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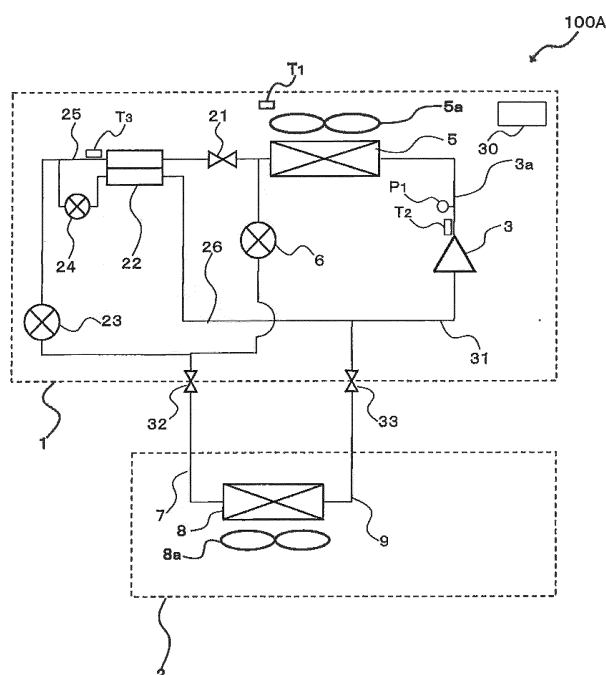
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(54) **REFRIGERATION CYCLE DEVICE**

(57) When temperature is a high outside-air temperature, which is equal to or higher than a normal outside-air temperature, a refrigeration cycle apparatus (100A) causes refrigerant to flow through a branch circuit and

an injection circuit to use a subcooling heat exchanger (22), and injects refrigerant having flowed through a secondary side of the subcooling heat exchanger (22) into a compressor (3).

FIG. 1



Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus, and more particularly, to a refrigeration cycle apparatus configured to suppress an increase in temperature of refrigerant discharged from a compressor while suppressing an increase in an amount of filled refrigerant.

Background Art

[0002] Hitherto, there has been a refrigeration cycle apparatus configured to execute a refrigeration cycle through use of an "HFC refrigerant", e.g., R410A that is non-combustible. R410A has a property in which a global warming potential (hereinafter referred to as "GWP") is high while an ozone depletion potential (hereinafter referred to as "ODP") is zero and does not deplete the ozone layer unlike an "HCFC refrigerant", e.g., R22 that has been used up to now. Therefore, as one effort to prevent global warming, it is currently being considered to change the refrigerant that is used from an HFC refrigerant having a high GWP, e.g., R410A, to a refrigerant having a low GWP (hereinafter referred to as "low-GWP refrigerant").

[0003] As a candidate for the low-GWP refrigerant, there has been an HFC refrigerant that does not have a carbon-carbon double bond in its composition, e.g., R32 (CH_2F_2 ; difluoromethane) having a GWP lower than that of R410A. Further, as a similar candidate refrigerant, there has been a halogenated hydrocarbon, which is one type of HFC refrigerant similar to R32 and has a carbon-carbon double bond in its composition. As such halogenated hydrocarbons, there have been known, for example, HFO-1234yf ($\text{CF}_3\text{CF}=\text{CH}_2$; tetrafluoropropene) and HFO-1234ze ($\text{CF}_3\text{-CH}=\text{CHF}$). In order to distinguish those refrigerants from an HFC refrigerant that does not have a carbon-carbon double bond in its composition like R32, the HFC refrigerant having a carbon-carbon double bond in its composition is expressed as an "HFO refrigerant" in many cases through use of "O" standing for olefin (unsaturated hydrocarbon having a carbon-carbon double bond is called "olefin").

[0004] While such low-GWP refrigerants (HFC refrigerant and HFO refrigerant) are not as highly combustible as HC refrigerants, e.g., R290 (C_3H_8 ; propane) that is a natural refrigerant, those refrigerants are slightly combustible unlike R410A that is non-combustible. In the following, refrigerant that is even slightly combustible is referred to as "combustible refrigerant".

[0005] When the combustible refrigerant is used in a refrigeration cycle apparatus, it is desired to suppress an increase in an amount of filled refrigerant in consideration of safety. At the same time, it is also necessary to take efficiency of the refrigeration cycle apparatus into consideration.

[0006] As the refrigeration cycle apparatus using the combustible refrigerant, there is proposed a refrigeration apparatus using an R32 refrigerant or a mixed refrigerant whose proportion of R32 is 70% or more, which is configured to calculate a target discharge temperature based on a condensing temperature, an evaporating temperature, and an opening degree of a subcooling expansion valve, and control an opening degree of a main expansion valve such that the target discharge temperature is reached (see, for example, Patent Literature 1).

[0007] Further, there is proposed a refrigeration circuit using a refrigerant whose property may change depending on temperature within a compressor, in which a part of refrigerant discharged from an outlet of a condenser branches and the part of refrigerant is supplied to the inside of the compressor (see, for example, Patent Literature 2).

Citation List

Patent Literature

[0008]

Patent Literature 1: Japanese Patent No. 3440910
Patent Literature 2: Japanese Unexamined Patent Application Publication No. 2010-19457

Summary of Invention

Technical Problem

[0009] However, with the technology disclosed in Patent Literature 1, while the increase in the temperature of refrigerant discharged from the compressor can be suppressed, the subcooling heat exchanger is used irrespective of an operation condition. Thus, the amount of filled refrigerant disadvantageously increases due to an increase in a capacity of a heat exchanger installed at the outlet of the condenser and a decrease in a quality at an inlet of the evaporator. Therefore, when the refrigerant leaks, the leakage of refrigerant not only causes a safety problem, but also disadvantageously contributes to the global warming.

[0010] Further, with the technology disclosed in Patent Literature 2, in a cooling operation under a state in which an outside-air temperature and a load are high, the increase in the refrigerant discharge temperature of the compressor can be suppressed, but the quality at the inlet of the evaporator cannot be reduced. As a result, the refrigerant cannot be held in the evaporator, and a condensing pressure increases. Thus, the property of the refrigerant may change due to the increase in the condensing pressure. When the property of the refrigerant changes, proper performance of the refrigerant can no longer be exerted.

[0011] The present invention has been made in order to overcome the above-mentioned problems, and it is an

object of the present invention to provide a refrigeration cycle apparatus capable of suppressing an increase in refrigerant discharge temperature of a compressor while suppressing an increase in an amount of filled refrigerant.

Solution to Problem

[0012] According to one embodiment of the present invention, there is provided a refrigeration cycle apparatus, including: a main refrigerant circuit formed by connecting a compressor, a first heat exchanger, a first expansion valve, and a second heat exchanger; a branch circuit formed by connecting the first heat exchanger, a primary side of a subcooling heat exchanger installed on a downstream side of refrigerant flow in a case where the first heat exchanger serves as a condenser, a second expansion valve, and the second heat exchanger; and an injection circuit formed by connecting, with an injection pipe branching from a downstream side of the primary side of the subcooling heat exchanger, a third expansion valve, a secondary side of the subcooling heat exchanger, and the compressor, the refrigeration cycle apparatus being operable in a normal operation mode of causing the refrigerant to flow through the main refrigerant circuit; and a high-outside-air-temperature operation mode of causing the refrigerant to flow through the branch circuit and the injection circuit to use the subcooling heat exchanger, and of injecting the refrigerant having flowed through the secondary side of the subcooling heat exchanger into the compressor, the refrigeration cycle apparatus being configured to perform the high-outside-air-temperature operation mode when an outside-air temperature is equal to or higher than a predetermined temperature.

Advantageous Effects of Invention

[0013] With the refrigeration cycle apparatus according to the present invention, the increase in the amount of filled refrigerant can be suppressed by suppressing a decrease in a quality at the inlet of the second heat exchanger serving as the evaporator in a predetermined normal operation. Further, the discharge temperature and the increase in the condensing pressure can be suppressed by injecting the refrigerant into the compressor during the high-outside-air-temperature cooling operation.

Brief Description of Drawings

[0014]

[Fig. 1] Fig. 1 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is an explanatory table for showing

patterns of control on actuators corresponding to operation modes executed by the refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus according to Embodiment 2 of the present invention.

[Fig. 4] Fig. 4 is an explanatory table for showing patterns of control on actuators corresponding to operation modes executed by the refrigeration cycle apparatus according to Embodiment 2 of the present invention.

