(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 4 467 897 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
27.11.2024 Bulletin 2024/48

(21) Application number: **22921859.9**

(22) Date of filing: **19.01.2022**

(51) International Patent Classification (IPC):
F25B 13/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25B 13/00

(86) International application number:
PCT/JP2022/001823

(87) International publication number:
WO 2023/139700 (27.07.2023 Gazette 2023/30)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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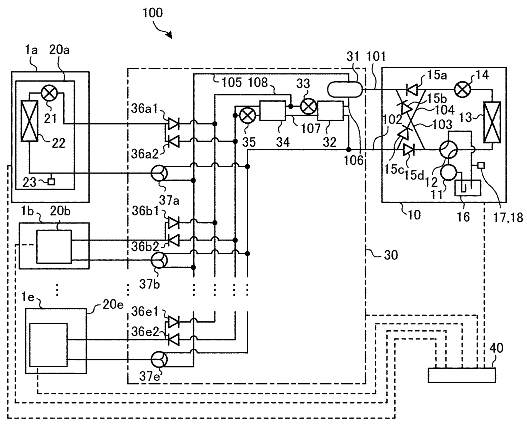
(54) REFRIGERATION AND AIR-CONDITIONING DEVICE

(57) A refrigerating and air-conditioning apparatus includes an outdoor unit including a compressor and an outdoor heat exchanger; a plurality of indoor units each including an indoor expansion valve and an indoor heat exchanger; a relay unit connected between the outdoor unit and the plurality of indoor units and including a plurality of three-way valves, the plurality of three-way valves each being configured to switch flows of refrigerant and to adjust a flow rate of the refrigerant that passes through the three-way valve, the plurality of three-way valves being provided in number relative to the number of the plurality of indoor units, the relay unit being configured to distribute the refrigerant in a low-temperature state to each of ones of the plurality of indoor units that perform cooling operations and the refrigerant in a high-temperature state to each of ones of the plurality of indoor units that perform heating operations; and a controller configured to control switching and opening degrees of the plurality of three-way valves. The plurality of indoor units each include an indoor-side pressure sensor configured to detect an indoor-side pressure, the indoor-side pressure being a pressure of the refrigerant that passes through the indoor heat exchanger. The controller is configured to control, with reference to the indoor-side pressure of each of ones of the plurality of indoor units that perform cooling operations, the opening degree of a corresponding three-way valve of the plurality of three-way valves such that the controller is configured to adjust the flow rate of the refrigerant passing through the corresponding three-way valve.

FIG. 1



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Description

Technical Field

[0001] The present disclosure relates to a refrigerating and air-conditioning apparatus capable of simultaneously performing cooling operations and heating operations on a plurality of air-conditioning target spaces.

Background Art

[0002] In known arts, buildings having a wide continuous space or many rooms, such as high-rises and factories, are provided with air-conditioning apparatuses each including a plurality of indoor units. Such buildings are to be subjected to cooling operations or heating operations that are performed by the air-conditioning apparatuses. For example, an air-conditioning apparatus disclosed in Patent Literature 1 includes a plurality of indoor units, an outdoor unit configured to cause refrigerant to circulate through the individual indoor units, and a control board on which operations of the units are to be controlled such that temperature-adjusted air is blown from the individual indoor units.

Citation List

Patent Literature

[0003] Patent Literature 1: International Publication No. 2018/155056

Summary of Invention

Technical Problem

[0004] In the air-conditioning apparatus disclosed in Patent Literature 1, however, the evaporating temperatures of the indoor units are controlled by an expansion valve device included in the outdoor unit. Therefore, the evaporating temperatures cannot be varied among the indoor units. Such an air-conditioning apparatus has a problem of incapability in controlling the indoor units individually according to their respective loads.

[0005] In view of the above technical problem in known arts, an object of the present disclosure is to provide a refrigerating and air-conditioning apparatus capable of controlling a plurality, if any, of indoor units individually.

