rapidly collect the refrigerant in the refrigerant circuit 252 into the expansion tanks 288 through the check valve 290 as compared with a case where the refrigerant is collected in the expansion tanks 288 through the capillary tube 289 at the stop of the compressor 254.

[0167] In consequence, the pressure in the refrigerant circuit 252 can be prevented from rising. When the compressor 254 is started by the control apparatus, the refrigerant is gradually returned from the expansion tanks 288 into the refrigerant circuit 252 through the capillary tube 289, which can alleviate a start load on the compressor 254.

[0168] Therefore, the refrigerant can rapidly be collected into the expansion tanks 288 at the stop of the compressor 254, whereby the pressure in the refrigerant circuit 252 can rapidly come to equilibrium. When the compressor 254 is restarted, any load is not applied to the compressor 254, but the compressor 254 can smoothly be restarted. In consequence, a time required for obtain-

ing an equilibrium pressure in the refrigerant circuit 252 at the start of the compressor can remarkably be shortened, whereby the operation efficiency of the compressor 254 can be enhanced, and a time required in, for example, a pull-down operation can be shortened to enhance convenience.

[0169] As in the present invention described above in detail, the capillary tube 258 is passed through the suction piping line 282 (the piping line 282A) through which the refrigerant returning from the evaporator 253 to the compressor 254 flows, to constitute the double tube structure, whereby the efficiency of the heat exchange between the refrigerant in the piping line 282A and the refrigerant in the capillary tube 258 can be enhanced to improve performance. In particular, as in the present invention, the capillary tube 258 is passed through the piping line 282A of the suction piping line 282 just exiting from the evaporator 253 to constitute the double tube structure, thereby enabling the heat exchange by the conduction of the heat transmitted along the wall surface of the whole periphery of the capillary tube 258, whereby the refrigerant returning from the evaporator 253 efficiently can cool the refrigerant having the lowest boiling point, to remarkably improve the performance. Therefore, the present invention is especially effective in the ultralow temperature refrigerator 1 of the present embodiment.

[0170] Furthermore, the piping line 282A formed in the double tube structure by passing the capillary tube 258 therethrough is surrounded with the insulating material 297, whereby the heat exchange efficiency can further be enhanced. In addition, the flow of the refrigerant through the capillary tube 258 and the flow of the refrigerant through the piping line 282A outside the capillary tube 258 form the counter flow, whereby the heat exchange ability can further be improved.

[0171] Generally, according to the present invention, the ultralow temperature refrigerator 1 can be realized in which the inside of the storage chamber 8 can efficiently be cooled to a desirable ultralow temperature. In particular, according to the present invention, energy saving of about 15% to 20% can be achieved as compared with a similarly used conventional refrigerating apparatus. Moreover, a lower temperature can be realized as the ambient temperature of the evaporator 253 as compared with the conventional apparatus. In consequence, even when the compressor is changed to a compressor having a smaller capability than a conventional compressor, a sufficient performance can be acquired. In consequence, further decrease of power consumption and miniaturization of the apparatus can be achieved.

[0172] It is to be noted that in the present embodiment, the only capillary tube 258 of the final stage of the low temperature side refrigerant circuit 252 is formed in the double tube structure of the present invention, but the present invention is not limited to this embodiment, and the present invention is effective even for a double tube structure obtained by similarly passing the capillary tube

218 of the high temperature side refrigerant circuit 212 through a part of the suction piping line 232 through which the refrigerant returning from the evaporator 213 to the compressor 214 in the high temperature side refrigerant circuit 212 flows. In this case, also in the high temperature side refrigerant circuit 212, the ability of the heat exchange between the refrigerant in the suction piping line 232 and the refrigerant in the capillary tube 218 can be improved. In consequence, the performance of the refrigerating apparatus R4 can further be improved.