[Fig. 5] Fig. 5 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus according to Embodiment 3 of the present invention.

[Fig. 6] Fig. 6 is an explanatory table for showing patterns of control on actuators corresponding to operation modes executed by the refrigeration cycle apparatus according to Embodiment 3 of the present invention.

Description of Embodiments

[0015] Now, embodiments of the present invention are described with reference to the drawings. In the following drawings, including Fig. 1, the relationships between the sizes of components may be different from the actual relationships. Further, in the following drawings, including Fig. 1, components denoted by the same reference symbols correspond to the same or equivalent components. This is common throughout the description herein. In addition, the forms of the components described herein are merely examples, and the components are not limited to the description herein.

Embodiment 1

[0016] Fig. 1 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus (hereinafter referred to as "refrigeration cycle apparatus 100A") according to Embodiment 1 of the present invention. Referring to Fig. 1, the refrigeration cycle apparatus 100A is described.

[0017] The refrigeration cycle apparatus 100A is assumed to use a combustible refrigerant as a main component, and includes an outdoor unit 1 and an indoor unit 2. The outdoor unit 1 and the indoor unit 2 are connected to each other with a liquid pipe 7 and a gas pipe 9. The number of the connected outdoor units 1 and the number of the connected indoor units 2 are not limited to one, and any one or both of the numbers may be two or more.

[0018] The outdoor unit (heat source apparatus) 1 includes a compressor 3 configured to compress refrigerant

ant, an outdoor heat exchanger (first heat exchanger) 5 configured to exchange heat between the refrigerant and ambient air of the outdoor unit 1 sent by an outdoor blower device 5a, a first electronic expansion valve (first expansion valve) 6 configured to control a flow rate of the refrigerant, an opening-closing valve 21 configured to control a flow of the refrigerant, a subcooling heat exchanger 22 configured to exchange heat between refrigerant and refrigerant, a second electronic expansion valve (second expansion valve) 23 configured to control a flow rate of the refrigerant, and a third electronic expansion valve (third expansion valve) 24 configured to control a flow rate of the refrigerant. The outdoor heat exchanger 5 includes the outdoor blower device 5a configured to supply air and an outside-air temperature sensor T_1 configured to detect an outside-air temperature. On a discharge side of the compressor 3, there are arranged a discharge temperature sensor T_2 configured to detect a temperature of the refrigerant discharged from the compressor 3 and a discharge pressure sensor P_1 configured to detect a pressure of the refrigerant discharged from the compressor 3. At one end of the subcooling heat exchanger 22, there is arranged a refrigerant temperature sensor T_3 configured to detect a temperature of the refrigerant that has passed through the subcooling heat exchanger 22.

[0019] The indoor unit (use-side device) 2 includes an indoor heat exchanger (second heat exchanger) 8 configured to exchange heat between the refrigerant and ambient air of the indoor unit 2 conveyed by an indoor blower device 8a to, for example, cool or heat an indoor space, to thereby implement cooling or heating. The indoor heat exchanger 8 includes the indoor blower device 8a configured to supply air.

[0020] As the compressor 3 configured to compress the refrigerant, it is preferred to use a positive-displacement compressor, which is a type of compressor having a rotation speed and an operation capacity controlled by an inverter circuit. Examples of the positive-displacement compressor include a rotary compressor, a scroll compressor, a screw compressor, and a reciprocating compressor. A discharge pipe 3a is connected to the compressor 3.

[0021] The outdoor heat exchanger 5 serves as a condenser or an evaporator. The outdoor heat exchanger 5 can be constructed with, for example, a cross fin-type fin-and-tube heat exchanger including heat transmission tubes and a large number of fins.

[0022] The outdoor blower device 5a is configured to supply the air to the outdoor heat exchanger 5. The outdoor blower device 5a is constructed with a device capable of changing a flow rate of the air. For example, as the outdoor blower device 5a, a centrifugal fan or a multiblade fan to be driven by a motor, e.g., a DC fan motor, can be used.

[0023] The first electronic expansion valve 6 is configured to have an opening degree controlled by a controller 30 described later, and is configured to, for example, control the flow rate of the refrigerant while reducing the pres-

sure of the refrigerant.

[0024] The indoor heat exchanger 8 functions as an evaporator or a condenser. The indoor heat exchanger 8 can be constructed with, for example, a cross fin-type fin-and-tube heat exchanger including heat transmission tubes and a large number of fins.

[0025] The indoor blower device 8a is configured to supply the air to the indoor heat exchanger 8. The indoor blower device 8a is constructed with a device capable of changing a flow rate of the air. For example, as the indoor blower device 8a, a centrifugal fan or a multiblade fan to be driven by a motor, e.g., a DC fan motor, can be used.

[0026] The compressor 3, the outdoor heat exchanger 5, the first electronic expansion valve 6, and the indoor heat exchanger 8 form a main refrigerant circuit by being connected to one another with a main refrigerant pipe 31 including the discharge pipe 3a, the liquid pipe 7, and the gas pipe 9.

[0027] The outdoor unit 1 further includes a branch pipe 25, which branches from a portion of the main refrigerant pipe 31 between the outdoor heat exchanger 5 and the first electronic expansion valve 6 and is connected to a portion between the first electronic expansion valve 6 and the indoor heat exchanger 8. The outdoor heat exchanger 5, a primary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the branch pipe 25), the second electronic expansion valve 23, and the indoor heat exchanger 8 form a branch circuit by being connected to one another with the branch pipe 25 and the main refrigerant pipe 31.

[0028] The outdoor unit 1 further includes an injection pipe 26, which branches from a portion of the branch pipe 25 between the subcooling heat exchanger 22 and the second electronic expansion valve 23 and is connected to a suction side of the compressor 3. The third electronic expansion valve 24, a secondary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the injection pipe 26), and the suction side of the compressor 3 form an injection circuit by being connected to one another with the injection pipe 26.

[0029] The opening-closing valve 21 is arranged on the branch pipe 25 between the outdoor heat exchanger 5 and the subcooling heat exchanger 22, and is configured to open and close the branch pipe 25. Opening and closing of the opening-closing valve 21 is controlled by the controller 30 described later.

[0030] The subcooling heat exchanger 22 is configured to exchange heat between the refrigerant flowing through the branch pipe 25 and the refrigerant flowing through the injection pipe 26. It is preferred that the subcooling heat exchanger 22 be constructed with, for example, a microchannel heat exchanger, a shell and tube heat exchanger, a heat pipe heat exchanger, a double pipe heat exchanger, or a plate heat exchanger.

[0031] The second electronic expansion valve 23 is arranged on the branch pipe 25 on a downstream side of the subcooling heat exchanger 22. The second electronic expansion valve 23 has an opening degree con-

trolled by the controller 30 described later, and is capable of, for example, controlling the flow rate of the refrigerant while reducing the pressure of the refrigerant flowing through the branch pipe 25.

[0032] The third electronic expansion valve 24 is arranged on the injection pipe 26 on an upstream side of the subcooling heat exchanger 22. The third electronic expansion valve 24 has an opening degree controlled by the controller 30 described later, and is capable of, for example, controlling the flow rate of the refrigerant while reducing the pressure of the refrigerant flowing through the injection pipe 26.

[0033] The refrigeration cycle apparatus 100A includes the controller 30 configured to generally control the refrigeration cycle apparatus 100A. The controller 30 is configured to perform operation modes by controlling actuators (parts to be driven, including the compressor 3, the outdoor blower device 5a, the first electronic expansion valve 6, the opening-closing valve 21, the second electronic expansion valve 23, the third electronic expansion valve 24, and the indoor blower device 8a) based on detection values obtained by detectors including the outside-air temperature sensor T_1 , the discharge pressure sensor P_1 , the discharge temperature sensor T_2 , and the refrigerant temperature sensor T_3 . The controller 30 can be constructed with hardware, e.g., a circuit device, for implementing its functions, or can be constructed with an arithmetic device, e.g., a microcontroller or a CPU, and software to be executed on the arithmetic device.

[0034] Parts of the liquid pipe 7 connecting the outdoor unit 1 and the indoor unit 2 to each other are connected to each other via a liquid-side stop valve 32.

[0035] Similarly, parts of the gas pipe 9 connecting the outdoor unit 1 and the indoor unit 2 to each other are connected to each other via a gas-side stop valve 33.

[0036] In other words, the outdoor unit 1 and the indoor unit 2 can be separated from each other via the liquid-side stop valve 32 and the gas-side stop valve 33.

