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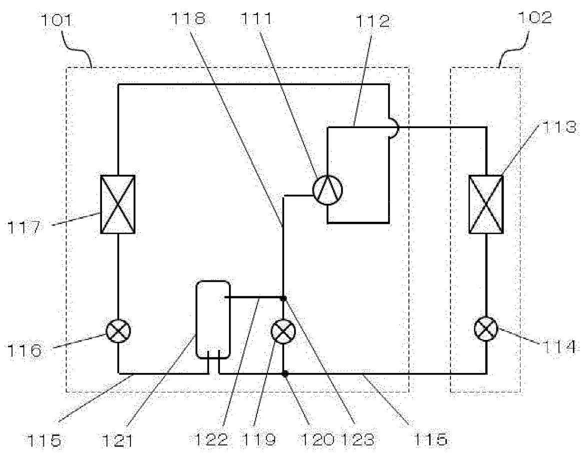
(54) REFRIGERATION CYCLE APPARATUS

(57) When refrigerant in a gas-liquid two-phase state depressurized to an intermediate pressure by a first pressure regulating valve flows from a first branch portion to an injection pipe, the present invention suppresses stagnant flow of liquid phase refrigerant and allows the liquid phase refrigerant to be supplied to a compressor. A first branch portion 120 is located on an upper side in a vertical direction than a joining portion 123. Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion 120 to the injection pipe 118 smoothly reaches the joining portion 123 by gravity without stagnant flow of the liquid phase refrigerant. Thus, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to a compression unit of an injection compressor 111.

FIG.1



101 OUTDOOR AIR CONDITIONING UNIT
102 INDOOR AIR CONDITIONING UNIT
111 INJECTION COMPRESSOR
112 DISCHARGE PIPE
113 INDOOR HEAT EXCHANGER
114 FIRST PRESSURE REGULATING DEVICE
115 INTERMEDIATE PRESSURE REFRIGERANT PIPE
116 SECOND PRESSURE REGULATING DEVICE
117 OUTDOOR HEAT EXCHANGER
118 INJECTION PIPE
119 FLOW CONTROL DEVICE
120 FIRST BRANCH PORTION
121 GAS-LIQUID SEPARATOR
122 GAS BYPASS PIPE
123 JOINING PORTION

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a refrigeration cycle apparatus comprising an indoor unit and a compressor, wherein the compressor includes a mechanism for injecting an intermediate pressure refrigerant in a process of compressing and discharging the refrigerant sucked into the compressor.

Description of the Related Art

[0002] There has conventionally been proposed an injection circuit in a refrigeration cycle apparatus, wherein an intermediate pressure refrigerant piping section includes a gas-liquid separator and an injection pipe, the injection pipe communicates with an injection hole of a compressor, and a gas bypass pipe connects the gas-liquid separator and the injection pipe (see Japanese Patent Laid-Open No. 2011-52883).

[0003] FIG. 7 illustrates a configuration view of the refrigeration cycle apparatus disclosed in Japanese Patent Laid-Open No. 2011-52883. In the configuration of the refrigeration cycle apparatus, an intermediate pressure refrigerant piping section is formed by a throttling device 26a, a throttling device 26b, and a throttling device 27. The configuration includes an injection pipe 29; a flow control device 30 which controls the refrigerant flow rate flowing in the injection pipe 29; a gas-liquid separator 31 disposed in the intermediate pressure refrigerant piping section; a gas bypass pipe 32 which connects the injection pipe 29 and the gas-liquid separator 31; and an open/close valve 33 which controls the refrigerant flow rate flowing in the gas bypass pipe 32, wherein the flow control device 30 and the open/close valve 33 are configured to open during operation of the compressor 23.

[0004] Therefore, this configuration can be expected to have effects such that during heating operation of the indoor unit, gas phase refrigerant flows in the gas bypass pipe 32 through the open/close valve 33 and enters an injection hole of the compressor 23, thereby increasing the operation efficiency of the refrigeration cycle apparatus, and refrigerant in a gas-liquid two-phase state flows in the injection pipe 29 through the flow control device 30 and enters the injection hole of the compressor 23, thereby suppressing an excessive increase in the temperature of the refrigerant discharged from the compressor 23.

[0005] However, in the configuration disclosed in the prior art, the refrigerant flowing in the injection pipe during heating operation of the indoor unit is in a gas-liquid two-phase state, and there is a small pressure difference between a joining portion of the injection pipe with the gas bypass pipe and a branch portion of the injection pipe. Thus, this configuration involves a problem in that low outside air temperature and the resultant increased compression ratio increases the temperature of the refrigerant discharged from the compressor, and thus even if the ratio of the liquid phase refrigerant having the effect of reducing temperature should be increased, only the gas phase refrigerant blows through the injection pipe, leading to a stagnant flow of the liquid phase refrigerant in the injection pipe, preventing the liquid phase refrigerant having the effect of reducing temperature from being supplied to the compressor, resulting in an excessive increase in temperature of the refrigerant discharged from the compressor. As a result, the performance of the refrigeration cycle apparatus is reduced by a reduction in motor efficiency due to an excessive increase in temperature of the motor winding and an increase in friction loss of the sliding portion due to reduced lubrication performance caused by deteriorated refrigerating machine oil.

SUMMARY OF THE INVENTION

[0006] The present invention has been made to solve the above problem, and an object of the present invention is to provide a refrigeration cycle apparatus capable of supplying a sufficient amount of liquid phase refrigerant flowing into a compressor when the temperature of the refrigerant discharged from the compressor is increased during heating operation of an indoor unit.

[0007] In order to solve the above problem, the refrigeration cycle apparatus of the present invention provides a refrigeration cycle apparatus including a compressor, an indoor heat exchanger, a first pressure regulating device, a second pressure regulating device, an outdoor heat exchanger, and an injection pipe, wherein the compressor, the indoor heat exchanger, the first pressure regulating device, the second pressure regulating device, and the outdoor heat exchanger are connected in order; and a first branch portion disposed in an intermediate pressure refrigerant pipe connecting the first pressure regulating device and the second pressure regulating device is connected to a compression unit of a compressor by an injection pipe, the refrigeration cycle apparatus comprising: a gas-liquid separator disposed between the first pressure regulating device and the second pressure regulating device; a gas bypass pipe disposed to connect the gas-liquid separator and the injection pipe and to flow gas refrigerant separated by the gas-liquid separator;

and a flow control device disposed between the first branch portion and a joining portion where the injection pipe joins the gas bypass pipe, wherein the first branch portion is located on an upper side in a vertical direction than the joining portion.

[0008] Therefore, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion to the injection pipe prevents only the gas phase refrigerant from blowing through since the high density liquid phase refrigerant to flow smoothly by gravity, and thus flows smoothly to the joining portion disposed on a lower side in a vertical direction while maintaining the gas-liquid two-phase state.