[0173] Moreover, in the present embodiment, the refrigerant circuit constituting the refrigerating apparatus has been described as the refrigerating apparatus R4 of the two unit multistage system comprising the high temperature side refrigerant circuit 212 and the low temperature side refrigerant circuit 252 to constitute independent closed refrigerant circuits, each of which condenses a refrigerant discharged from the compressor 214 or 254, reduces a pressure of the refrigerant and evaporates the refrigerant by the evaporator 213 or 253 to exert the cooling function. The low temperature side refrigerant circuit 252 comprises the compressor 254, the condensing pipe 255, the evaporator 253, the plurality of, i.e., four intermediate heat exchangers 262, 266, 270 and 272 connected in series so that the refrigerant returning from the evaporator 253 circulates therethrough and the plurality of, i.e., three capillary tubes 264, 268 and 258. The plurality of types of non-azeotropic mixed refrigerants are introduced. The refrigerating apparatus allows the condensed refrigerant of the refrigerants flowing through the condensing pipe 255 to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools a non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to successively condense the refrigerants having a lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator 253 through the capillary tube 258 of the final stage to exert the cooling function. Moreover, the evaporator 213 of the high temperature side refrigerant circuit 212 and the condensing pipe 255 of the low temperature side refrigerant circuit 252 constitute the cascade heat exchanger 216, and the evaporator 253 of the low temperature side refrigerant circuit 252 acquires the ultralow temperature. However, the present invention is not limited to this embodiment, and may be a refrigerating apparatus of a multiunit multistage system. Moreover, the present invention is effective also for a refrigerating apparatus of a two-unit single-stage system including one gas-liquid separator and one intermediate heat exchanger.

[Description of Reference Numerals]

[0174]

- | | |
|---|-----------------------------------|
| R | refrigerating apparatus |
| 1 | ultralow temperature refrigerator |

2	insulating box member	
7	insulating material	
8	storage chamber	5
9	insulating door	
12	refrigerant circuit	10
13	evaporator	
14	compressor	
15	condenser	15
16	heat exchanger (cascade condenser)	
18	capillary tube	20
21	preliminary condenser	
22	frame pipe	
23	condensing pipe	25
25	double tube structure	
31	refrigerant discharge tube	30
32	suction piping line	
32A	piping line (constituting a part of the suction piping line)	35
35	insulating material	

Claims

1. A refrigerating apparatus which condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube, and evaporates the refrigerant by an evaporator to exert a cooling function, wherein the capillary tube is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute a double tube structure.
2. A refrigerating apparatus comprising: a high temperature side refrigerant circuit and a low temperature side refrigerant circuit to constitute independent closed refrigerant circuits, each of which condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube and evaporates the refrigerant by an evaporator to exert a cooling function, the evaporator of the high tem-

perature side refrigerant circuit and a condenser of the low temperature side refrigerant circuit constituting a cascade heat exchanger, the evaporator of the low temperature side refrigerant circuit being configured to exert a final cooling function, wherein the capillary tube of the low temperature side refrigerant circuit is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute a double tube structure.

3. A refrigerating apparatus which comprises a compressor, a condenser, an evaporator, a single or a plurality of intermediate heat exchangers connected so that a refrigerant returning from the evaporator circulates therethrough and a plurality of capillary tubes and into which a plurality of types of non-azeotropic mixed refrigerants are introduced and which allows a condensed refrigerant of the refrigerants flowing through the condenser to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools a non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having a lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert a cooling function, wherein the capillary tube of the final stage is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor flows, to constitute a double tube structure.

4. A refrigerating apparatus comprising: a high temperature side refrigerant circuit and a low temperature side refrigerant circuit to constitute independent closed refrigerant circuits, each of which condenses a refrigerant discharged from a compressor, reduces a pressure of the refrigerant by a capillary tube and evaporates the refrigerant by an evaporator to exert a cooling function, the low temperature side refrigerant circuit comprising the compressor, a condenser, the evaporator, a single or a plurality of intermediate heat exchangers connected so that the refrigerant returning from the evaporator circulates therethrough and a plurality of capillary tubes, a plurality of types of non-azeotropic mixed refrigerants being introduced, the refrigerating apparatus having a constitution which allows a condensed refrigerant of the refrigerants flowing through the evaporator to join the refrigerants in the intermediate heat exchangers through the capillary tubes, cools a non-condensed refrigerant of the refrigerants in the intermediate heat exchangers to condense the refrigerant having a lower boiling point, and evaporates the refrigerant having the lowest boiling point by the evaporator through the capillary tube of the final stage to exert the cooling function, the evaporator of the high tem-

perature side refrigerant circuit and the condenser of the low temperature side refrigerant circuit constituting a cascade heat exchanger, the evaporator of the low temperature side refrigerant circuit being configured to exert a final cooling function, wherein the capillary tube of the final stage of the low temperature side refrigerant circuit is passed through a suction piping line through which the refrigerant returning from the evaporator to the compressor of the low temperature side refrigerant circuit flows, to constitute a double tube structure.