[0037] Fig. 2 is an explanatory table for showing patterns of control by the controller 30 on actuators (in this case, the opening-closing valve 21, the first electronic expansion valve 6, the second electronic expansion valve 23, and the third electronic expansion valve 24) corresponding to operation modes executed by the refrigeration cycle apparatus 100A. Referring to Fig. 1 and Fig. 2, the operation of the refrigeration cycle apparatus 100A is described.

[0038] The refrigeration cycle apparatus 100A is configured to determine whether or not to use the subcooling heat exchanger 22 depending on the outside-air temperature detected by the outside-air temperature sensor T_1 . In the following description, an operation mode at the time when the subcooling heat exchanger 22 is not used at a normal outside-air temperature is referred to as "normal operation mode", and an operation mode at the time when the subcooling heat exchanger 22 is used at a high outside-air temperature is referred to as "high-outside-

air-temperature operation mode".

[0039] While a strict temperature range of the "normal outside-air temperature" cannot be defined, it is assumed that, when the outside-air temperature detected by the outside-air temperature sensor T_1 is at the "normal outside-air temperature", such temperature falls within a range of temperatures in which the refrigeration cycle apparatus 100A is used normally in a region in which the refrigeration cycle apparatus 100A is used. The range of the "normal outside-air temperature" is determined in advance.

[0040] While a strict temperature range of the "high outside-air temperature" cannot be defined, it is assumed that, when the outside-air temperature detected by the outside-air temperature sensor T_1 is at the "high outside-air temperature", such temperature is equal to or higher than an upper limit of the normal outside-air temperature of the refrigeration cycle apparatus 100A defined in advance (e.g., equal to or higher than 40 degrees C). The range of the "high outside-air temperature" is determined in advance.

<Normal Operation Mode>

[0041] In the normal operation mode, as shown in Fig. 2, under the control of the controller 30, the opening-closing valve 21 is controlled to be closed, the second electronic expansion valve 23 is controlled to be fully opened, and the third electronic expansion valve 24 is controlled to be fully closed. Further, based on the detection result obtained by the discharge temperature sensor T_2 , the first electronic expansion valve 6 controls the refrigerant discharge temperature of the compressor 3. In other words, at the normal outside-air temperature, the refrigeration cycle apparatus 100A bypasses the refrigerant through the subcooling heat exchanger 22 in order to suppress a decrease in a quality at an inlet of the indoor heat exchanger 8 functioning as the evaporator and suppress an increase in an amount of refrigerant required for the indoor heat exchanger 8.

[0042] A high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 serving as the condenser, and transfers its heat to outdoor air conveyed by the outdoor blower device 5a. This refrigerant has its pressure reduced by the first electronic expansion valve 6 to turn into a low-pressure two-phase refrigerant, and the low-pressure two-phase refrigerant then cools indoor air in the indoor heat exchanger 8 serving as the evaporator to turn into a low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

<High-outside-air-temperature Operation Mode>

[0043] In the high-outside-air-temperature operation mode, as shown in Fig. 2, under the control of the controller 30, the opening-closing valve 21 is controlled to

be opened, and the first electronic expansion valve 6 is controlled to be fully closed. Further, based on the detection result obtained by the discharge temperature sensor T_2 , the second electronic expansion valve 23 controls the temperature of the refrigerant discharged from the compressor 3, and the third electronic expansion valve 24 controls a degree of subcooling (SC) of the refrigerant at an outlet of the subcooling heat exchanger 22. In other words, at the high outside-air temperature, the refrigeration cycle apparatus 100A causes the refrigerant to flow into the branch circuit, uses the subcooling heat exchanger 22 to keep the quality at the inlet of the indoor heat exchanger 8 serving as the evaporator at a low level, and causes the indoor heat exchanger 8 to hold a large amount of refrigerant, to thereby suppress an increase in the high pressure of the refrigerant discharged from the compressor 3.

[0044] Further, at the high outside-air temperature, the refrigeration cycle apparatus 100A injects the refrigerant that has passed through the subcooling heat exchanger 22 into the suction side of the compressor 3, to thereby suppress the increase in the refrigerant discharge temperature from the compressor 3.

[0045] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 serving as the condenser, and transfers its heat to the outdoor air conveyed by the outdoor blower device 5a. This refrigerant flows into the subcooling heat exchanger 22 via the opening-closing valve 21. This refrigerant is cooled by a low-pressure refrigerant in the subcooling heat exchanger 22, and then has its pressure reduced by the second electronic expansion valve 23 to turn into the low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant cools the indoor air in the indoor heat exchanger 8 functioning as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0046] On the other hand, the refrigerant of the injection circuit having flowed into the injection pipe 26 has its pressure reduced by the third electronic expansion valve 24, and is then heated by a high-pressure refrigerant in the subcooling heat exchanger 22. This refrigerant is injected into the suction side of the compressor 3, and merges with the refrigerant having flowed through the gas pipe 9. After that, the refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0047] The degree of subcooling (SC) of the refrigerant at the outlet of the subcooling heat exchanger 22 can be calculated based on a difference between a high-pressure-side saturation temperature of the refrigerant and the temperature of the refrigerant that has passed through the subcooling heat exchanger 22. The high-pressure-side saturation temperature of the refrigerant is obtained based on the pressure of the refrigerant discharged from the compressor 3, which is detected by the discharge pressure sensor P_1 . The temperature of the

refrigerant that has passed through the subcooling heat exchanger 22 is detected by the refrigerant temperature sensor T_3 .

5 <Switching of Operation Mode>

[0048] An amount of refrigerant to be filled into a refrigerant circuit is defined at the normal outside-air temperature. Therefore, the refrigeration cycle apparatus 100A executes the normal operation mode to bypass the refrigerant through the subcooling heat exchanger 22 and to keep the quality of the refrigerant at a high level at the inlet of the indoor heat exchanger 8 functioning as the evaporator, to thereby suppress the increase in the amount of filled refrigerant. Meanwhile, however, because the increase in the amount of filled refrigerant is suppressed, at the high outside-air temperature, the high pressure may disadvantageously increase.

[0049] In view of this, at the high outside-air temperature, the refrigeration cycle apparatus 100A executes the high-outside-air-temperature operation mode to keep the quality of the refrigerant at a low level at the inlet of the indoor heat exchanger 8 serving as the evaporator, through use of the subcooling heat exchanger 22 and to cause the indoor heat exchanger 8 to hold a large amount of refrigerant, to thereby enable suppression of the increase in the high pressure. In addition, the refrigeration cycle apparatus 100A executes the high-outside-air-temperature operation mode to inject the refrigerant that has passed through the subcooling heat exchanger 22 into the suction side of the compressor 3, to thereby enable suppression of the increase in the discharge temperature of the refrigerant discharged from the compressor 3.

[0050] As described above, the refrigeration cycle apparatus 100A is configured to determine whether or not to use the subcooling heat exchanger 22 depending on whether the outside-air temperature is the high outside-air temperature. Therefore, with the refrigeration cycle apparatus 100A, the amount of refrigerant to be filled into the refrigerant circuit is determined based on the normal operation mode, to thereby suppress the increase in the amount of filled refrigerant. Further, with the refrigeration cycle apparatus 100A, the subcooling heat exchanger 22 is used as the need arises, and hence when the subcooling heat exchanger 22 is not used, the amount of filled refrigerant can be reduced without causing a decrease in a pressure on the high-pressure side of the subcooling heat exchanger 22. In other words, the refrigeration cycle apparatus 100A is assumed to use the combustible refrigerant as the main component, and hence safety can be taken into consideration even if the refrigerant leaks by suppressing the increase in the amount of filled refrigerant, and the influence on global warming can be reduced.

[0051] Still further, at the high outside-air temperature at which the high pressure may increase, the refrigeration cycle apparatus 100A executes the high-outside-air-temperature operation mode to achieve, through use of the

subcooling heat exchanger 22 and the injection pipe 26, suppression of the increase in the discharge temperature and suppression of the increase in the condensing pressure due to the decrease in the quality of the refrigerant at the inlet of the indoor heat exchanger 8 serving as the evaporator. Therefore, the refrigeration cycle apparatus 100A can continue a highly efficient operation even at the high outside-air temperature.

[0052] Next, the refrigerant to be used in the refrigeration cycle apparatus 100A is described.