[0009] Further, the refrigeration cycle apparatus of the present invention comprises a rising pipe between the first branch portion and an outdoor unit connecting portion. A first supercooling heat exchanger for exchanging heat with low pressure refrigerant is provided on the rising pipe portion or between the rising pipe portion and the outdoor unit connecting portion.

[0010] Thus, the refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state flowing into the rising pipe dissipates heat in the first supercooling heat exchanger to become low temperature refrigerant having a dryness degree of 0.2 or less.

[0011] When refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state flows in the rising pipe, the flow mode becomes an annular flow where gas phase refrigerant may blow through and liquid phase refrigerant may not flow smoothly inside the rising pipe, but in the first supercooling heat exchanger, the dryness degree becomes 0.2 or less, and thus the flow mode becomes a churn flow where gas and liquid are mixed and flow in the rising pipe. Therefore, the liquid phase refrigerant is stably supplied to the first branch portion.

[0012] Further, the refrigeration cycle apparatus of the present invention comprises a second supercooling heat exchanger for exchanging heat with low pressure refrigerant, the second supercooling heat exchanger being provided between the first branch portion and a flow control valve.

[0013] Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion to the injection pipe dissipates heat in the second supercooling heat exchanger to become low temperature refrigerant in a supercooled liquid state. When the refrigerant having a dryness degree of 0.1 or less in a gas-liquid two-phase state flows in the flow control device, a state change easily occurs between a saturated liquid state and a gas-liquid two-phase state due to load fluctuation during indoor air conditioning operation. A sudden decrease in the refrigerant flow rate flowing in the flow control device occurs due to volume expansion by the state change from liquid single phase to gas-liquid two phase, but the refrigerant dissipates heat in the second supercooling heat exchanger to be in the supercooled state. Therefore, the flow rate of the liquid phase refrigerant flowing in the flow control device becomes stable without a sudden decrease in the refrigerant flow rate.

[0014] In the refrigeration cycle apparatus of the present invention, when the indoor unit performs a heating operation and the refrigerant in a gas-liquid two-phase state depressurized to an intermediate pressure by the first pressure regulating valve flows from the first branch portion to the injection pipe, the refrigerant reaches the joining portion while maintaining the gas-liquid two-phase state. The refrigerant flows into the compression unit of the compressor together with the gas phase refrigerant flowing from the gas bypass pipe to the injection pipe. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the compressor, thus suppressing an excessive increase in the temperature of the refrigerant discharged from the compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a configuration view of a refrigeration cycle apparatus according to a first embodiment of the present invention;

FIG. 2 is an elevational view, as seen from the horizontal direction, of the injection circuit according to the first embodiment of the present invention;

FIG. 3 is a relational view between height difference and mass flow rate ratio of refrigerant in a gas-liquid two-phase state;

FIG. 4 is a configuration view of a refrigeration cycle apparatus according to a second embodiment of the present invention;

FIG. 5 is an elevational view, as seen from the horizontal direction, of the injection circuit according to the second embodiment of the present invention;

FIG. 6 is a configuration view of a refrigeration cycle apparatus according to a third embodiment of the present invention; and

FIG. 7 is a configuration view of a refrigeration cycle apparatus disclosed in Japanese Patent Laid-Open No. 2011-52883.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] A first aspect of the present invention is a refrigeration cycle apparatus including a compressor, an indoor heat exchanger, a first pressure regulating device, a second pressure regulating device, an outdoor heat exchanger, and an injection pipe, wherein the compressor, the indoor heat exchanger, the first pressure regulating device, the second pressure regulating device, and the outdoor heat exchanger are connected in order; and a first branch portion disposed in an intermediate pressure refrigerant pipe connecting the first pressure regulating device and the second pressure regulating device is connected to a compression unit of a compressor by an injection pipe, the refrigeration cycle apparatus comprising: a gas-liquid separator disposed between the first pressure regulating device and the second pressure regulating device; a gas bypass pipe disposed to connect the gas-liquid separator and the injection pipe and to flow gas refrigerant separated by the gas-liquid separator; and a flow control device disposed between the first branch portion and a joining portion where the injection pipe joins the gas bypass pipe, wherein the first branch portion is located on an upper side in a vertical direction than the joining portion.

[0017] Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion to the injection pipe prevents only the gas phase refrigerant from blowing through since the high density liquid phase refrigerant to flow smoothly by gravity, and thus flows smoothly to the joining portion disposed on a lower side in a vertical direction while maintaining the gas-liquid two-phase state.

[0018] Therefore, in the refrigeration cycle apparatus of the present invention, when the refrigerant in a gas-liquid two-phase state depressurized to an intermediate pressure by the first pressure regulating device flows from the first branch portion to the injection pipe, the refrigerant reaches the joining portion while maintaining the gas-liquid two-phase state. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the compressor, thus suppressing an excessive increase in the temperature of the refrigerant discharged from the compressor.

[0019] In the refrigeration cycle apparatus according to the first aspect of the present invention, a second aspect of the present invention comprises a rising pipe between the first branch portion and the outdoor unit connecting portion, wherein a first supercooling heat exchanger for exchanging heat with low pressure refrigerant is provided on the rising pipe portion or between the rising pipe portion and the outdoor unit connecting portion.

[0020] Thus, the refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state flowing into the rising pipe dissipates heat in the first supercooling heat exchanger to become low temperature refrigerant having a dryness degree of 0.2 or less. When the refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state flows in the rising pipe, the flow mode becomes an annular flow where gas phase refrigerant may blow through and liquid phase refrigerant may not flow smoothly inside the rising pipe, but in the first supercooling heat exchanger, the dryness degree becomes 0.2 or less, and thus the flow mode becomes a churn flow where gas and liquid are mixed and flow in the rising pipe. Therefore, the liquid phase refrigerant is stably supplied to the first branch portion.

[0021] Therefore, when the indoor temperature is high, the supercooling degree cannot be secured by the indoor heat exchanger, and the intermediate pressure refrigerant has a high dryness degree, the liquid phase refrigerant stably flows in the rising pipe portion. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the compressor, thus suppressing an excessive increase in the discharge temperature.

[0022] In the refrigeration cycle apparatus according to the first or second aspect of the present invention, a third aspect of the present invention comprises a second supercooling heat exchanger for exchanging heat with low pressure refrigerant, the second supercooling heat exchanger being provided between the first branch portion and a flow control valve.