5. The refrigerating apparatus according to claim 2 or 4, wherein the capillary tube of the high temperature side refrigerant circuit is passed through the suction piping line through which the refrigerant returning from the evaporator to the compressor of the high temperature side refrigerant circuit flows, to constitute the double tube structure.
6. The refrigerating apparatus according to any one of claims 1 to 5, wherein the suction piping line formed in the double tube structure by passing the capillary tube therethrough is surrounded with an insulating material.
7. The refrigerating apparatus according to any one of claims 1 to 6, wherein a flow of the refrigerant through the capillary tube and a flow of the refrigerant through the suction piping line outside the capillary tube form a counter flow.

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FIG. 1

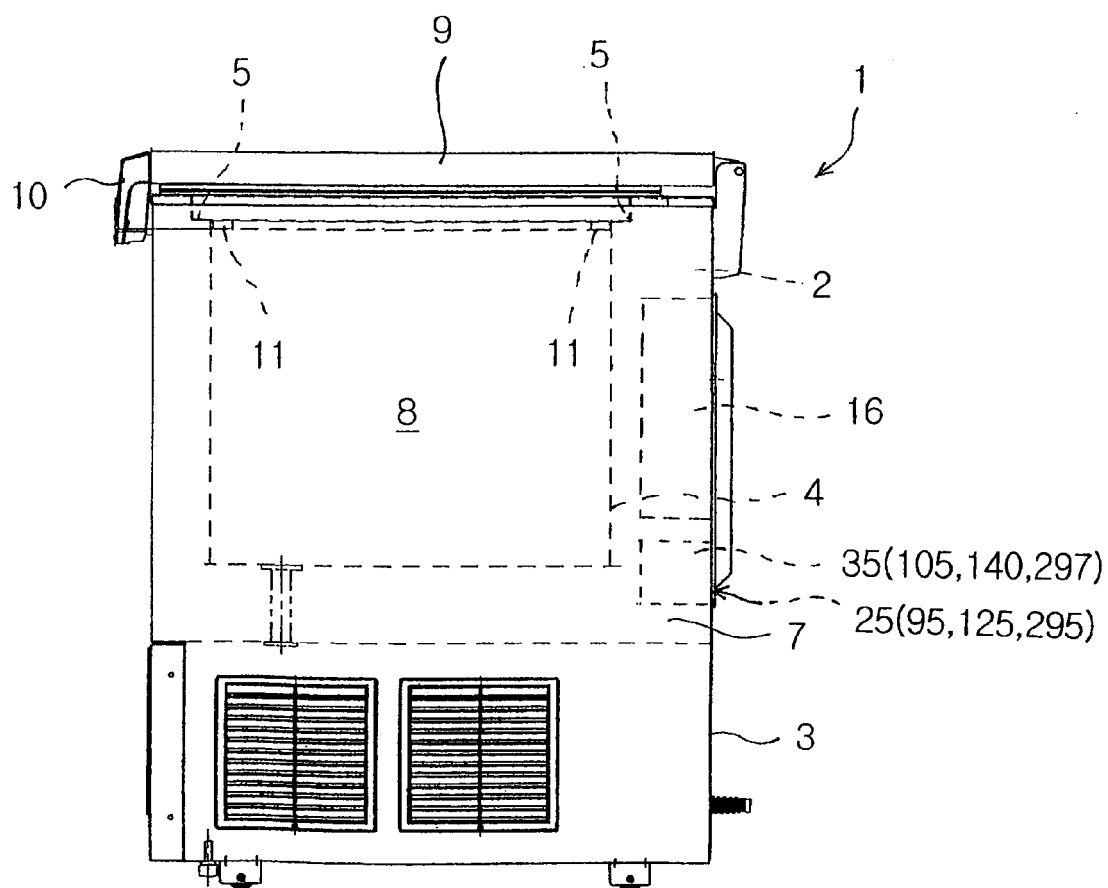