[0053] The refrigeration cycle apparatus 100A is assumed to use the refrigerant that is the combustible refrigerant as the main component, but the refrigerant to be used in the refrigeration cycle apparatus 100A is not limited thereto. As the combustible refrigerant, there are known, for example, R32, HFO-1234yf, HFO-1234ze, R290 (C₃H₈; propane), and R1270 (C₃H₆; propylene).

[0054] "Using the combustible refrigerant as the main component" means that a contained amount of another refrigerant (which may be a plurality of types of refrigerants) to be mixed does not exceed a contained amount of the combustible refrigerant in terms of mass%, including a case where one of the combustible refrigerants exemplified above is used alone. Further, in Embodiment 1 and the following embodiments, a circuit in which the injection pipe 26 is connected to the suction side of the compressor 3 is given as an example, but the injection pipe 26 may be connected to an intermediate port communicating to an intermediate pressure portion of the compressor 3.

[0055] As described above, the refrigeration cycle apparatus 100A can suppress the increase in the discharge temperature while suppressing the increase in the amount of filled refrigerant. Therefore, safety can be taken into consideration even for the case where the refrigerant leaks, with the refrigeration cycle apparatus 100A that can suppress the increase in the amount of filled refrigerant. Further, the influence on global warming can be reduced. Still further, a highly efficient operation can be continued without causing a change in the property of the refrigerant by suppressing the increase in the discharge temperature.

Embodiment 2

[0056] Fig. 3 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus (hereinafter referred to as "refrigeration cycle apparatus 100B") according to Embodiment 2 of the present invention. Referring to Fig. 3, the refrigeration cycle apparatus 100B is described. In Embodiment 2, differences from Embodiment 1 are mainly described. The same components as those of Embodiment 1 are denoted by the same reference numerals, and a description thereof is omitted.

[0057] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle appa-

ratus 100B is assumed to use the combustible refrigerant as the main component. The refrigeration cycle apparatus 100B is different from the refrigeration cycle apparatus 100A according to Embodiment 1 in the configuration of the outdoor unit 1. Further, the refrigeration cycle apparatus 100B is different from the refrigeration cycle apparatus 100A according to Embodiment 1 in the configurations of the main refrigerant pipe 31 and the branch pipe 25.

[0058] The outdoor unit (heat source apparatus) 1 includes the compressor 3, the outdoor heat exchanger 5, a three-way valve 27, the subcooling heat exchanger 22, the second electronic expansion valve 23, and the third electronic expansion valve 24. In other words, the refrigeration cycle apparatus 100B includes the three-way valve 27 instead of including the first electronic expansion valve 6 and the opening-closing valve 21 included in the outdoor unit 1 of the refrigeration cycle apparatus 100A according to Embodiment 1. Therefore, the second electronic expansion valve 23 functions as the "first electronic expansion valve" of the present invention.

[0059] The three-way valve 27 has a function as a flow switching device, and is arranged on a downstream side of the outdoor heat exchanger 5. The three-way valve is configured to, under the control of the controller 30, switch a refrigerant passage to any one of the main refrigerant pipe 31 (main refrigerant circuit) and the branch pipe 25 (branch circuit). The following description discusses a case where the flow switching device is the three-way valve 27 as an example, but the flow switching device is not limited to the three-way valve 27. For example, the flow switching device only needs to be a device capable of switching the refrigerant passage. For example, the flow switching device may be constructed by using two-way valves in combination, or may be constructed by blocking one passage of a four-way valve.

[0060] In the refrigeration cycle apparatus 100B, the compressor 3, the outdoor heat exchanger 5, the three-way valve 27, the second electronic expansion valve 23, and the indoor heat exchanger 8 form the main refrigerant circuit by being connected to one another with the main refrigerant pipe 31 including the discharge pipe 3a, the liquid pipe 7, and the gas pipe 9.

[0061] The branch pipe 25 branches from the main refrigerant pipe 31 via the three-way valve 27 and passes through the subcooling heat exchanger 22. The branch pipe 25 is then connected to a portion between the three-way valve 27 and the second electronic expansion valve 23. The outdoor heat exchanger 5, the three-way valve 27, the primary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the branch pipe 25), the second electronic expansion valve 23, and the indoor heat exchanger 8 form the branch circuit by being connected to one another with the branch pipe 25 and the main refrigerant pipe 31.

[0062] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the outdoor unit 1 includes the injection pipe 26, which branches from the portion of the

branch pipe 25 between the subcooling heat exchanger 22 and the second electronic expansion valve 23 and is connected to the suction side of the compressor 3. The third electronic expansion valve 24, the secondary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the injection pipe 26), and the suction side of the compressor 3 form the injection circuit by being connected to one another with the injection pipe 26.

[0063] Fig. 4 is an explanatory table for showing patterns of control by the controller 30 on actuators (in this case, the three-way valve 27, the second electronic expansion valve 23, and the third electronic expansion valve 24) corresponding to the operation modes executed by the refrigeration cycle apparatus 100B. Referring to Fig. 3 and Fig. 4, the operation of the refrigeration cycle apparatus 100B is described.

[0064] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle apparatus 100B is configured to determine whether or not to use the subcooling heat exchanger 22 depending on the outside-air temperature detected by the outside-air temperature sensor T_1 . Definitions of the normal operation mode and the high-outside-air-temperature operation mode are the same as those of Embodiment 1.

<Normal Operation Mode>

[0065] In the normal operation mode, as shown in Fig. 4, under the control of the controller 30, the three-way valve 27 is controlled to be switched such that the outdoor heat exchanger 5 and the second electronic expansion valve 23 communicate to each other. Further, the third electronic expansion valve 24 is controlled to be fully closed, and based on the detection result obtained by the discharge temperature sensor T_2 , the second electronic expansion valve 23 controls the temperature of the refrigerant discharged from the compressor 3. In other words, at the normal outside-air temperature, the refrigeration cycle apparatus 100B bypasses the refrigerant through the subcooling heat exchanger 22 in order to suppress the decrease in the quality at the inlet of the indoor heat exchanger 8 functioning as the evaporator and suppress the increase in the amount of refrigerant required for the indoor heat exchanger 8.

[0066] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 operating as the condenser, and transfers its heat to the outdoor air sent by the outdoor blower device 5a. This refrigerant flows into the second electronic expansion valve 23 via the three-way valve 27. The refrigerant then has its pressure reduced by the second electronic expansion valve 23 to turn into the low-pressure two-phase refrigerant, and the low-pressure two-phase refrigerant then cools the indoor air in the indoor heat exchanger 8 operating as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

<High-outside-air-temperature Operation Mode>

[0067] In the high-outside-air-temperature operation mode, as shown in Fig. 4, under the control of the controller 30, the three-way valve 27 is controlled to be switched such that the outdoor heat exchanger 5 and the subcooling heat exchanger 22 communicate to each other, and based on the detection result obtained by the discharge temperature sensor T_2 , the second electronic expansion valve 23 controls the temperature of the refrigerant discharged from the compressor 3. Further, under the control of the controller 30, the third electronic expansion valve 24 controls the degree of subcooling (SC) of the refrigerant at the outlet of the subcooling heat exchanger 22. In other words, at the high outside-air temperature, the refrigeration cycle apparatus 100B causes the refrigerant to flow into the branch circuit, uses the subcooling heat exchanger 22 to keep the quality at a low level at the inlet of the indoor heat exchanger 8 functioning as the evaporator, and causes the indoor heat exchanger 8 to hold a large amount of refrigerant, to thereby suppress the increase in the high pressure of the refrigerant discharged from the compressor 3.

[0068] Further, at the high outside-air temperature, the refrigeration cycle apparatus 100B injects the refrigerant of the injection circuit that has passed through the subcooling heat exchanger 22 into the suction side of the compressor 3, to thereby suppress the increase in the discharge temperature of the refrigerant discharged from the compressor 3.