[0023] Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion to the injection pipe dissipates heat in the second supercooling heat exchanger to become low temperature refrigerant in a supercooled liquid state. When the refrigerant having a dryness degree of 0.1 or less in a gas-liquid two-phase state flows in the flow control device, a state change easily occurs between a saturated liquid state and a gas-liquid two-phase state due to load fluctuation during indoor air conditioning operation. A sudden decrease in the refrigerant flow rate flowing in the flow control device occurs due to volume expansion by the state change from liquid single phase to gas-liquid two phase, but the refrigerant dissipates heat in the second supercooling heat exchanger to enter the supercooled state. Therefore, the flow rate of the liquid phase refrigerant flowing in the flow control device becomes stable without a sudden decrease in the refrigerant flow rate.

[0024] Thus, when the number of operated indoor units decreases, and the refrigerant depressurized to an intermediate pressure by the first pressure regulating valve flows in a gas-liquid two-phase state with a dryness degree of 0.1 or less from the first branch portion to the injection pipe, the refrigerant enters the supercooled liquid state before passing through the flow control device, thus preventing a sudden decrease in the refrigerant flow rate flowing in the flow control device. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the compressor, thus suppressing an excessive increase in the discharge temperature.

[0025] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. Note that the present invention is not limited to the embodiments.

(First embodiment)

[0026] FIG. 1 is a configuration view of a refrigeration cycle apparatus according to a first embodiment of the present invention.

[0027] In the configuration of the refrigeration cycle apparatus in FIG. 1, one outdoor air conditioning unit is connected to one indoor air conditioning unit. Note that the configuration of the refrigeration cycle apparatus is not limited to the configuration illustrated in FIG. 1. For example, two or more outdoor air conditioning units may be connected in parallel to two or more indoor air conditioning units.

[0028] In an outdoor air conditioning unit 101, an injection compressor 111 is a compressor which compresses refrigerant and the refrigerant compressed by the injection compressor 111 is discharged to a discharge pipe 112. An outdoor heat exchanger 117 is a heat exchanger for exchanging heat between surrounding air and air conditioning refrigerant. A fin-and-tube heat exchanger or a micro-tube heat exchanger is commonly used as the outdoor heat exchanger 117.

[0029] In the outdoor air conditioning unit 101, an injection pipe 118 is a pipe which flows refrigerant when a part of the refrigerant is injected from the refrigeration cycle apparatus to the injection compressor 111. The injection pipe 118 controls the flow rate of refrigerant flowing from a flow control device 119 to the injection pipe 118. An intermediate pressure refrigerant pipe 115 is a pipe which flows intermediate pressure refrigerant. The intermediate pressure refrigerant pipe 115 branches at a first branch portion 120 into the injection pipe 118 and the intermediate pressure refrigerant pipe 115. A gas-liquid separator 121 is a pressure-resistant container which contains liquid refrigerant and gas refrigerant and is connected to the intermediate pressure refrigerant pipe 115. A gas bypass pipe 122 is a pipe which connects the injection pipe 118 and the gas-liquid separator 121 and is connected to the injection pipe 118 at a joining portion 123. In FIG. 1, the first branch portion 120 is disposed between a first pressure regulating device 114 and the gas-liquid separator 121 but may be disposed between a second pressure regulating device 116 and the gas-liquid separator 121.

[0030] In an indoor air conditioning unit 102, an indoor heat exchanger 113 is a heat exchanger for exchanging heat with surrounding air and refrigerant circulating in the refrigeration cycle apparatus. The indoor heat exchanger 113 controls the flow rate of the refrigerant flowing from the first pressure regulating device 114 to the indoor heat exchanger 113. A fin-and-tube heat exchanger or a micro-tube heat exchanger is commonly used as the indoor heat exchanger 113.

[0031] FIG. 2 is an elevational view, as seen from the horizontal direction, of the injection circuit according to the first embodiment of the present invention.

[0032] In FIG. 2, the first branch portion 120 is located on an upper side in a vertical direction than the joining portion 123.

[0033] Now, the description will focus on the operation of the refrigeration cycle apparatus according to the present embodiment.

[0034] In FIG. 1, the refrigerant enters the injection compressor 111 where the refrigerant is compressed to a high pressure and discharged from the injection compressor 111. Then, the refrigerant passes through the discharge pipe 112 and is discharged from the outdoor air conditioning unit 101 to the indoor air conditioning unit 102. In the indoor air conditioning unit 102, the refrigerant enters the indoor heat exchanger 113 where the refrigerant dissipates heat to the surrounding air and condenses into a high pressure supercooled liquid state. Then, the refrigerant enters the first pressure regulating device 114 where the refrigerant expands to an intermediate pressure and enters a gas-liquid two-phase state, and then is discharged from the indoor air conditioning unit 102.

[0035] The refrigerant discharged from the indoor air conditioning unit 102 and returned to the outdoor air conditioning unit 101 branches at the first branch portion 120 where a part of the refrigerant flows into the injection pipe 118 and the remaining refrigerant enters the gas-liquid separator 121. The refrigerant in a gas-liquid two-phase state enters the gas-liquid separator 121 where the refrigerant is separated into a gas phase refrigerant and a liquid phase refrigerant. The gas phase refrigerant flows into the gas bypass pipe 122, while the liquid phase refrigerant is discharged from the gas-liquid separator 121 and enters the second pressure regulating device 116. The second pressure regulating device 116 depressurizes the refrigerant. The depressurized refrigerant enters the outdoor heat exchanger 117 where the refrigerant dissipates heat to the surrounding air and evaporates into a low pressure superheated gas state, and then enters the injection compressor 111.

[0036] When the temperature of the refrigerant discharged from the injection compressor 111 is increased or the like, the flow control device 119 is opened thereby to allow the refrigerant in a gas-liquid two-phase state to flow into the injection pipe 118. More specifically, the refrigerant flowing in the injection pipe 118 passes through the flow control device 119 in the open state and then reaches the joining portion 123 where the refrigerant joins the gas phase refrigerant flowing in the gas bypass pipe 122, and then is supplied to the injection compressor 111.

[0037] Here, the first branch portion 120 is located on an upper side in a vertical direction than the joining portion 123. Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion 120 to the injection pipe 118 flows toward the lower side in the vertical direction up to the joining portion 123.

[0038] As described above, in the present embodiment, the first branch portion 120 is located on an upper side in a vertical direction than the joining portion 123. Thus, the refrigerant in a gas-liquid two-phase state flowing from the first branch portion 120 to the injection pipe 118 allows the liquid phase refrigerant to flow smoothly by gravity and prevents only the gas phase refrigerant from blowing through. As a result, the refrigerant flows smoothly toward the lower side in the vertical direction up to the joining portion 123 while maintaining the gas-liquid two-phase state.