FIG. 2

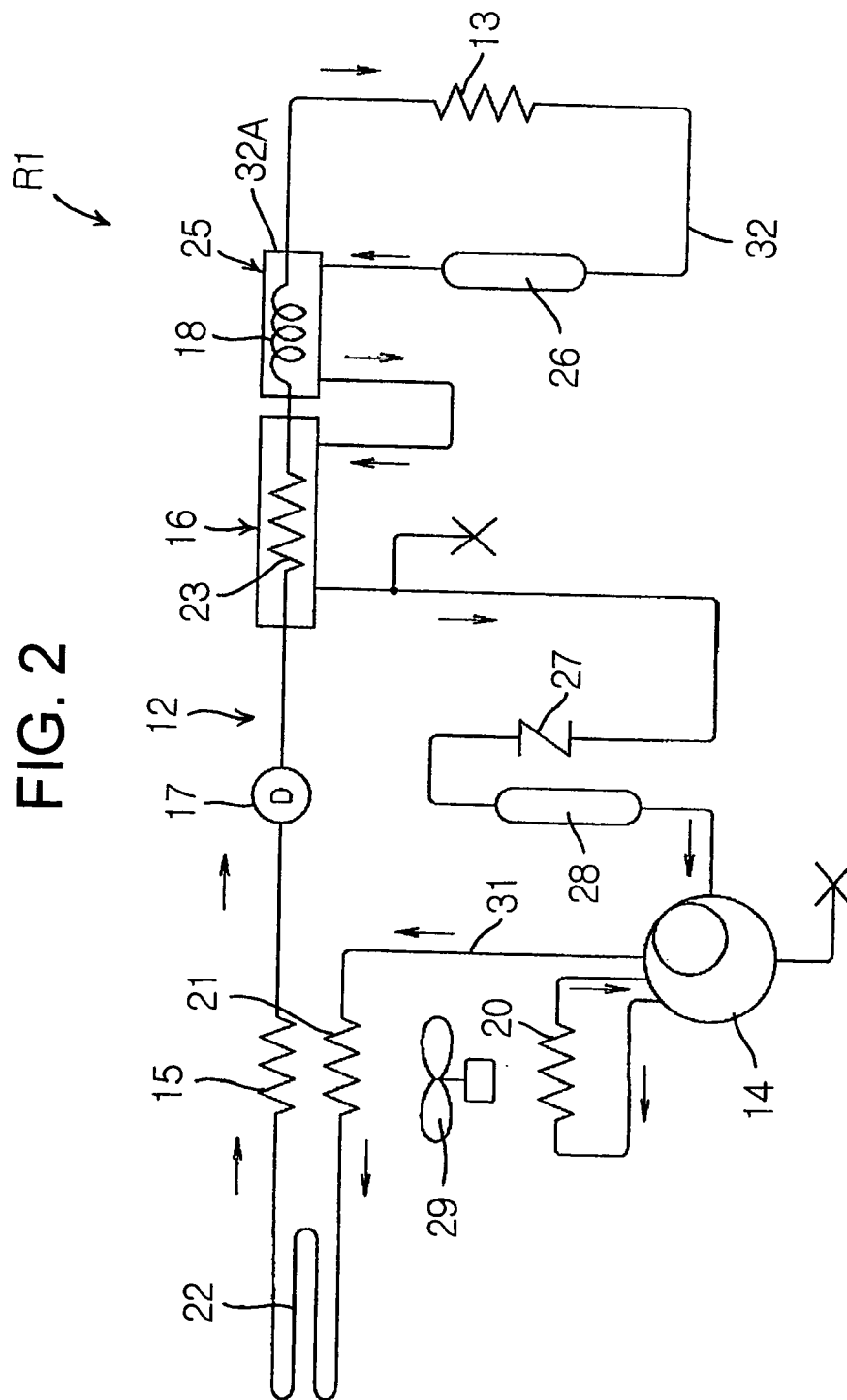


FIG. 3

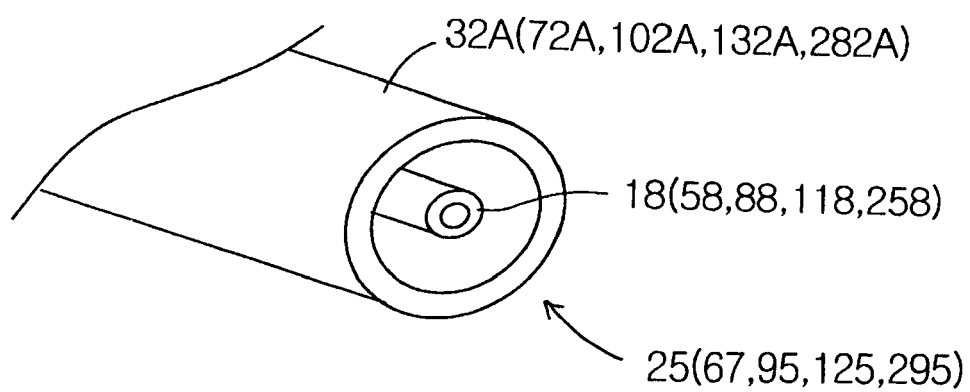


FIG. 4

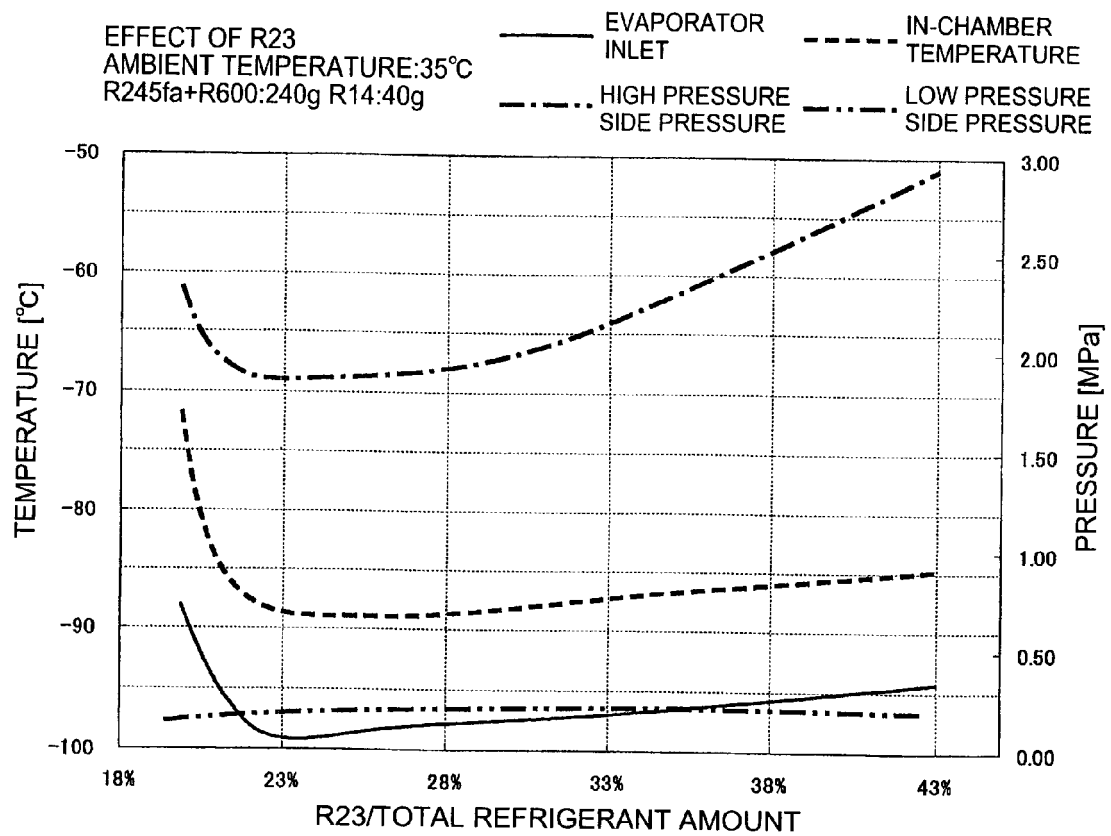


FIG. 5

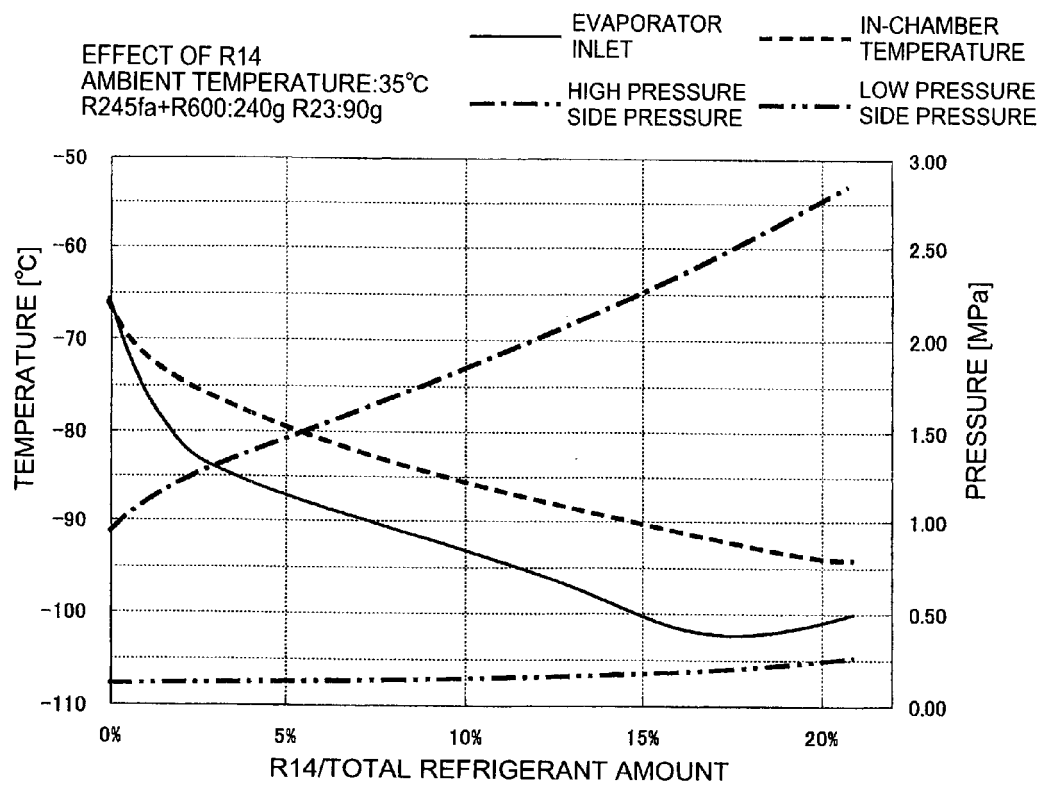


FIG. 6