[0069] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 operating as the condenser, and transfers its heat to the outdoor air sent by the outdoor blower device 5a. This refrigerant flows into the subcooling heat exchanger 22 via the three-way valve 27. This refrigerant is cooled by the low-pressure refrigerant in the subcooling heat exchanger 22, and then has its pressure reduced by the second electronic expansion valve 23 to turn into the low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant cools the indoor air in the indoor heat exchanger 8 operating as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0070] Meanwhile, the refrigerant having flowed into the injection pipe 26 has its pressure reduced by the third electronic expansion valve 24, and is then heated by the high-pressure refrigerant in the subcooling heat exchanger 22. This refrigerant is injected into the suction side of the compressor 3, and merges with the refrigerant having flowed through the gas pipe 9. After that, the refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0071] As described above, as in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle apparatus 100B can achieve suppression

of the increase in the discharge temperature and suppression of the increase in the condensing pressure due to the decrease in the quality of the refrigerant at the inlet of the indoor heat exchanger 8 functioning as the evaporator while suppressing the increase in the amount of filled refrigerant. Therefore, with the refrigeration cycle apparatus 100B, safety can be taken into consideration even if the refrigerant leaks by suppressing the increase in the amount of filled refrigerant. Further, the influence on global warming can be reduced. Still further, a highly efficient operation can be continued without causing a change in the property of the refrigerant by suppressing the increase in the discharge temperature.

[0072] Further, with the refrigeration cycle apparatus 100B, the number of valves can be made smaller than in the refrigeration cycle apparatus 100A according to Embodiment 1.

Embodiment 3

[0073] Fig. 5 is a refrigerant circuit configuration diagram for schematically illustrating an example of a refrigerant circuit configuration of a refrigeration cycle apparatus (hereinafter referred to as "refrigeration cycle apparatus 100C") according to Embodiment 3 of the present invention. Referring to Fig. 5, the refrigeration cycle apparatus 100C is described. In Embodiment 3, differences from Embodiments 1 and 2 are mainly described. The same components as those of Embodiments 1 and 2 are denoted by the same reference numerals, and a description thereof is omitted.

[0074] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle apparatus 100C is assumed to use the combustible refrigerant as the main component. The refrigeration cycle apparatus 100C is different from the refrigeration cycle apparatus 100A according to Embodiment 1 in the configuration of the outdoor unit 1. Further, the refrigeration cycle apparatus 100C is different from the refrigeration cycle apparatus 100A according to Embodiment 1 in the configurations of the main refrigerant pipe 31 and the branch pipe 25.

[0075] The outdoor unit (heat source apparatus) 1 includes the compressor 3, a refrigerant flow switching device 28, the outdoor heat exchanger 5, a fourth electronic expansion valve (fourth expansion valve) 29, the subcooling heat exchanger 22, the second electronic expansion valve 23, and the third electronic expansion valve 24. In other words, the refrigeration cycle apparatus 100C includes the refrigerant flow switching device 28 and the fourth electronic expansion valve 29 instead of including the first electronic expansion valve 6 and the opening-closing valve 21 included in the outdoor unit 1 of the refrigeration cycle apparatus 100A according to Embodiment 1. Therefore, the fourth electronic expansion valve 29 functions as the "first electronic expansion valve" of the present invention.

[0076] In the refrigeration cycle apparatus 100C, a con-

figuration is employed in which the branch pipe 25 does not branch from the main refrigerant pipe 31 included in the outdoor unit 1 of the refrigeration cycle apparatus 100A according to Embodiment 1 and the branch pipe 25 is connected to the main refrigerant pipe 31.

[0077] The refrigerant flow switching device 28 is arranged on the discharge side of the compressor 3, and is configured to switch the flow of the refrigerant under the control of the controller 30. The refrigerant flow switching device 28 may be constructed with, for example, a four-way valve as illustrated in Fig. 5. However, the refrigerant flow switching device 28 is not limited to the four-way valve, and a two-way valve and a three-way valve may be used in combination to form the refrigerant flow switching device 28.

[0078] The fourth electronic expansion valve 29 has its opening degree controlled by the controller 30, and is configured to, for example, control the flow rate of the refrigerant while reducing the pressure of the refrigerant.

The fourth electronic expansion valve 29 is arranged between the outdoor heat exchanger 5 and the subcooling heat exchanger 22.

[0079] In the refrigeration cycle apparatus 100C, the compressor 3, the refrigerant flow switching device 28, the outdoor heat exchanger 5, the fourth electronic expansion valve 29, the subcooling heat exchanger 22, and the indoor heat exchanger 8 form the main refrigerant circuit by being connected to one another with the main refrigerant pipe 31 including the discharge pipe 3a, the branch pipe 25, the liquid pipe 7, and the gas pipe 9. In other words, the branch pipe 25 forms a part of the main refrigerant pipe 31.

[0080] The outdoor heat exchanger 5, the fourth electronic expansion valve 29, the primary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the branch pipe 25), the second electronic expansion valve 23, and the indoor heat exchanger 8 form the branch circuit by being connected to one another with the branch pipe 25 and the main refrigerant pipe 31.

[0081] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the outdoor unit 1 includes the injection pipe 26, which branches from the portion of the branch pipe 25 between the subcooling heat exchanger 22 and the second electronic expansion valve 23 and is connected to the suction side of the compressor 3. The third electronic expansion valve 24, the secondary side of the subcooling heat exchanger 22 (side of the refrigerant flowing through the injection pipe 26), and the suction side of the compressor 3 form the injection circuit by being connected to one another with the injection pipe 26.

[0082] Fig. 6 is an explanatory table for showing patterns of control by the controller 30 on actuators (in this case, the second electronic expansion valve 23, the third electronic expansion valve 24, and the fourth electronic expansion valve 29) corresponding to the operation modes executed by the refrigeration cycle apparatus 100C. Referring to Fig. 5 and Fig. 6, the operation of the refrigeration cycle apparatus 100C is described.

[0083] As in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle apparatus 100C is configured to determine whether or not to use the subcooling heat exchanger 22 depending on the outside-air temperature detected by the outside-air temperature sensor T_1 . Definitions of the normal operation mode and the high-outside-air-temperature operation mode are the same as those of Embodiment 1. Further, in the refrigeration cycle apparatus 100C, an operation mode at the time when the flow of the refrigerant is inverted through the operation of the refrigerant flow switching device 28 is referred to as "heating operation mode".

<Normal Operation Mode>

[0084] In the normal operation mode, as shown in Fig. 6, under the control of the controller 30, the second electronic expansion valve 23 is controlled to be fully opened, the third electronic expansion valve 24 is controlled to be fully closed, and based on the detection result obtained by the discharge temperature sensor T_2 , the fourth electronic expansion valve 29 controls the temperature of the refrigerant discharged from the compressor 3. In other words, at the normal outside-air temperature, the refrigeration cycle apparatus 100C bypasses the refrigerant through the subcooling heat exchanger 22 in order to suppress the decrease in the quality at the inlet of the indoor heat exchanger 8 functioning as the evaporator and suppress the increase in the amount of refrigerant required for the indoor heat exchanger 8.

[0085] In the refrigeration cycle apparatus 100C, the refrigerant flows through the subcooling heat exchanger 22 but the refrigerant does not flow through the injection pipe 26, and hence heat is not exchanged between the refrigerant of the subcooling heat exchanger 22 and the refrigerant of the injection pipe 26. Therefore, this case is also expressed as "bypasses the refrigerant through the subcooling heat exchanger 22".

[0086] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 operating as the condenser, and transfers its heat to the outdoor air sent by the outdoor blower device 5a. This refrigerant flows into the fourth electronic expansion valve 29. Then, this refrigerant has its pressure reduced by the fourth electronic expansion valve 29 to turn into the low-pressure two-phase refrigerant, and the low-pressure two-phase refrigerant then cools the indoor air in the indoor heat exchanger 8 operating as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

<High-outside-air-temperature Operation Mode>

[0087] In the high-outside-air-temperature operation mode, as shown in Fig. 6, under the control of the con-

troller 30, the second electronic expansion valve 23 controls the temperature of the refrigerant discharged from the compressor 3 based on the detection result obtained by the discharge temperature sensor T_2 , the third electronic expansion valve 24 controls the degree of subcooling (SC) of the refrigerant at the outlet of the subcooling heat exchanger 22, and the fourth electronic expansion valve 29 is controlled to be fully opened. In other words, at the high outside-air temperature, the refrigeration cycle apparatus 100C causes the refrigerant to flow into the branch circuit, uses the subcooling heat exchanger 22 to keep the quality at a low level at the inlet of the indoor heat exchanger 8 functioning as the evaporator, and causes the indoor heat exchanger 8 to hold a large amount of refrigerant, to thereby suppress the increase in the high pressure of the refrigerant discharged from the compressor 3.

[0088] Further, at the high outside-air temperature, the refrigeration cycle apparatus 100C injects the refrigerant of the injection circuit that has passed through the subcooling heat exchanger 22 into the suction side of the compressor 3, to thereby suppress the increase in the discharge temperature of the refrigerant discharged from the compressor 3.