[0039] Therefore, in the refrigeration cycle apparatus of the present invention, when the refrigerant in a gas-liquid two-phase state depressurized to an intermediate pressure by the first pressure regulating device 114 flows from the first branch portion 120 to the injection pipe 118, the refrigerant reaches the joining portion 123 while maintaining the gas-liquid two-phase state, and a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the injection compressor 111, thus suppressing an excessive increase in the discharge temperature.

[0040] Note that assuming that h represents the height difference between the first branch portion 120 and the joining portion 123, the height difference h affects the mixing ratio between the refrigerant in a gas-liquid two-phase state flowing in the first branch portion 120 and the gas phase refrigerant flowing in the gas bypass pipe 122, and the mixing ratio of the refrigerant in a gas-liquid two-phase state affects the discharge temperature reduction effect ΔT of the refrigerant discharged from the injection compressor 111. At this time, the height difference h for obtaining the necessary amount of the discharge temperature reduction effect ΔT of the refrigerant discharged from the injection compressor 111 can be obtained as follows.

[0041] Assuming that ρ' represents the density of the refrigerant in a gas-liquid two-phase state flowing in the first branch portion 120, v' represents the flow velocity of the refrigerant in a gas-liquid two-phase state flowing in the first branch portion 120, ρ" represents the density of the gas phase refrigerant flowing in the gas bypass pipe 122, v" represents the flow velocity of the gas phase refrigerant flowing in the gas bypass pipe 122, ρ represents the density of the refrigerant in a gas-liquid two-phase state flowing from the joining portion 123 to the injection compressor 111, v represents the flow velocity of the refrigerant in a gas-liquid two-phase state flowing from the joining portion 123 to the injection compressor 111, and g represents the gravitational acceleration of the refrigerant in a gas-liquid two-phase state flowing from the joining portion 123 to the injection compressor 111, the potential energy of the refrigerant flowing in the first branch portion 120 with reference to the height of the joining portion 123 can be expressed as p'gh, the kinetic energy of the refrigerant flowing from the first branch portion 120 to the injection pipe 118 can be expressed as 0.5xρ'v'^2, and the kinetic energy of the refrigerant flowing in the gas bypass pipe 122 can be expressed as 0.5xρ"v"^2.

[0042] Considering that the two flows join at the joining portion 123, the static pressure of the refrigerant in a gas-liquid two-phase state flowing in the first branch portion 120 decreases in front of the joining portion 123 by the amount converted into kinetic energy at the joining portion 123, and the static pressure of the gas phase refrigerant flowing in the gas bypass pipe 122 also decreases in front of the joining portion 123 by the amount converted into kinetic energy at the joining portion 123.

[0043] Here, if the decrease width of the static pressure of the refrigerant in a gas-liquid two-phase state is greater than the decrease width of the static pressure of the gas phase refrigerant, the refrigerant in a gas-liquid two-phase state does not flow. Thus, it is necessary to increase the static pressure of the refrigerant in a gas-liquid two-phase state in front of the joining portion 123 by compensating the static pressure with the potential energy of the refrigerant in a gas-liquid two-phase state. In other words, if the following expression (1) is established, the refrigerant in a gas-liquid two-phase state flows in the joining portion 123.

$$\rho' g h \geq 0.5 x \rho' v'^{\wedge}2 - 0.5 x \rho'' v''^{\wedge}2 \ldots \text{ expression (1)}$$

[0044] Here, assuming that m represents the mass flow rate ratio of the refrigerant in a gas-liquid two-phase state at the joining portion 123, it is clear that if the mass flow rate ratio m of the refrigerant in a gas-liquid two-phase state increases, v' increases and v" decreases, and thus the height difference h increases.

[0045] FIG. 3 is a relational view between the height difference and the mass flow rate ratio of the refrigerant in a gas-liquid two-phase state. FIG. 3 is a graph illustrating the relationship between the height difference h and the mass flow rate ratio m of the refrigerant in a gas-liquid two-phase state based on the expression (1). The more the mass flow rate ratio m of the refrigerant in a gas-liquid two-phase state having a cooling effect increases, the more the discharge temperature reduction effect ΔT increases. Thus, it is preferable to calculate the height difference h enough to obtain the necessary discharge temperature reduction effect ΔT from FIG. 3 and to arrange the first branch portion 120 and the joining portion 123 so as to have a height difference equal to or greater than the height difference h.

[0046] At this time, the flow rate of the gas-liquid two-phase refrigerant flowing from the joining portion 123 to the injection compressor 111 largely depends on the volumetric flow rate depending on the structure of the injection mechanism portion, and thus the height difference h is calculated, assuming that the volumetric flow rate is constant.

[0047] Further, assuming that ΔP represents the pressure loss in the pipe from the first branch portion 120 to the gas-liquid separator 121, and considering the pressure loss ΔP, the height difference h may be calculated by the following expression (2).

$$\rho'gh \geq 0.5x\rho'v'^2 - 0.5x\rho''v''^2 + \Delta P\text{... expression (2)}$$

(Second embodiment)

[0048] FIG. 4 is a configuration view of a refrigeration cycle apparatus according to a second embodiment of the present invention.

[0049] In the configuration of the refrigeration cycle apparatus in FIG. 4, a suction bypass pipe 126 is a refrigerant pipe which branches between the first branch portion 120 and an outdoor unit connecting portion 125 and connects to a suction pipe 128. A suction bypass flow control device 127 is a device which controls the flow rate of the refrigerant flowing in the suction bypass pipe 126. A first supercooling heat exchanger 124 is a heat exchanger which can exchange heat with the refrigerant flowing in the injection pipe 118. The first supercooling heat exchanger 124 is structured to allow each of the refrigerant flowing in the suction bypass pipe 126 and the refrigerant flowing in the injection pipe 118 to circulate through each partitioned flow path. A plate heat exchanger or a double tube heat exchanger is commonly used as the first supercooling heat exchanger 124.

[0050] FIG. 5 is an elevational view, as seen from the horizontal direction, of the injection circuit according to the second embodiment of the present invention.

[0051] In FIG. 5, when the outdoor unit connecting portion 125 is located on a lower side in a vertical direction than the joining portion 123, a rising pipe portion 129 is a refrigerant pipe disposed between the outdoor unit connecting portion 125 and the first branch portion 120 so that the first branch portion 120 is located on an upper side in a vertical direction than the joining portion 123. In addition, the first supercooling heat exchanger 124 is provided in the rising pipe portion 129 or between the rising pipe portion 129 and the outdoor unit connecting portion 125.

[0052] Now, the description will focus on the operation of the refrigeration cycle apparatus of the present embodiment with reference to FIGS. 4 and 5.