Solution to Problem

[0006] A refrigerating and air-conditioning apparatus according to an embodiment of the present disclosure includes an outdoor unit including a compressor and an outdoor heat exchanger; a plurality of indoor units each including an indoor expansion valve and an indoor heat exchanger; a relay unit connected between the outdoor unit and the plurality of indoor units and including a plurality of three-way valves, the plurality of three-way valves each being configured to switch flows of refrigerant and to adjust a flow rate of the refrigerant that passes through the three-way valve, the plurality of three-way valves being provided in number relative to the number of the plurality of indoor units, the relay unit being configured to distribute the refrigerant in a low-temperature state to each of ones of the plurality of indoor units that perform cooling operations and the refrigerant in a high-temperature state to each of ones of the plurality of indoor units that perform heating operations; and a controller configured to control switching and opening degrees of the plurality of three-way valves. The plurality of indoor units each include an indoor-side pressure sensor configured to detect an indoor-side pressure, the indoor-side pressure being a pressure of the refrigerant that passes through the indoor heat exchanger. The controller is configured to control, with reference to the indoor-side pressure of each of ones of the plurality of indoor units that perform cooling operations, the opening degree of a corresponding three-way valve of the plurality of three-way valves such that the controller is configured to adjust the flow rate of the refrigerant passing through the corresponding three-way valve.

Advantageous Effects of Invention

[0007] According to an embodiment of the present disclosure, the opening degree of the three-way valve of each of ones of the indoor units that perform cooling operations is controlled with reference to the indoor-side pressure of the indoor unit. Therefore, even when the refrigerating and air-conditioning apparatus includes a plurality of indoor units, the indoor units are controllable individually.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a circuit diagram illustrating an exemplary configuration of a refrigerating and air-conditioning apparatus according to Embodiment 1.
[Fig. 2] Fig. 2 is a functional block diagram illustrating an exemplary configuration of a controller illustrated in Fig. 1.
[Fig. 3] Fig. 3 illustrates an exemplary hardware configuration of the controller illustrated in Fig. 2.
[Fig. 4] Fig. 4 illustrates another exemplary hardware configuration of the controller illustrated in Fig. 2.
[Fig. 5] Fig. 5 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in a cooling only operation mode.
[Fig. 6] Fig. 6 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in a heating only operation mode.

[Fig. 7] Fig. 7 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in a cooling main operation mode.

[Fig. 8] Fig. 8 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in a heating main operation mode.

[Fig. 9] Fig. 9 is a flow chart illustrating an exemplary flow of an evaporating-temperature-adjusting process according to Embodiment 1.

[Fig. 10] Fig. 10 is a flow chart illustrating an exemplary flow of a liquid-carryover-prevention process according to Embodiment 1.

[Fig. 11] Fig. 11 is a flow chart illustrating an exemplary flow of a first liquid-carryover-prevention process illustrated in Fig. 10.

[Fig. 12] Fig. 12 is a flow chart illustrating an exemplary flow of a second liquid-carryover-prevention process illustrated in Fig. 10.

[Fig. 13] Fig. 13 is a circuit diagram illustrating an exemplary configuration of a refrigerating and air-conditioning apparatus according to Embodiment 2.

Description of Embodiments

[0009] Embodiments of the present disclosure will be described below with reference to the drawings. The present disclosure is not limited to the following embodiments. Various modifications can be made to the embodiments without departing from the essence of the present disclosure. Furthermore, the present disclosure includes any combination of features that are combinable among the features described in the following embodiments. Whether the temperature, the pressure, and any other factors are high or low is not determined by their relationships with absolute values but is determined by their relative values regarding the conditions, behaviors, and any other factors of relevant systems, devices, and other elements. In the drawings, the same reference signs denote the same or equivalent elements, which applies throughout this specification.

Embodiment 1

[0010] A refrigerating and air-conditioning apparatus according to Embodiment 1 will be described below. The refrigerating and air-conditioning apparatus according to Embodiment 1 is configured to perform on a plurality of air-conditioning target spaces cooling operations alone, heating operations alone, or cooling operations and heating operations simultaneously.

[Configuration of Refrigerating and Air-conditioning Apparatus 100]

[0011] Fig. 1 is a circuit diagram illustrating an exemplary configuration of the refrigerating and air-conditioning apparatus according to Embodiment 1. A refrigerating and air-conditioning apparatus 100 according to Embodiment 1 includes an outdoor unit 10, a plurality of indoor units 20, a relay unit 30, and a controller 40. In the example illustrated in Fig. 1, the refrigerating and air-conditioning apparatus 100 has one outdoor unit 10, five indoor units 20a to 20e, and one relay unit 30. In the refrigerating and air-conditioning apparatus 100, the outdoor unit 10, the relay unit 30, and the indoor units 20a to 20e are connected to one another by a high-pressure pipe 101 and a low-pressure pipe 102, whereby a refrigerant circuit is formed. The number of the indoor units 20 is not limited to the above and may be two or more and four or less, or six or more.