[0089] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the outdoor heat exchanger 5 operating as the condenser, and transfers its heat to the outdoor air sent by the outdoor blower device 5a. This refrigerant flows into the subcooling heat exchanger 22 via the fourth electronic expansion valve 29. This refrigerant is cooled by the low-pressure refrigerant in the subcooling heat exchanger 22, and then has its pressure reduced by the second electronic expansion valve 23 to turn into the low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant cools the indoor air in the indoor heat exchanger 8 operating as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0090] Meanwhile, the refrigerant having flowed into the injection pipe 26 has its pressure reduced by the third electronic expansion valve 24, and is then heated by the high-pressure refrigerant in the subcooling heat exchanger 22. This refrigerant is injected into the suction side of the compressor 3, and merges with the refrigerant having flowed through the gas pipe 9. After that, the refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

<Heating Operation Mode>

[0091] In the heating operation mode, as shown in Fig. 6, under the control of the controller 30, the fourth electronic expansion valve 29 controls the temperature of the refrigerant discharged from the compressor 3 based on the detection result obtained by the discharge temperature sensor T_2 , the third electronic expansion valve 24

controls the degree of subcooling (SC) of the refrigerant at the outlet of the subcooling heat exchanger 22, and the second electronic expansion valve 23 is controlled to be fully opened. In other words, in the heating operation mode, the refrigeration cycle apparatus 100C uses the subcooling heat exchanger 22 to keep the quality at a low level at the inlet of the indoor heat exchanger 8 functioning as the evaporator, and causes the indoor heat exchanger 8 to hold a large amount of refrigerant, to thereby suppress the increase in the high pressure of the refrigerant discharged from the compressor 3.

[0092] Further, in the heating operation mode, the refrigeration cycle apparatus 100C injects the refrigerant that has passed through the subcooling heat exchanger 22 into the suction side of the compressor 3, to thereby suppress the increase in the discharge temperature of the refrigerant discharged from the compressor 3.

[0093] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 flows into the indoor heat exchanger 8 operating as the condenser via the refrigerant flow switching device 28, and transfers its heat to the outdoor air sent by the indoor blower device 8a. This refrigerant flows into the subcooling heat exchanger 22 via the second electronic expansion valve 23. This refrigerant is cooled by the low-pressure refrigerant in the subcooling heat exchanger 22, and then has its pressure reduced by the fourth electronic expansion valve 29 to turn into the low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant cools the outdoor air in the outdoor heat exchanger 5 operating as the evaporator to turn into the low-pressure gas refrigerant. After that, the low-pressure gas refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0094] Meanwhile, the refrigerant having flowed into the injection pipe 26 has its pressure reduced by the third electronic expansion valve 24, and is then heated by the high-pressure refrigerant in the subcooling heat exchanger 22. This refrigerant is injected into the suction side of the compressor 3, and merges with the refrigerant having flowed through the gas pipe 9. After that, the refrigerant passes through the gas pipe 9 to be sucked into the compressor 3 again.

[0095] As described above, as in the refrigeration cycle apparatus 100A according to Embodiment 1, the refrigeration cycle apparatus 100C can achieve suppression of the increase in the discharge temperature and suppression of the increase in the condensing pressure due to the decrease in the quality of the refrigerant at the inlet of the indoor heat exchanger 8 functioning as the evaporator while suppressing the increase in the amount of filled refrigerant. Therefore, with the refrigeration cycle apparatus 100C, safety can be taken into consideration even if the refrigerant leaks by suppressing the increase in the amount of filled refrigerant. Further, the influence on global warming can be reduced. Still further, a highly efficient operation can be continued without causing a change in the property of the refrigerant by suppressing

the increase in the discharge temperature.

[0096] Further, with the refrigeration cycle apparatus 100C, as compared to the refrigeration cycle apparatus 100A according to Embodiment 1, the increase in the discharge temperature can be suppressed by injecting the refrigerant that has passed through the subcooling heat exchanger 22 in the heating operation mode. Still further, with the refrigeration cycle apparatus 100C, even in the heating operation mode, the refrigerant flowing through the liquid pipe 7 can be changed to a two-phase refrigerant. As a result, the refrigeration cycle apparatus 100C contributes to reduction in the amount of filled refrigerant.

[0097] The refrigeration cycle apparatus described in each of the embodiments is applicable, for use, to an apparatus including a refrigeration cycle, e.g., an air-conditioning apparatus (e.g., a refrigeration apparatus, a room air conditioner, a package air conditioner, or a multi-air conditioner for a building), or a heat pump water heater.

Reference Signs List

[0098]

1 outdoor unit 2 indoor unit 3 compressor 3a discharge pipe
5 outdoor heat exchanger 5a outdoor blower device
6 first electronic expansion valve 7 liquid pipe 8 indoor heat exchanger 8a indoor blower device 9 gas pipe 21 valve 22 subcooling heat exchanger 23 second electronic expansion valve 24 third electronic expansion valve 25 branch pipe 26 injection pipe 27 three-way valve 28 refrigerant flow switching device 29 fourth electronic expansion valve 30 controller 31 main refrigerant pipe 32 liquid-side stop valve 33 gas-side stop valve 100A refrigeration cycle apparatus 100B refrigeration cycle apparatus 100C refrigeration cycle apparatus T₁ outside-air temperature sensor T₂ discharge temperature sensor T₃ refrigerant temperature sensor P₁ discharge pressure sensor

Claims

1. A refrigeration cycle apparatus, comprising:

a main refrigerant circuit formed by connecting a compressor, a first heat exchanger, a first expansion valve, and a second heat exchanger; a branch circuit formed by connecting the first heat exchanger, a primary side of a subcooling heat exchanger installed on a downstream side of refrigerant flow in a case where the first heat exchanger serves as a condenser, a second expansion valve, and the second heat exchanger; and

an injection circuit formed by connecting, with an injection pipe branching from a downstream side of the primary side of the subcooling heat exchanger, a third expansion valve, a secondary side of the subcooling heat exchanger, and the compressor, the refrigeration cycle apparatus being operable in

a normal operation mode of causing the refrigerant to flow through the main refrigerant circuit; and

a high-outside-air-temperature operation mode of causing the refrigerant to flow through the branch circuit and the injection circuit to use the subcooling heat exchanger, and of injecting the refrigerant having flowed through the secondary side of the subcooling heat exchanger into the compressor,

the refrigeration cycle apparatus being configured to perform the high-outside-air-temperature operation mode when an outside-air temperature is equal to or higher than a predetermined temperature.

2. The refrigeration cycle apparatus of claim 1, further comprising a controller configured to perform the normal operation mode and the high-outside-air-temperature operation mode by controlling the main refrigerant circuit, the branch circuit, and the injection circuit.

3. The refrigeration cycle apparatus of claim 2, further comprising an opening-closing valve arranged between the first heat exchanger and the subcooling heat exchanger, wherein the controller is configured to

in the normal operation mode, cause the opening-closing valve to be closed, cause the second expansion valve to be fully opened, cause the third expansion valve to be fully closed, and control temperature of the refrigerant discharged from the compressor with the first expansion valve, and

in the high-outside-air-temperature operation mode, cause the opening-closing valve to be opened, cause the first expansion valve to be fully closed, control the temperature of the refrigerant discharged from the compressor with the second expansion valve, and control a degree of subcooling of the refrigerant at an outlet of the subcooling heat exchanger with the third expansion valve.

4. The refrigeration cycle apparatus of claim 2, further

comprising a flow switching device arranged between the first heat exchanger and the subcooling heat exchanger and configured to switch a refrigerant passage between the main refrigerant circuit and the branch circuit, wherein the controller is configured to

in the normal operation mode, switch the flow switching device such that the first heat exchanger and the second expansion valve communicate to each other to cause the second expansion valve to serve as the first expansion valve, cause the third expansion valve to be fully closed, and control the temperature of the refrigerant discharged from the compressor with the second expansion valve, and

in the high-outside-air-temperature operation mode, switch the flow switching device such that the first heat exchanger and the subcooling heat exchanger communicate to each other, control the temperature of the refrigerant discharged from the compressor with the second expansion valve, and control a degree of subcooling of the refrigerant at the outlet of the subcooling heat exchanger with the third expansion valve.