[0053] The refrigerant enters the injection compressor 111 where the refrigerant is compressed to a high pressure and discharged from the injection compressor 111. Then, the refrigerant passes through the discharge pipe 112 and is discharged from the outdoor air conditioning unit 101 to the indoor air conditioning unit 102. In the indoor air conditioning unit 102, the refrigerant enters the indoor heat exchanger 113 where the refrigerant dissipates heat to the surrounding air and condenses into a high pressure supercooled liquid state. Then, the refrigerant enters the first pressure regulating device 114 where the refrigerant expands to an intermediate pressure and enters a gas-liquid two-phase state, and then is discharged from the indoor air conditioning unit 102.

[0054] A part of the refrigerant discharged from the indoor air conditioning unit 102 and returned to the outdoor air conditioning unit 101 flows into the suction bypass pipe 126, being depressurized by the suction bypass flow control device 127, heat being absorbed by the first supercooling heat exchanger 124 into a superheated gas state, and then joins the refrigerant flowing in the suction pipe 128. The remaining refrigerant returned to the outdoor air conditioning unit 101 flows into the rising pipe portion 129, heat being dissipated by the first supercooling heat exchanger 124, and then discharged from the first supercooling heat exchanger 124. The refrigerant discharged from the first supercooling heat exchanger 124 branches at the first branch portion 120, a part of the refrigerant flows into the injection pipe 118, and the remaining refrigerant enters the gas-liquid separator 121. The refrigerant in a gas-liquid two-phase state enters the gas-liquid separator 121 where the refrigerant is separated into a gas phase refrigerant and a liquid phase refrigerant. The gas phase refrigerant flows into the gas bypass pipe 122, while the liquid phase refrigerant is discharged from the gas-liquid separator 121 and enters the second pressure regulating device 116. The second pressure regulating device 116 depressurizes the refrigerant. The depressurized refrigerant enters the outdoor heat exchanger 117 where heat is removed from the surrounding air, evaporating to a low pressure superheated gas state, and enters the injection compressor 111.

[0055] When the temperature of the refrigerant discharged from the injection compressor 111 is increased or the like, the flow control device 119 is opened thereby to allow the refrigerant in a gas-liquid two-phase state to flow into the injection pipe 118. More specifically, the refrigerant flowing in the injection pipe 118 passes through the flow control device 119 in the open state and then reaches the joining portion 123 where the refrigerant joins the gas phase refrigerant flowing in the gas bypass pipe 122, and then is supplied to the injection compressor 111.

[0056] As described above, the present embodiment comprises the rising pipe portion 129 between the first branch portion 120 and the outdoor unit connecting portion 125; and the first supercooling heat exchanger 124 disposed in the rising pipe portion 129 or between the rising pipe portion 129 and the outdoor unit connecting portion 125, exchanging heat with the refrigerant flowing in the suction bypass pipe 126. Thus, the refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state returned to the outdoor air conditioning unit 101 enters the first supercooling heat exchanger 124 where the heat is dissipated to the refrigerant flowing in the suction bypass pipe 126 and the dryness degree becomes equal to or less than 0.2.

[0057] When the refrigerant having a dryness degree of 0.2 to 0.4 in a gas-liquid two-phase state flows in the rising pipe portion 129, the flow mode becomes an annular flow where the gas phase refrigerant may blow through between the liquid phase refrigerant stuck to the inner wall surface of the pipe and thereby the liquid phase refrigerant may not flow smoothly inside the rising pipe portion 129, but in the present embodiment, in the first supercooling heat exchanger 124, heat is dissipated and the dryness degree becomes 0.2 or less, and thus the flow mode becomes a churn flow where gas and liquid are mixed and flow in the rising pipe portion 129. Therefore, the liquid phase refrigerant is stably supplied to the first branch portion 120.

[0058] Therefore, when the indoor temperature is high, the supercooling degree cannot be secured by the indoor heat exchanger 113, and the intermediate pressure refrigerant has a high dryness degree, the liquid phase refrigerant stably flows in the rising pipe portion 129. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the injection compressor 111, thus suppressing an excessive increase in the discharge temperature.

(Third embodiment)

[0059] FIG. 6 is a configuration view of a refrigeration cycle apparatus according to a third embodiment of the present invention.

[0060] In the configuration of the refrigeration cycle apparatus in FIG. 6, a second supercooling heat exchanger 130 is a heat exchanger for exchanging heat between the refrigerant branched at the first branch portion 120 and the refrigerant flowing in the suction pipe 128. The second supercooling heat exchanger 130 is disposed between the flow control device 119 and the first branch portion 120.

[0061] Now, the description will focus on the operation of the refrigeration cycle apparatus according to the present embodiment.

[0062] In FIG. 6, the refrigerant enters the injection compressor 111 where the refrigerant is compressed to a high pressure and discharged from the injection compressor 111. Then, the refrigerant passes through the discharge pipe 112 and is discharged from the outdoor air conditioning unit 101 to the indoor air conditioning unit 102. In the indoor air conditioning unit 102, the refrigerant enters the indoor heat exchanger 113 where the refrigerant dissipates heat to the surrounding air and condenses into a high pressure supercooled liquid state. Then, the refrigerant enters the first pressure regulating device 114 where the refrigerant expands to an intermediate pressure and enters a gas-liquid two-phase state, and then is discharged from the indoor air conditioning unit 102.

[0063] The refrigerant returned to the outdoor air conditioning unit 101 branches at the first branch portion 120 where a part of the refrigerant flows into the injection pipe 118. Then, the refrigerant enters the second supercooling heat exchanger 130, where heat is dissipated to the refrigerant flowing in the suction pipe 128. Then, the refrigerant passes through the flow control device 119 and reaches the joining portion 123 where the refrigerant joins the refrigerant flowing in the gas bypass pipe 122 and enters the injection compressor 111. Meanwhile, the remaining refrigerant returned to the outdoor air conditioning unit 101 enters the gas-liquid separator 121.

[0064] The refrigerant in a gas-liquid two-phase state enters the gas-liquid separator 121 where the refrigerant is separated into a gas phase refrigerant and a liquid phase refrigerant. The gas phase refrigerant flows into the gas bypass pipe 122, while the liquid phase refrigerant is discharged from the gas-liquid separator 121 and enters the second pressure regulating device 116. The second pressure regulating device 116 depressurizes the refrigerant. The depressurized refrigerant enters the outdoor heat exchanger 117 where the refrigerant dissipates heat to the surrounding air and evaporates into a low pressure superheated gas state, and then enters the injection compressor 111.

[0065] When the temperature of the refrigerant discharged from the injection compressor 111 is increased or the like, the flow control device 119 is opened thereby to allow the refrigerant in a gas-liquid two-phase state to flow into the injection pipe 118. More specifically, the refrigerant flowing in the injection pipe 118 passes through the flow control device 119 in the open state and then reaches the joining portion 123 where the refrigerant joins the gas phase refrigerant flowing in the gas bypass pipe 122, and then is supplied to the injection compressor 111.