[0012] In the present example, the indoor units 20a to 20e are provided in respective rooms 1a to 1e, which are air-conditioning target spaces and are different from one another. The high-pressure pipe 101 and the low-pressure pipe 102 connect the outdoor unit 10 and the relay unit 30 and connect each of the indoor units 20a to 20e and the relay unit 30.

[0013] The plurality of indoor units 20a to 20e have the same configuration. Therefore, in Fig. 1, the indoor units 20c and 20d and a part of the circuit configuration of the relay unit 30 that is connected to the indoor units 20c and 20d are not illustrated. Furthermore, the circuit configurations of the indoor units 20b and 20e are the same as that of the indoor unit 20a and are therefore not illustrated.

(Outdoor Unit 10)

[0014] The outdoor unit 10 includes a compressor 11, a refrigerant-flow switching device 12, an outdoor heat exchanger 13, an outdoor expansion valve 14, check valves 15a to 15d, and an accumulator 16. The outdoor unit 10 further includes an outdoor-side pressure sensor 17 and an outdoor-side temperature sensor 18.

[0015] The compressor 11 is configured to suck low-temperature and low-pressure refrigerant, compress the refrigerant into high-temperature and high-pressure refrigerant, and discharge the refrigerant. The compressor 11 is, for example, an inverter compressor whose capacity is controllable by changing the driving frequency as appropriate. The capacity of the inverter compressor refers to the amount of refrigerant delivery per unit time. The driving frequency of the compressor 11 is controlled by the controller 40, which will be described separately below.

[0016] The refrigerant-flow switching device 12 is, for example, a four-way valve and is configured to switch directions for the refrigerant to flow, thereby switching between a cooling operation and a heating operation. The switching by the refrigerant-flow switching device 12 is controlled by the controller 40. The refrigerant-flow switching device 12 is not limited to the above and may be, for example, a combination of any of other valves such as two-way valves and three-way valves.

[0017] The outdoor heat exchanger 13 causes air and the refrigerant to exchange heat with each other. The air (hereinafter referred to as "outdoor air" as appropriate) is supplied by an air-sending device such as a fan, which is not illustrated. Specifically, in the cooling operation, the outdoor heat exchanger 13 serves as a condenser that transfers the heat of the refrigerant to the outdoor air, thereby condensing the refrigerant. In the heating operation, the outdoor heat exchanger 13 serves as an evaporator that evaporates the refrigerant into heat of vaporization, thereby taking away heat from the outdoor air.

[0018] The outdoor expansion valve 14 is configured to depressurize and expand the refrigerant by adjusting the flow rate of the refrigerant. The outdoor expansion valve 14 is, for example, an electronic expansion valve whose opening degree is controllable. In such a case, the opening degree of the outdoor expansion valve 14 is controlled by the controller 40. The outdoor expansion valve 14 is not limited to the above and may be any other expansion device such as a capillary.

[0019] The check valves 15a to 15d are each configured to allow the refrigerant in the refrigerant circuit to flow only in a predetermined direction. The check valve 15a is provided to the high-pressure pipe 101 at a position between the outdoor heat exchanger 13 and the relay unit 30. In the cooling operation, which includes a cooling only operation and a cooling main operation to be described separately below, the check valve 15a allows the refrigerant to flow only in a direction from the outdoor unit 10 toward the relay unit 30. The check valve 15d is provided to the low-pressure pipe 102 at a position between the relay unit 30 and the refrigerant-flow switching device 12. In the cooling operation, the check valve 15d allows the refrigerant to flow only in a direction from the relay unit 30 toward the outdoor unit 10.

[0020] The check valve 15b is provided to a first connecting pipe 103, which connects a portion of the high-pressure pipe 101 that is located downstream of the check valve 15a and a portion of the low-pressure pipe 102 that is located downstream of the check valve 15d to each other. In the heating operation, which includes a heating only operation and a heating main operation to be described separately below, the check valve 15b allows the refrigerant to flow only in a direction from the compressor 11 toward the relay unit 30. The check valve 15c is provided to a second connecting pipe 104, which connects a portion of the high-pressure pipe 101 that is located upstream of the check valve 15a and a portion of the low-pressure pipe 102 that is located upstream of the check valve 15d to each other. In the heating operation, the check valve 15c allows the refrigerant to flow only in a direction from the relay unit 30 toward the compressor 11.