5. The refrigeration cycle apparatus of claim 2, further comprising a fourth expansion valve arranged between the first heat exchanger and the subcooling heat exchanger, wherein the controller is configured to

in the normal operation mode, cause the second expansion valve to be fully opened, cause the third expansion valve to be fully closed, and cause the fourth expansion valve to serve as the first expansion valve to control the temperature of the refrigerant discharged from the compressor with the fourth expansion valve,

in the high-outside-air-temperature operation mode, cause the fourth expansion valve to be fully opened, control the temperature of the refrigerant discharged from the compressor with the second expansion valve, and control a degree of subcooling of the refrigerant at the outlet of the subcooling heat exchanger with the third expansion valve, and

in an operation at a time when the first heat exchanger serves as an evaporator, cause the second expansion valve to be fully opened, cause the fourth expansion valve to serve as the first expansion valve to control the temperature of the refrigerant discharged from the compressor with the fourth expansion valve, and control the degree of subcooling of the refrigerant at the outlet of the subcooling heat exchanger with the third expansion valve.

6. The refrigeration cycle apparatus of claim 5, further comprising a refrigerant flow switching device arranged on a discharge side of the compressor, wherein the refrigeration cycle apparatus is configured to cause the first heat exchanger to serve as the condenser or the evaporator with the refrigerant flow switching device. 5
7. A refrigeration cycle apparatus, comprising: 10
- a main refrigerant circuit formed by connecting a compressor, a first heat exchanger, a first expansion valve, and a second heat exchanger; and
- a branch circuit formed by connecting the first heat exchanger, a subcooling heat exchanger installed on a downstream side of a flow of refrigerant when the first heat exchanger serves as a condenser, a second expansion valve, and the second heat exchanger, 15 20
- the refrigeration cycle apparatus being operable in
- a normal operation mode of causing the refrigerant to flow through the main refrigerant circuit, and 25
- a high-outside-air-temperature operation mode of causing the refrigerant to flow through the branch circuit to use the subcooling heat exchanger, and 30
- the refrigeration cycle apparatus being configured to perform the high-outside-air-temperature operation mode when an outside-air temperature is equal to or higher than a predetermined temperature. 35

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FIG. 1

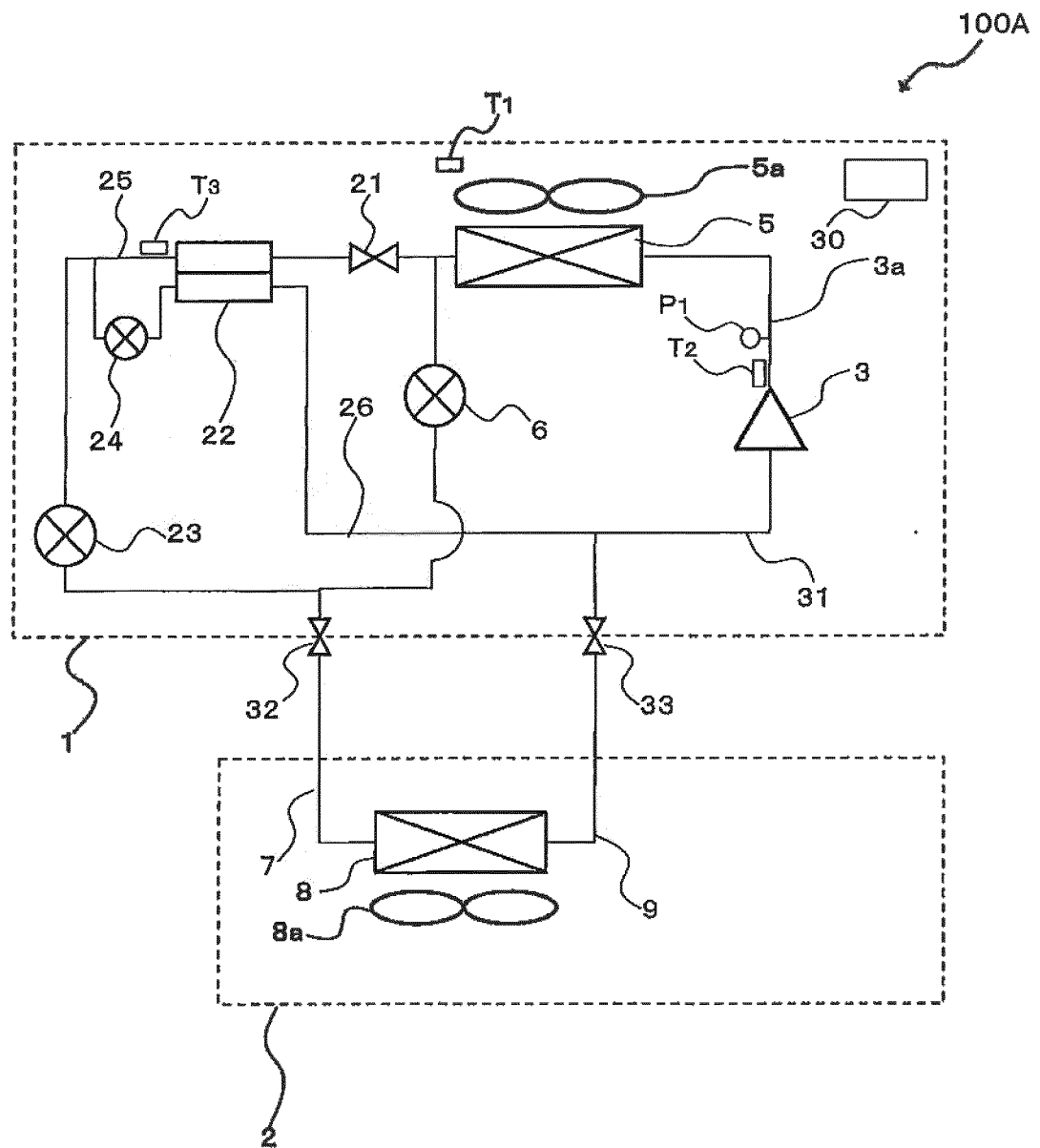


FIG. 2

	NORMAL COOLING OPERATION	HIGH-OUTSIDE-AIR- TEMPERATURE COOLING OPERATION
OPENING-CLOSING VALVE 21	CLOSED	OPEN
FIRST ELECTRONIC EXPANSION VALVE 6	CONTROL DISCHARGE TEMPERATURE	FULLY OPEN
SECOND ELECTRONIC EXPANSION VALVE 23	FULLY OPEN	CONTROL DISCHARGE TEMPERATURE
THIRD ELECTRONIC EXPANSION VALVE 24	FULLY CLOSED	CONTROL SC AT OUTLET OF SUBCOOLING HEAT EXCHANGER