[0066] As described above, the present embodiment comprises the second supercooling heat exchanger 130 between the flow control device 119 and the first branch portion 120. Thus, the refrigerant in a gas-liquid two-phase state returned to the outdoor air conditioning unit 101 enters the second supercooling heat exchanger 130 where heat is dissipated to the refrigerant flowing in the suction pipe 128 and enters the supercooled liquid state.

[0067] When the refrigerant having a dryness degree of 0.1 or less close to a saturated liquid state maintaining a gas-liquid two-phase state flows in the flow control device 119, a state change easily occurs between a saturated liquid state and a gas-liquid two-phase state due to load fluctuation during indoor air conditioning operation. A sudden decrease in the refrigerant flow rate flowing in the flow control device 119 occurs due to volume expansion by the state change from liquid single phase to gas-liquid two phase. However, in the present embodiment, after the second supercooling heat exchanger 130 dissipates heat to the refrigerant flowing in the suction pipe 128, the refrigerant enters the supercooled state and then flows in the flow control device 119. Therefore, the flow rate is stable without a sudden decrease in the refrigerant flow rate and the liquid phase refrigerant is stably supplied to the first branch portion 120.

[0068] Therefore, when the refrigerant flowing from the first branch portion 120 to the injection pipe 118 has a small dryness degree and a state change occurs between a saturated liquid state and a gas-liquid two-phase state due to air conditioning load fluctuation of the indoor unit, the liquid phase refrigerant can be stably supplied to the joining portion 123. Therefore, a sufficient amount of liquid phase refrigerant having a high cooling effect is supplied to the compression unit of the compressor, thus suppressing an excessive increase in the discharge temperature.

[0069] As described above, the refrigeration cycle apparatus according to the present invention can suppress stagnant flow of the liquid phase refrigerant and allows the liquid phase refrigerant to be supplied to the injection compressor 111 when the refrigerant in a gas-liquid two-phase state depressurized to an intermediate pressure by the first pressure regulating device 114 flows from the first branch portion 120 to the injection pipe 118. Thus, the refrigeration cycle apparatus of the present invention can suppress a reduction in motor efficiency due to an excessive increase in temperature of gas refrigerant discharged from the compressor causing an increase in the motor winding temperature during air conditioning operation of the indoor unit and thus can be suitably used as a device which can operate with high efficiency.

101 outdoor air conditioning unit
102 indoor air conditioning unit
111 injection compressor
112 discharge pipe
113 indoor heat exchanger
114 first pressure regulating device
115 intermediate pressure refrigerant pipe
116 second pressure regulating device
117 outdoor heat exchanger
118 injection pipe
119 flow control device
120 first branch portion
121 gas-liquid separator
122 gas bypass pipe
123 joining portion
124 first supercooling heat exchanger
125 outdoor unit connecting portion
126 suction bypass pipe
127 suction bypass flow control device
128 suction pipe
129 rising pipe portion
130 second supercooling heat exchanger

Claims

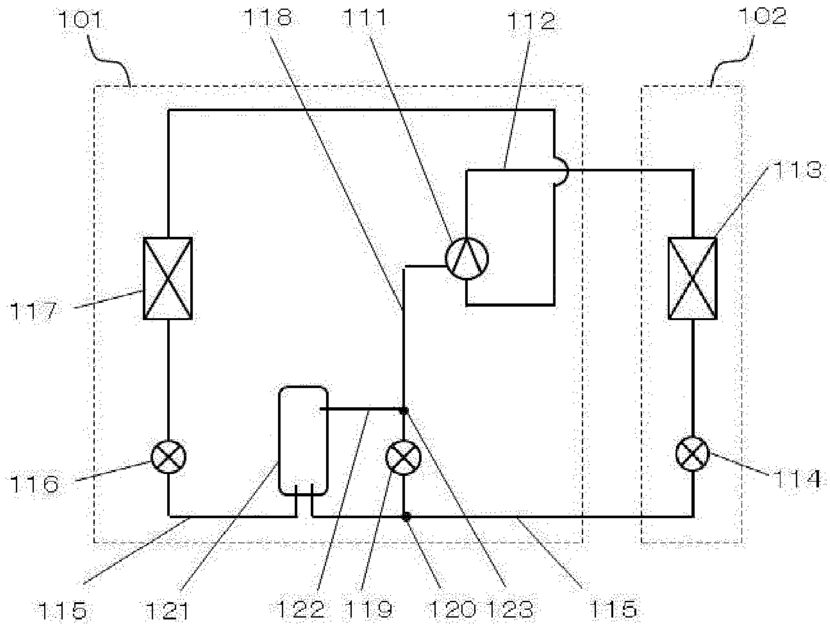
1. A refrigeration cycle apparatus including a compressor (111), an indoor heat exchanger (113), a first pressure regulating device (114), a second pressure regulating device (116), an outdoor heat exchanger (117), and an injection pipe (118), the compressor, the indoor heat exchanger, the first pressure regulating device, the second pressure regulating device, and the outdoor heat exchanger being annularly connected, **characterized in that** the refrigeration cycle apparatus comprises a first branch portion (120) and a gas-liquid separator (121) disposed in an intermediate pressure refrigerant pipe (115) connecting the first pressure regulating device and the second pressure regulating device, wherein the first branch portion and a compression unit of the compressor are connected by the injection pipe, the gas-liquid separator comprises a gas bypass pipe (122) in which gas refrigerant separated by the gas-liquid separator flows, the gas bypass pipe and the injection pipe are connected at a joining portion (123), and the first branch portion is located on an upper side in a vertical direction than the joining portion.

2. The refrigeration cycle apparatus according to claim 1, further comprising: an outdoor unit connecting portion (125) between the first branch portion and the first pressure regulating device; a rising pipe portion (129) between the first branch portion and the outdoor unit connecting portion; and a first supercooling heat exchanger (124) for exchanging heat with low pressure refrigerant, the first supercooling heat exchanger being provided between the rising pipe

portion and the outdoor unit connecting portion.

3. The refrigeration cycle apparatus according to claim 1 or 2, further comprising a flow control device (119) between the joining portion and the first branch portion, and a second supercooling heat exchanger (130) for exchanging heat with low pressure refrigerant, the second supercooling heat exchanger being provided between the first branch portion and the flow control device.