[0021] The accumulator 16 is provided at a position on a suction side, that is, a low-pressure side, of the compressor 11. The accumulator 16 stores, for example, excess refrigerant that is generated with differences between conditions of the cooling operation and the heating operation and excess refrigerant that is generated at a transition between operations. The accumulator 16 does not necessarily need to be provided.

[0022] The outdoor-side pressure sensor 17 is provided to a pipe extending between the refrigerant-suction side of the compressor 11 and the refrigerant-flow switching device 12. The outdoor-side pressure sensor 17 is configured to detect a suction pressure, which is the pressure of the refrigerant that is sucked into the compressor 11. The outdoor-side temperature sensor 18 is provided to the pipe extending between the refrigerant-suction side of the compressor 11 and the refrigerant-flow switching device 12. The outdoor-side temperature sensor 18 is configured to detect a suction temperature, which is the temperature of the refrigerant that is sucked into the compressor 11.

(Indoor Units 20a to 20e)

[0023] The indoor units 20a to 20e are each configured to cool and heat air in, for example, a corresponding one of the rooms 1a to 1e. The indoor units 20a to 20e each include an indoor expansion valve 21 and an indoor heat exchanger 22. The indoor units 20a to 20e each further include an indoor-side pressure sensor 23. Hereinafter, the indoor units 20a to 20e are simply denoted as "indoor unit 20" as appropriate when the indoor units 20a to 20e do not need to be distinguished from one another.

[0024] The indoor expansion valve 21 is configured to depressurize and expand the refrigerant by adjusting the flow rate of the refrigerant. The indoor expansion valve 21 is, for example, an electronic expansion valve whose opening degree is controllable. In such a case, the opening degree of the indoor expansion valve 21 is controlled by the controller 40. The indoor expansion valve 21 is not limited to the above and may be any other expansion device such as a capillary.

[0025] The indoor heat exchanger 22 causes air and the refrigerant to exchange heat with each other. The air is supplied by an air-sending device such as a fan, which is not illustrated. Thus, heating air or cooling air to be supplied to a corresponding one of the rooms 1a to 1e is generated. Specifically, in the cooling operation, the indoor heat exchanger 22 serves as an evaporator to cool the air in a corresponding one of the rooms 1a to 1e, which are air-conditioning target spaces. Furthermore, in the heating operation, the indoor heat exchanger 22 serves as a condenser to heat the air in a corresponding one of the rooms 1a to 1e.

[0026] The indoor-side pressure sensor 23 is provided to the low-pressure pipe 102 at a position between the indoor heat exchanger 22 and the relay unit 30. The indoor-side pressure sensor 23 is configured to detect an indoor-side pressure, which is the pressure of the refrigerant that passes through the indoor heat exchanger 22. In particular, in the cooling operation in which the indoor heat exchanger 22 serves as an evaporator, the indoor-side pressure sensor 23 detects a pressure equivalent to the evaporating pressure of the indoor heat exchanger 22. The indoor-side pressure in this case is obtained as follows, for example: a sensor is inserted into the pipe; or a distortion sensor is attached to the pipe to detect the amount of deformation of the pipe, and the indoor-side pressure is calculated from the relationship between the amount of deformation and the pressure received by the pipe.

(Relay Unit 30)

[0027] The relay unit 30 is configured to switch flows of the refrigerant according to the operating states of the indoor units 20 such that the refrigerant in a low-temperature state is distributed to those indoor units 20 that perform cooling operations and the refrigerant in a high-temperature state is distributed to those indoor units 20 that perform heating operations.

[0028] The relay unit 30 includes a gas-liquid separator 31, a first refrigerant-heat exchanger 32, a first relay expansion valve 33, a second refrigerant-heat exchanger 34, a second relay expansion valve 35, check valves 36, and three-way linear expansion valves 37. The relay unit 30 further includes a gas pipe 105, which is for gas refrigerant to flow through; and a liquid pipe 106, which is for liquid refrigerant to flow through. The relay unit 30 further includes a branch pipe 107 and a merging pipe 108. The branch pipe 107 branches off from a portion of the liquid pipe 106 that is located downstream of the second refrigerant-heat exchanger 34, and is connected to the low-pressure pipe 102. The merging pipe 108 is connected to the individual indoor units 20 and is connected to the liquid pipe 106 at a position between the first relay expansion valve 33 and the second refrigerant-heat exchanger 34.