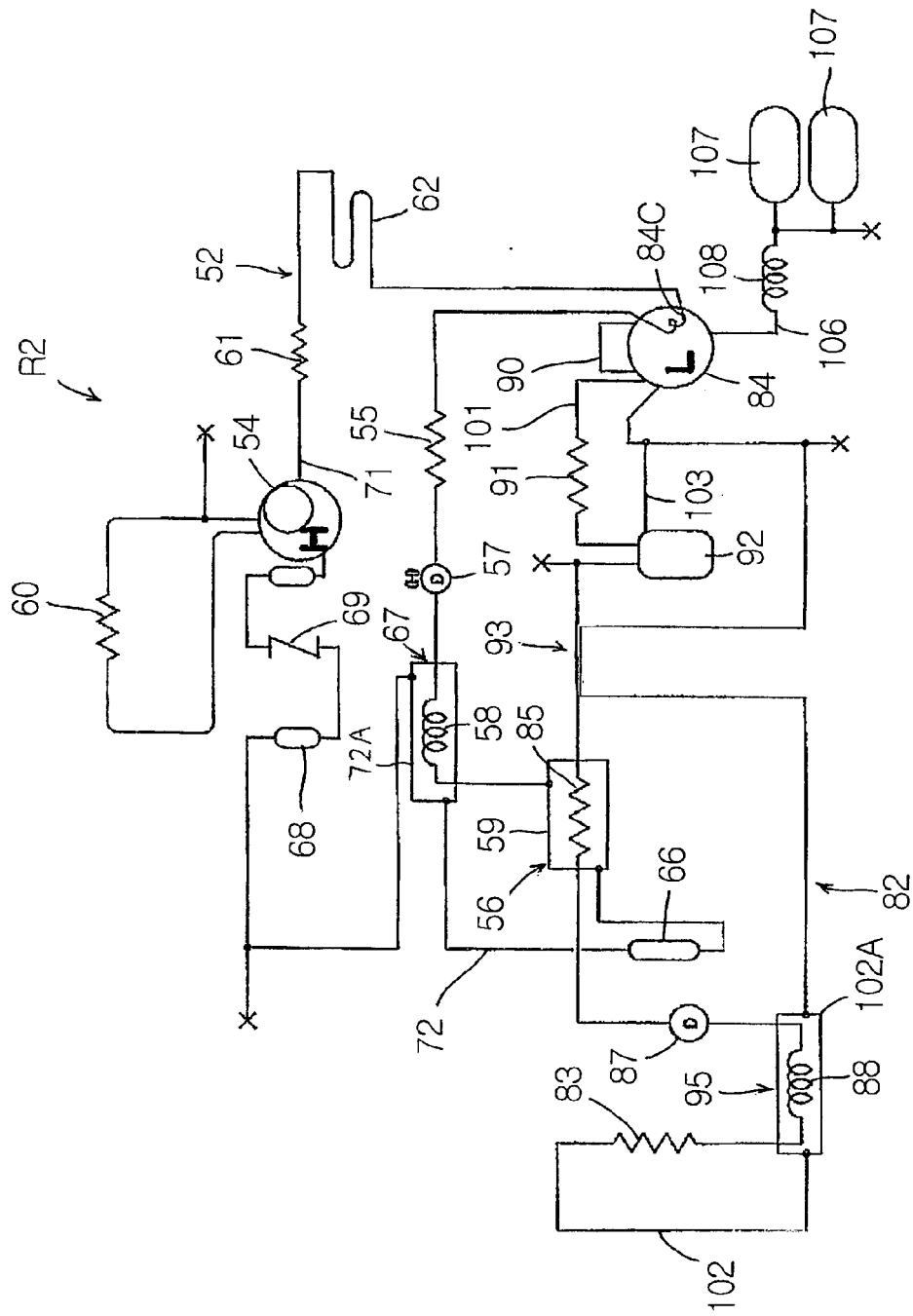


FIG. 7

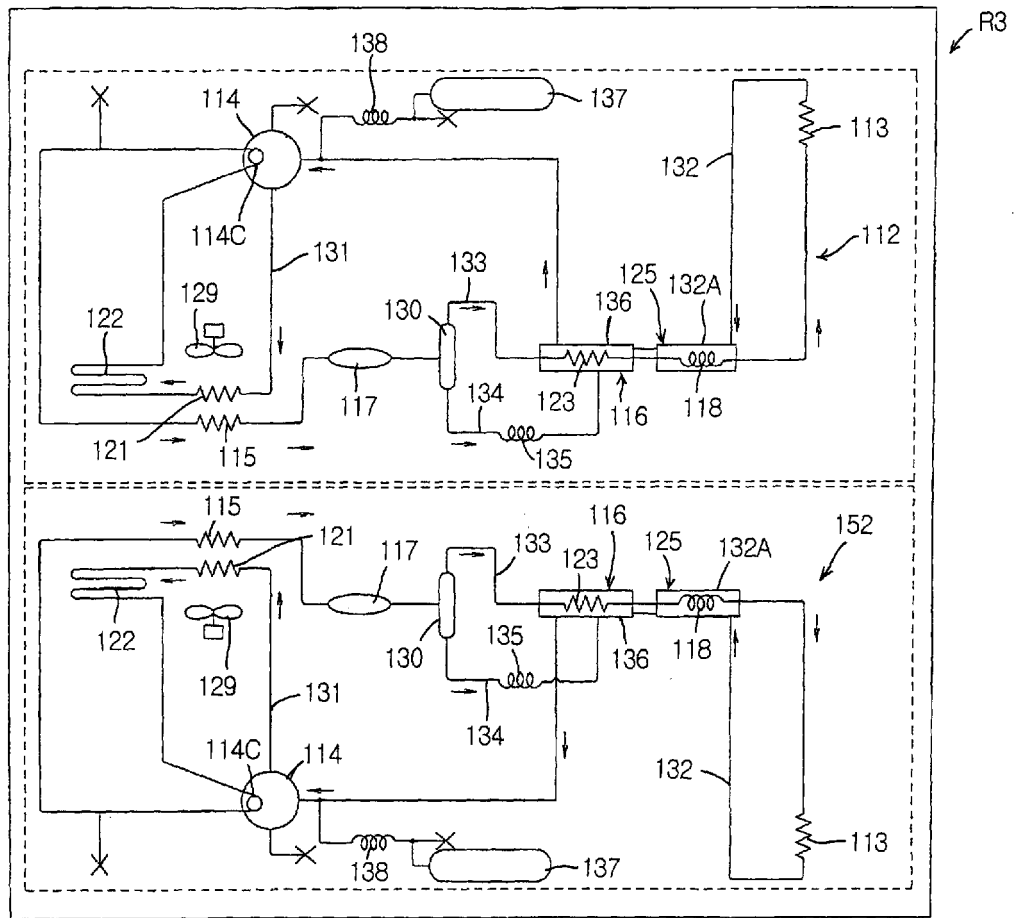
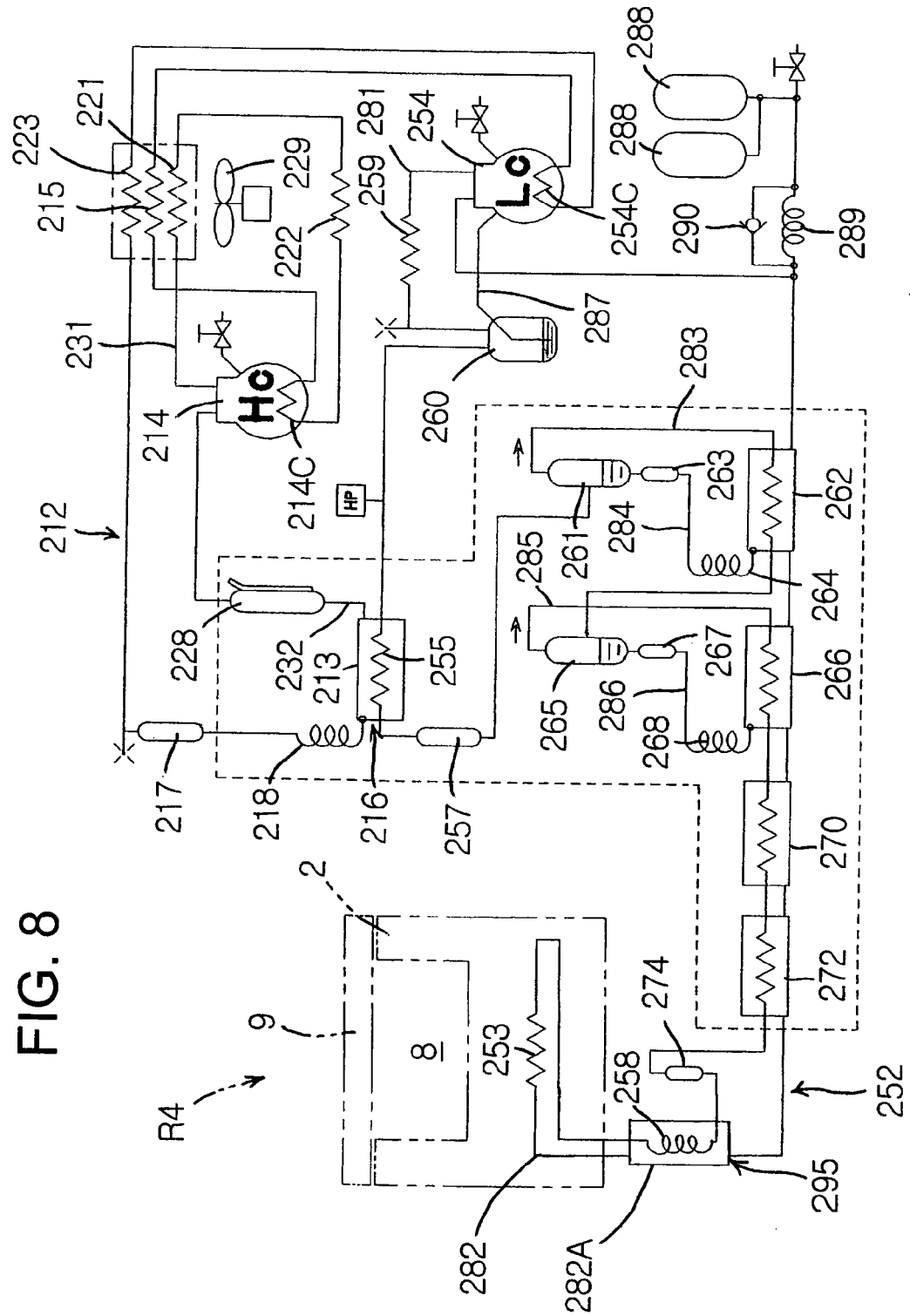


FIG. 8



REFERENCES CITED IN THE DESCRIPTION

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