FIG.1



101	OUTDOOR AIR CONDITIONING UNIT	117	OUTDOOR HEAT EXCHANGER
102	INDOOR AIR CONDITIONING UNIT	118	INJECTION PIPE
111	INJECTION COMPRESSOR	119	FLOW CONTROL DEVICE
112	DISCHARGE PIPE	120	FIRST BRANCH PORTION
113	INDOOR HEAT EXCHANGER	121	GAS-LIQUID SEPARATOR
114	FIRST PRESSURE REGULATING DEVICE	122	GAS BYPASS PIPE
115	INTERMEDIATE PRESSURE REFRIGERANT PIPE	123	JOINING PORTION
116	SECOND PRESSURE REGULATING DEVICE		

FIG.2

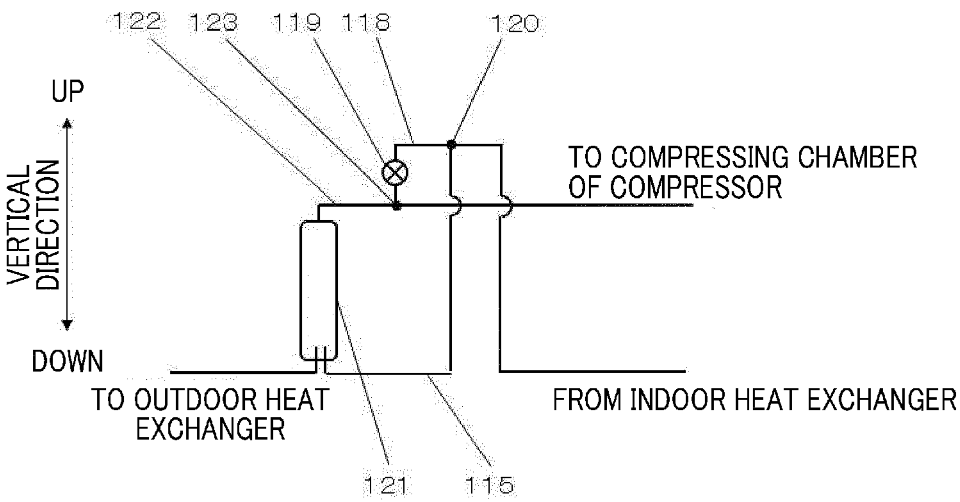

122
123
119
118
120
UP
VERTICAL DIRECTION
DOWN
TO COMPRESSING CHAMBER OF COMPRESSOR
TO OUTDOOR HEAT EXCHANGER
FROM INDOOR HEAT EXCHANGER
121
115

FIG.3

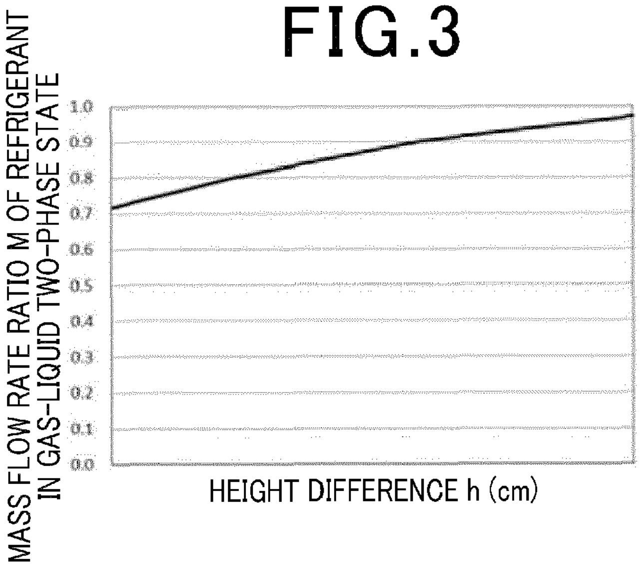
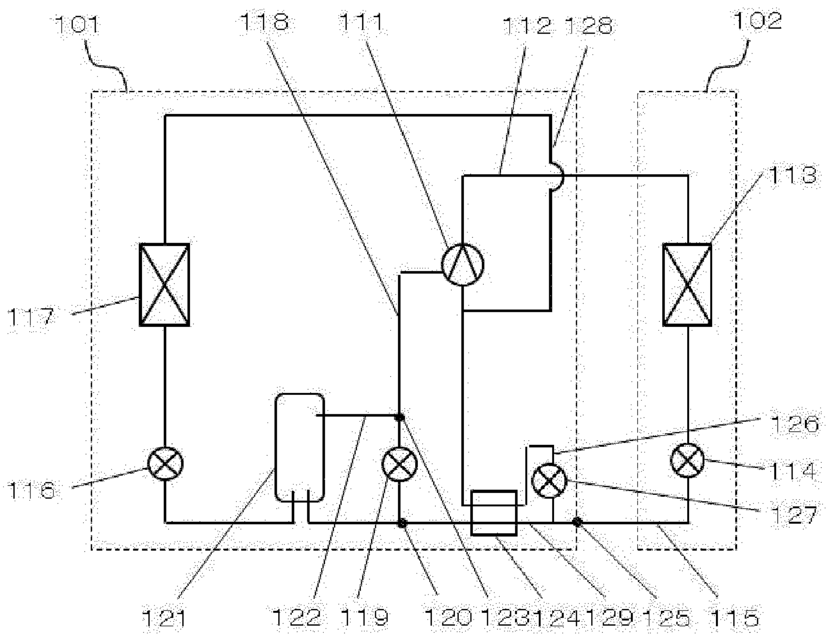

MASS FLOW RATE RATIO M OF REFRIGERANT IN GAS-LIQUID TWO-PHASE STATE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
HEIGHT DIFFERENCE h (cm)

FIG.4



101	OUTDOOR AIR CONDITIONING UNIT	117	OUTDOOR HEAT EXCHANGER
102	INDOOR AIR CONDITIONING UNIT	118	INJECTION PIPE
111	INJECTION COMPRESSOR	119	FLOW CONTROL DEVICE
112	DISCHARGE PIPE	120	FIRST BRANCH PORTION
113	INDOOR HEAT EXCHANGER	121	GAS-LIQUID SEPARATOR
114	FIRST PRESSURE REGULATING DEVICE	122	GAS BYPASS PIPE
115	INTERMEDIATE PRESSURE REFRIGERANT PIPE	123	JOINING PORTION
116	SECOND PRESSURE REGULATING DEVICE	124	FIRST SUPERCOOLING HEAT EXCHANGER
		125	OUTDOOR UNIT CONNECTING PORTION
		126	SUCTION BYPASS PIPE
		127	SUCTION BYPASS FLOW CONTROL DEVICE
		128	SUCTION PIPE
		129	RISING PIPE PORTION