[0029] The gas-liquid separator 31 is connected to the high-pressure pipe 101, to the gas pipe 105, and to the liquid pipe 106 and is configured to separate a two-phase refrigerant received from the high-pressure pipe 101 into gas refrigerant and liquid refrigerant. The gas refrigerant obtained in the gas-liquid separator 31 flows through the gas pipe 105 and is supplied to the three-way linear expansion valves 37. The liquid refrigerant obtained in the gas-liquid separator 31 flows through the liquid pipe 106 and is supplied to the first refrigerant-heat exchanger 32.

[0030] The first refrigerant-heat exchanger 32 includes a primary-side passage and a secondary-side passage. Refrigerant flowing in the primary-side passage and refrigerant flowing in the secondary-side passage are caused to exchange heat with each other, whereby the refrigerant flowing in the primary-side passage is subcooled. The primary-side passage of the first refrigerant-heat exchanger 32 is connected to the gas-liquid separator 31 and to the first relay expansion valve 33 and allows the liquid refrigerant obtained in the gas-liquid separator 31 to flow through. The secondary-side passage of the first refrigerant-heat exchanger 32 is connected to a secondary-side passage of the second refrigerant-heat exchanger 34 and to the low-pressure pipe 102 and allows the refrigerant discharged from the secondary-side passage of the second refrigerant-heat exchanger 34 to flow through.

[0031] The first relay expansion valve 33 is connected to the primary-side passage of the first refrigerant-heat exchanger 32 and to a primary-side passage of the second refrigerant-heat exchanger 34. The first relay expansion valve 33 is configured to depressurize and expand the refrigerant by adjusting the flow rate of the refrigerant. The first relay expansion valve 33 is, for example, an electronic expansion valve whose opening degree is controllable. In such a case, the opening degree of the first relay expansion valve 33 is controlled by the controller 40. The first relay expansion valve 33 is not limited to the above and may be any other expansion device such as a capillary.

[0032] The second refrigerant-heat exchanger 34 includes the primary-side passage and the secondary-side passage. Refrigerant flowing in the primary-side passage and refrigerant flowing in the secondary-side passage are caused to exchange heat with each other, whereby the refrigerant flowing in the primary-side passage is subcooled. The primary-side passage of the second refrigerant-heat exchanger 34 is connected to the first relay expansion valve 33 and allows the refrigerant discharged from the first relay expansion valve 33 to flow through. The secondary-side passage of the second refrigerant-heat exchanger 34 is connected to the second relay expansion valve 35 and to the secondary-side passage of the first refrigerant-heat exchanger 32 and allows the refrigerant discharged from the second relay expansion valve 35 to flow through.

[0033] The second relay expansion valve 35 is provided to the branch pipe 107 and its downstream end is connected to the secondary-side passage of the second refrigerant-heat exchanger 34. The second relay expansion valve 35 is configured to depressurize and expand the refrigerant by adjusting the flow rate of the refrigerant. The second relay expansion valve 35 is, for example, an electronic expansion valve whose opening degree is controllable. In such a case, the opening degree of the second relay expansion valve 35 is controlled by the controller 40. The second relay expansion valve 35 is not limited to the above and may be any other expansion device such as a capillary.

[0034] The check valves 36 each allow the refrigerant in the refrigerant circuit to flow only in a predetermined direction. The check valves 36 are provided in number relative to the number of the indoor units 20. Specifically, in the example illustrated in Fig. 1, check valves 36a1 and 36a2 are provided for the indoor unit 20a. The check valves 36b1 and 36b2 are provided for the indoor unit 20b. The check valves 36c1 and 36c2 are provided for the indoor unit 20c. The check valves 36d1 and 36d2 are provided for the indoor unit 20d. The check valves 36e1 and 36e2 are provided for the indoor unit 20e.

[0035] The check valves 36a1, 36b1, 36c1, 36d1, and 36e1 are each located between a corresponding one of the indoor units 20a to 20e and the merging pipe 108. The check valves 36a1, 36b1, 36c1, 36d1, and 36e1 each allow the refrigerant to flow from a corresponding one of the indoor units 20a to 20e toward the merging pipe 108.