FIG. 3

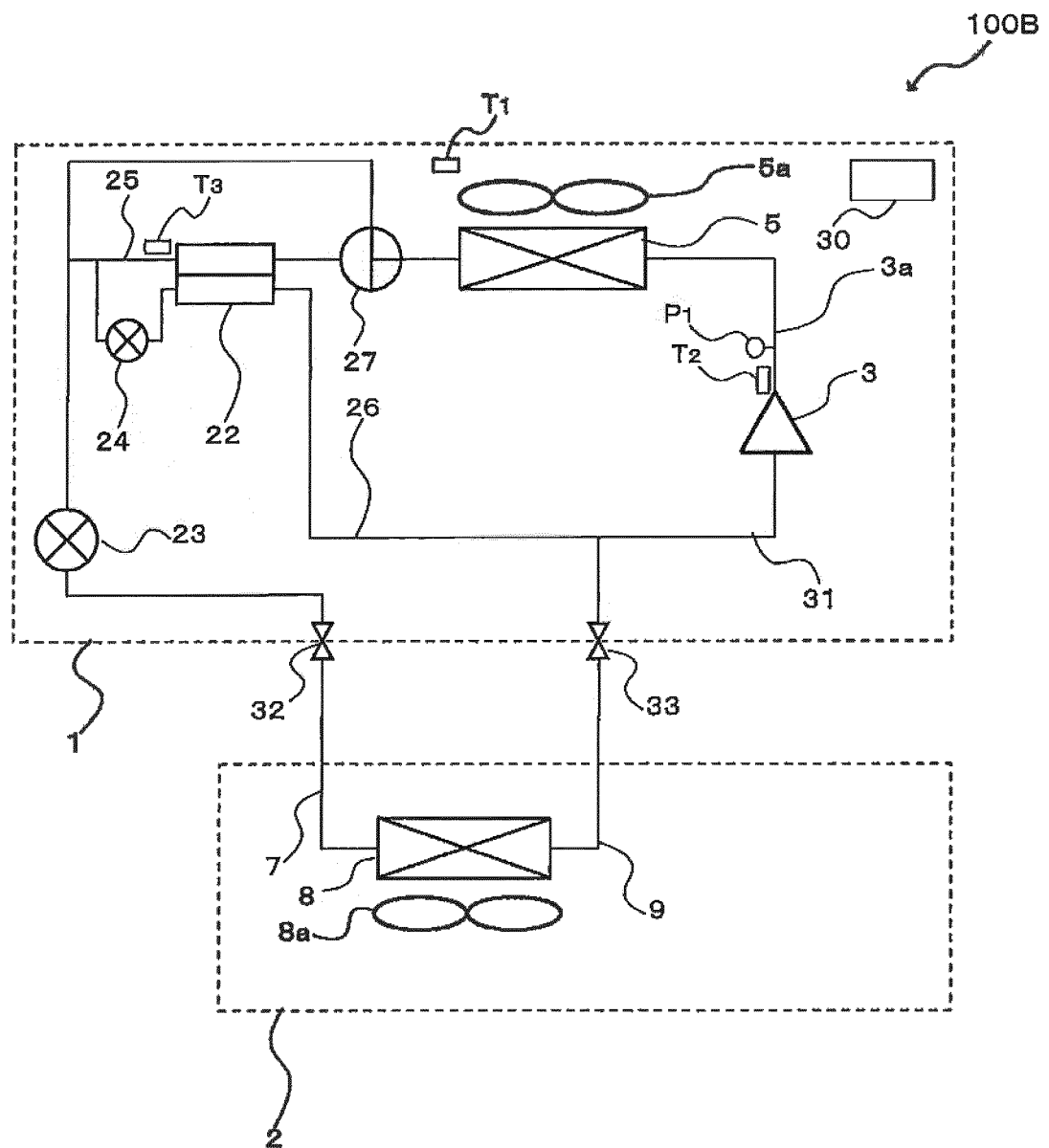


FIG. 4

	NORMAL COOLING OPERATION	HIGH-OUTSIDE-AIR- TEMPERATURE COOLING OPERATION
THREE-WAY VALVE 27	CONNECT OUTDOOR HEAT EXCHANGER AND SECOND ELECTRONIC EXPANSION VALVE	CONNECT OUTDOOR HEAT EXCHANGER AND SUBCOOLING HEAT EXCHANGER
SECOND ELECTRONIC EXPANSION VALVE 23	CONTROL DISCHARGE TEMPERATURE	CONTROL DISCHARGE TEMPERATURE
THIRD ELECTRONIC EXPANSION VALVE 24	FULLY CLOSED	CONTROL SC AT OUTLET OF SUBCOOLING HEAT EXCHANGER

FIG. 5

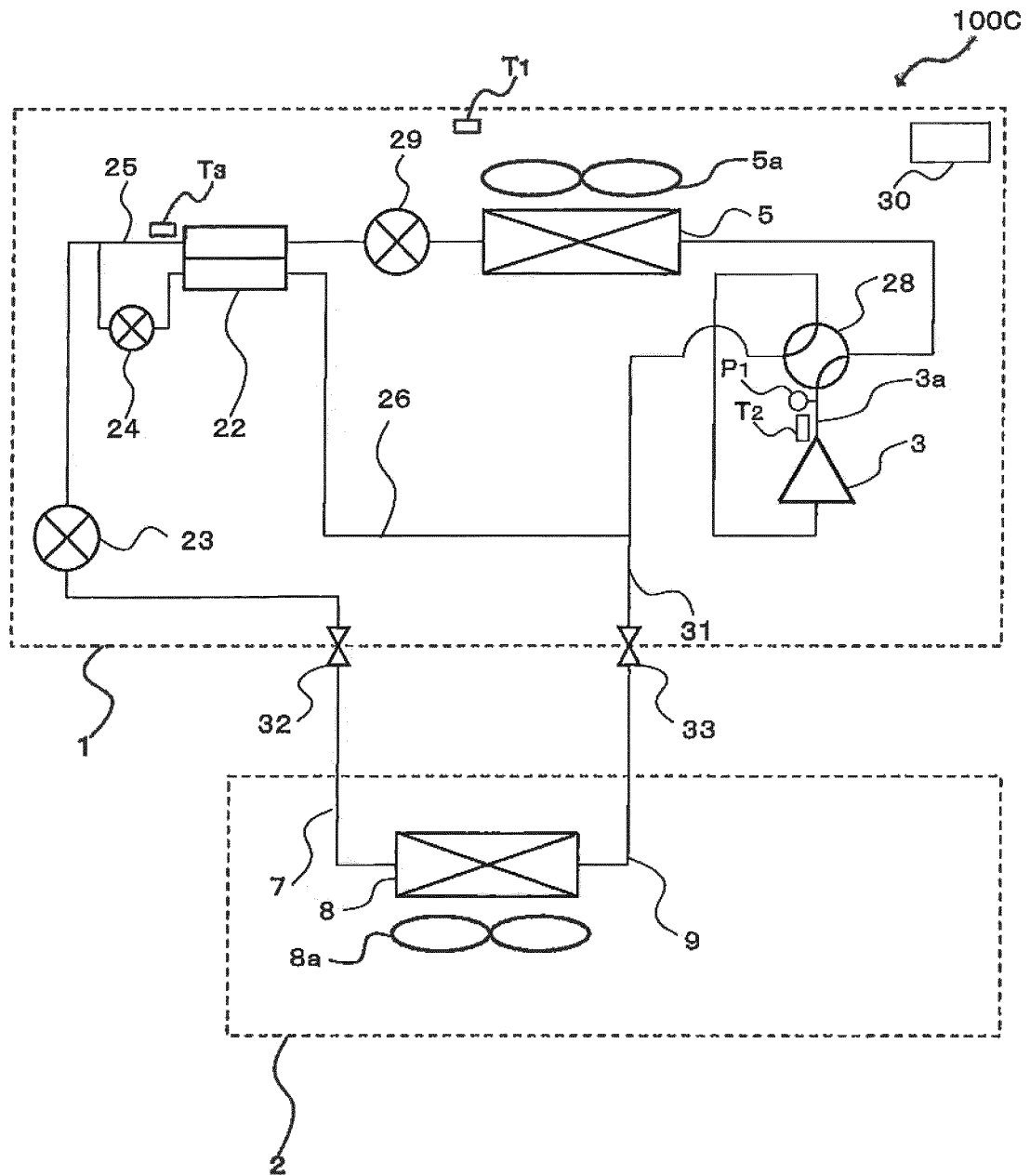


FIG. 6

	NORMAL COOLING OPERATION	HIGH-OUTSIDE-AIR- TEMPERATURE COOLING OPERATION	HEATING OPERATION
SECOND ELECTRONIC EXPANSION VALVE 23	FULLY OPEN	CONTROL DISCHARGE TEMPERATURE	FULLY OPEN
THIRD ELECTRONIC EXPANSION VALVE 24	FULLY CLOSED	CONTROL SC AT OUTLET OF SUBCOOLING HEAT EXCHANGER	CONTROL SC AT OUTLET OF SUBCOOLING HEAT EXCHANGER
FOURTH ELECTRONIC EXPANSION VALVE 29	CONTROL DISCHARGE TEMPERATURE	FULLY OPEN	CONTROL DISCHARGE TEMPERATURE

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/055855

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/00(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2012-117708 A (Fujitsu General Ltd.), 21 June 2012 (21.06.2012), claims; paragraphs [0024] to [0026]; fig. 1, 3 (Family: none)	7 1-6
A	JP 2012-21744 A (Daikin Industries, Ltd.), 02 February 2012 (02.02.2012), claims; paragraphs [0029] to [0055]; fig. 1 (Family: none)	1-7
A	JP 2010-2109 A (Mitsubishi Electric Corp.), 07 January 2010 (07.01.2010), claims; paragraphs [0016] to [0018]; fig. 1 (Family: none)	1-7

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 ☐ See patent family annex.

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Date of the actual completion of the international search
21 May 2015 (21.05.15)Date of mailing of the international search report
02 June 2015 (02.06.15)Name and mailing address of the ISA/
Japan Patent Office
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Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/055855

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-207844 A (Fujitsu General Ltd.), 25 October 2012 (25.10.2012), claims; paragraphs [0016] to [0018]; fig. 1 (Family: none)	1-7

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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