FIG.5

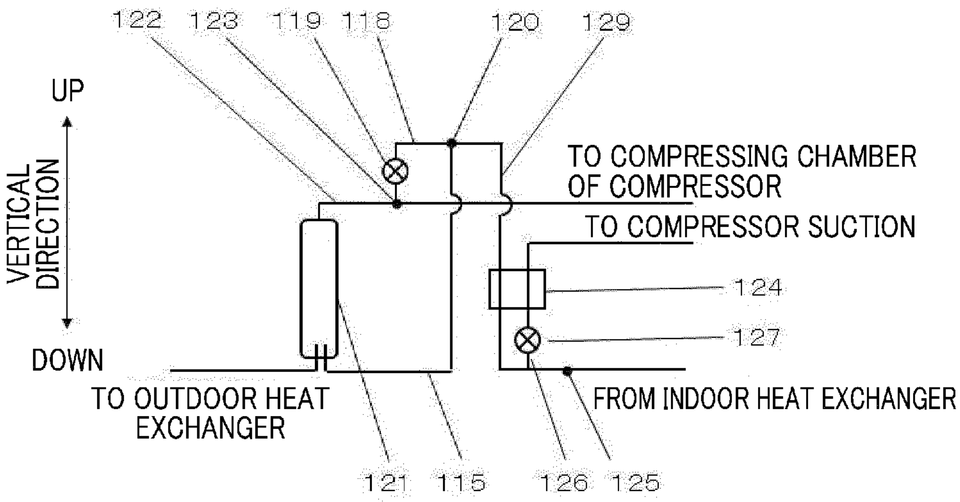
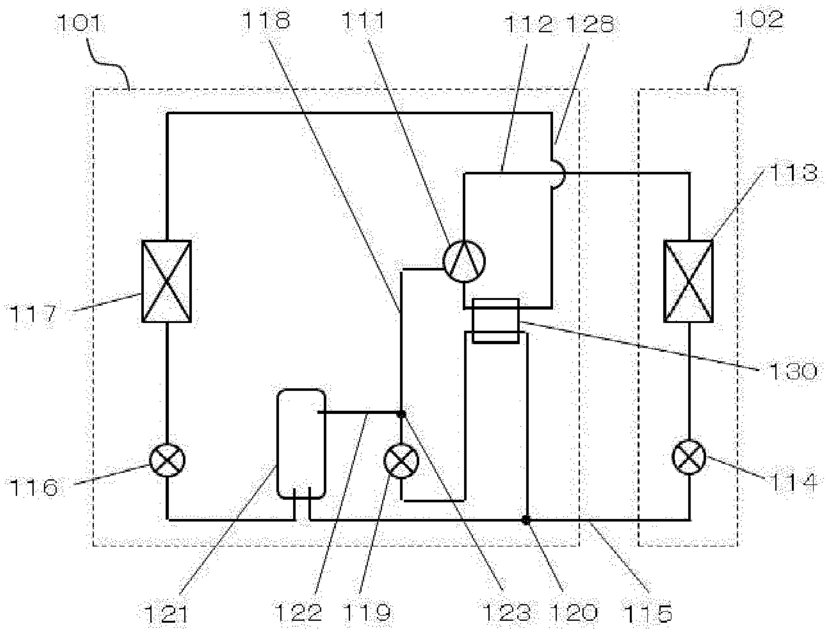
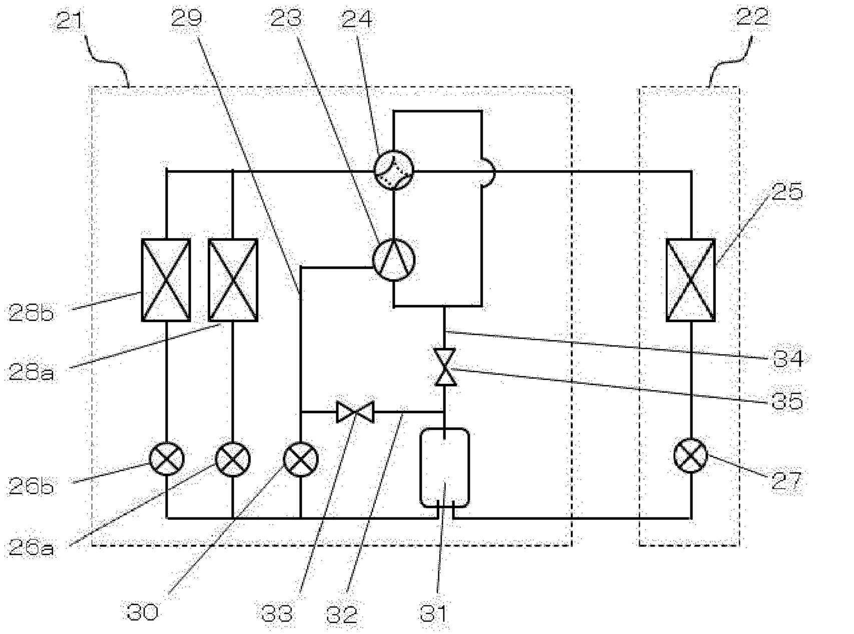

122
123
119
118
120
129
UP
VERTICAL DIRECTION
DOWN
TO COMPRESSING CHAMBER OF COMPRESSOR
TO COMPRESSOR SUCTION
124
127
TO OUTDOOR HEAT EXCHANGER
FROM INDOOR HEAT EXCHANGER
121
115
126
125

FIG.6



101	OUTDOOR AIR CONDITIONING UNIT	117	OUTDOOR HEAT EXCHANGER
102	INDOOR AIR CONDITIONING UNIT	118	INJECTION PIPE
111	INJECTION COMPRESSOR	119	FLOW CONTROL DEVICE
112	DISCHARGE PIPE	120	FIRST BRANCH PORTION
113	INDOOR HEAT EXCHANGER	121	GAS-LIQUID SEPARATOR
114	FIRST PRESSURE REGULATING DEVICE	122	GAS BYPASS PIPE
115	INTERMEDIATE PRESSURE REFRIGERANT PIPE	123	JOINING PORTION
116	SECOND PRESSURE REGULATING DEVICE	128	SUCTION PIPE
		130	SECOND SUPERCOOLING HEAT EXCHANGER

FIG.7



21	OUTDOOR AIR CONDITIONING UNIT	29	INJECTION PIPE
22	INDOOR AIR CONDITIONING UNIT	30	FLOW CONTROL DEVICE
23	COMPRESSOR	31	GAS-LIQUID SEPARATOR
24	FOUR WAY VALVE	32	GAS BYPASS PIPE
25	INDOOR HEAT EXCHANGER	33	OPEN/CLOSE VALVE
26a	THROTTLING DEVICE	34	GAS BYPASS PIPE
26b	THROTTLING DEVICE	35	OPEN/CLOSE VALVE
27	THROTTLING DEVICE		
28a	OUTDOOR HEAT EXCHANGER		
28b	OUTDOOR HEAT EXCHANGER		

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 9439

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2

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 March 2019	Ritter, Christoph

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