[0036] The check valves 36a2, 36b2, 36c2, 36d2, and 36e2 are each located between the downstream end of the primary-side passage of the second refrigerant-heat exchanger 34 and a corresponding one of the indoor units 20a to 20e. The check valves 36a2, 36b2, 36c2, 36d2, and 36e2 each allow the refrigerant to flow from the second refrigerant-heat exchanger 34 toward a corresponding one of the indoor units 20a to 20e.

[0037] The three-way linear expansion valves 37 are each connected to a corresponding one of the indoor units 20, to the low-pressure pipe 102, and to the gas pipe 105 and are each configured to switch directions of the refrigerant flow according to the operating state of the corresponding indoor unit 20. Specifically, when the corresponding indoor unit 20 is operated to perform a cooling operation, the three-way linear expansion valve 37 switches its connection to the one that allows the indoor unit 20 to communicate with the low-pressure pipe 102. On the other hand, when the corresponding indoor unit 20 is operated to perform a heating operation, the three-way linear expansion valve 37 switches its connection to the one that allows the gas pipe 105 to communicate with the indoor unit 20.

[0038] The three-way linear expansion valves 37 each also have a function of depressurizing and expanding the refrigerant by adjusting the flow rate of the refrigerant. The three-way linear expansion valves 37 are, for example, electronic expansion valves whose opening degrees are controllable. The switching and the opening degrees of the three-way linear expansion valves 37 are controlled by the controller 40.

[0039] The three-way linear expansion valves 37 are provided in number relative to the number of the indoor units 20. Specifically, in the example illustrated in Fig. 1, three-way linear expansion valves 37a to 37e are provided for the respective indoor units 20a to 20e.

(Controller 40)

[0040] The controller 40 is configured to control the entirety of the refrigerating and air-conditioning apparatus 100. For example, the controller 40 controls the refrigerant-flow switching device 12, the outdoor expansion valve 14, the indoor expansion valves 21, the first relay expansion valve 33, the second relay expansion valve 35, the three-way linear expansion valves 37, and other relevant devices according to the operating state of the refrigerating and air-conditioning apparatus 100. In particular, the controller 40 according to Embodiment 1 is configured to control the opening degrees of the three-way linear expansion valves 37 to execute an evaporating-temperature-adjusting process, in which the evaporating temperatures of the indoor heat exchangers 22 provided in the respective indoor units 20 are adjusted individually. Furthermore, the controller 40 is configured to execute a liquid-carryover-prevention process, in which the occurrence of a liquid carryover into the compressor 11 is prevented. These processes will be described in detail separately below.

[0041] Fig. 2 is a functional block diagram illustrating an exemplary configuration of the controller illustrated in Fig. 1. As illustrated in Fig. 2, the controller 40 includes information acquisition circuitry 41, arithmetic circuitry 42, comparison circuitry 43, valve control circuitry 44, and storage circuitry 45. In the controller 40, various functions are implemented by executing pieces of software on an arithmetic device such as a microcomputer. Alternatively, for example, the controller 40 is provided as hardware such as a circuit device configured to implement various functions. Herein, among the functions of the controller 40, only those functions that are characteristic to Embodiment 1 will be described.

[0042] The information acquisition circuitry 41 is configured to acquire a suction pressure that is detected by the outdoor-side pressure sensor 17, a suction temperature that is detected by the outdoor-side temperature sensor 18, and indoor-side pressures that are detected by the respective indoor-side pressure sensors 23. The suction pressure is the pressure of the refrigerant that is sucked into the compressor 11. The suction temperature is the temperature of the refrigerant that is sucked into the compressor 11.

[0043] The arithmetic circuitry 42 is configured to derive saturation temperatures, regarded as evaporating temperatures, from the pressures acquired by the information acquisition circuitry 41. Specifically, in the evaporating-temperature-adjusting process, the arithmetic circuitry 42 derives an evaporating temperature of the indoor heat exchanger 22 of each of those indoor units 20 that are in cooling operation from a corresponding one of the indoor-side pressures detected by the indoor-side pressure sensors 23 and acquired by the information acquisition circuitry 41. On the other hand, in the liquid-carryover-prevention process, the arithmetic circuitry 42 derives an evaporating temperature from the suction pressure detected by the outdoor-side pressure sensor 17 and acquired by the information acquisition circuitry 41. Furthermore, in the liquid-carryover-prevention process, the arithmetic circuitry 42 calculates a degree of superheat from the suction temperature detected by the outdoor-side temperature sensor 18 and acquired by the information acquisition circuitry 41 and the calculated evaporating temperature.

[0044] The comparison circuitry 43 is configured to compare such a value calculated by the arithmetic circuitry 42 with a corresponding one of set values stored in the storage circuitry 45. Specifically, in the evaporating-temperature-adjusting process, the comparison circuitry 43 compares the evaporating temperature derived by the arithmetic circuitry 42 with a set evaporating temperature stored in the storage circuitry 45. The set evaporating temperature is an evaporating temperature to be set for cooling a corresponding indoor space to a set temperature.

[0045] On the other hand, in the liquid-carryover-prevention process, the comparison circuitry 43 compares the degree of superheat calculated by the arithmetic circuitry 42 with a set degree of superheat stored in the storage circuitry 45. The set degree of superheat is a value that is set in advance for preventing the occurrence of a liquid carryover. The set degree of superheat is determined by, for example, the outdoor-air temperature, the refrigerant pressure, the refrigerant temperature, and any other relevant factors of the refrigerating and air-conditioning apparatus 100.

[0046] The valve control circuitry 44 is configured to control the opening degrees of the outdoor expansion valve 14, the indoor expansion valves 21, and the three-way linear expansion valves 37 with reference to the result of the comparison performed by the comparison circuitry 43. For example, in the evaporating-temperature-adjusting process, the valve control circuitry 44 controls the opening degrees of the three-way linear expansion valves 37 with reference to the result of the comparison by the comparison circuitry 43 between the evaporating temperatures and the set evaporating temperatures. On the other hand, in the liquid-carryover-prevention process, the valve control circuitry 44 controls the opening degrees of the outdoor expansion valve 14, the indoor expansion valves 21, and the three-way linear expansion valves 37 with reference to the result of the comparison by the comparison circuitry 43 between the degree of superheat and the set degree of superheat.

[0047] The storage circuitry 45 is configured to store relevant values and other pieces of information to be used by pieces of circuitry included in the controller 40. For example, the storage circuitry 45 stores in advance set evaporating temperatures to be compared by the comparison circuitry 43 with evaporating temperatures, and a set degree of superheat to be compared with the degree of superheat.

[0048] Fig. 3 illustrates an exemplary hardware configuration of the controller illustrated in Fig. 2. When the functions of the controller 40 are executed by hardware, the controller 40 illustrated in Fig. 2 is provided as a processing circuit 51 as illustrated in Fig. 3. The functions of the information acquisition circuitry 41, the arithmetic circuitry 42, the comparison circuitry 43, the valve control circuitry 44, and the storage circuitry 45 illustrated in Fig. 2 are implemented by the processing circuit 51.

[0049] When the functions are executed by hardware, the processing circuit 51 corresponds to, for example, a single circuit, a composite circuit, a programmed processor, a parallel-programmed processor, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of any of the foregoing. The functions of the information acquisition circuitry 41, the arithmetic circuitry 42, the comparison circuitry 43, the valve control circuitry 44, and the storage circuitry 45 may be implemented by respective processing circuits 51 or may collectively be implemented by a single processing circuit 51.

[0050] Fig. 4 illustrates another exemplary hardware configuration of the controller illustrated in Fig. 2. When the functions of the controller 40 are executed by software, the controller 40 illustrated in Fig. 2 is provided as a combination of a processor 52 and a memory 53 as illustrated in Fig. 4. The functions of the information acquisition circuitry 41, the arithmetic circuitry 42, the comparison circuitry 43, the valve control circuitry 44, and the storage circuitry 45 are implemented by the processor 52 and the memory 53.

[0051] When the functions are executed by software, the functions of the information acquisition circuitry 41, the arithmetic circuitry 42, the comparison circuitry 43, the valve control circuitry 44, and the storage circuitry 45 are implemented by software, firmware, or a combination of software and firmware. Such software and firmware is written as programs and is stored in the memory 53. The processor 52 is configured to implement the functions by reading and executing the programs stored in the memory 53.

[0052] The memory 53 is, for example, a nonvolatile or volatile semiconductor memory such as a random access memory (RAM), a read only memory (ROM), a flash memory, an erasable and programmable ROM (EPROM), and an electrically erasable and programmable ROM (EEPROM). The memory 53 may alternatively be, for example, a detachable recording medium such as a magnetic disk, a flexible disk, an optical disc, a compact disc (CD), a mini disc (MD), and a digital versatile disc (DVD).

[Refrigerant Behaviors in Refrigerating and Air-conditioning Apparatus 100]

[0053] Behaviors of the refrigerant in different operation modes of the refrigerating and air-conditioning apparatus 100 configured as above will be described below. The refrigerating and air-conditioning apparatus 100 according to Embodiment 1 is configured to perform any of the following operation modes: a cooling only operation, a heating only operation, a cooling main operation, and a heating main operation.

[0054] The cooling only operation is an operation in which all of the indoor units 20 perform cooling operations. The heating only operation is an operation in which all of the indoor units 20 perform heating operations. The cooling main operation is an operation performed when the cooling load generated by those indoor units 20 that perform cooling operations exceeds the heating load generated by those indoor units 20 that perform heating operations. The heating main operation is an operation performed when the heating load generated by those indoor units 20 that perform heating operations exceeds the cooling load generated by those indoor units 20 that perform cooling operations.

[0055] The cooling main operation in which the cooling load exceeds the heating load is performed when, for example, the number of the indoor units 20 that perform cooling operations is greater than the number of the indoor units 20 that perform heating operations. The heating main operation in which the heating load exceeds the cooling load is performed when, for example, the number of the indoor units 20 that perform heating operations is greater than the number of the indoor units 20 that perform cooling operations.

(Cooling Only Operation Mode)

[0056] Fig. 5 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in the cooling only operation mode. In the cooling only operation mode, all of the indoor units 20a to 20e perform cooling operations. In Fig. 5, bold lines represent the refrigerant passages in the cooling only operation mode, and arrows represent the direction in which the refrigerant flows in the refrigerant passages.

[0057] In the cooling only operation mode, the refrigerant-flow switching device 12 of the outdoor unit 10 is first controlled such that the discharge side of the compressor 11 is connected to the outdoor heat exchanger 13 while the suction side of the compressor 11 is connected to the low-pressure pipe 102. Furthermore, the three-way linear expansion valves 37a to 37e are each controlled such that the corresponding indoor unit 20 is connected to the low-pressure pipe 102.

[0058] Low-temperature and low-pressure refrigerant is compressed by the compressor 11 into high-temperature and high-pressure gas refrigerant, which is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant-flow switching device 12 and flows into the outdoor heat exchanger 13. The high-temperature and high-pressure gas refrigerant received by the outdoor heat exchanger 13 exchanges heat with outdoor air and thus transfers heat to the outdoor air and condenses into high-pressure liquid refrigerant, which is discharged from the outdoor heat exchanger 13. The high-pressure liquid refrigerant discharged from the outdoor heat exchanger 13 flows through the check valve 15a, is discharged from the outdoor unit 10, and flows into the relay unit 30.

[0059] The high-pressure liquid refrigerant received by the relay unit 30 flows through the gas-liquid separator 31 into the primary-side passage of the first refrigerant-heat exchanger 32. The liquid refrigerant received by the primary-side passage of the first refrigerant-heat exchanger 32 is subcooled by the refrigerant flowing in the secondary-side passage of the first refrigerant-heat exchanger 32 and is discharged from the primary-side passage of the first refrigerant-heat exchanger 32. The liquid refrigerant discharged from the primary-side passage of the first refrigerant-heat exchanger 32 flows through the first relay expansion valve 33 into the primary-side passage of the second refrigerant-heat exchanger 34. The liquid refrigerant received by the primary-side passage of the second refrigerant-heat exchanger 34 is further subcooled by the refrigerant flowing in the secondary-side passage of the second refrigerant-heat exchanger 34 and is discharged from the primary-side passage of the second refrigerant-heat exchanger 34.

[0060] The liquid refrigerant discharged from the primary-side passage of the second refrigerant-heat exchanger 34 is split into portions, some of which flow through the check valves 36a2, 36b2, 36c2, 36d2, and 36e2 and are discharged from the relay unit 30. The portions of the liquid refrigerant that are discharged from the relay unit 30 flow into the respective indoor units 20a to 20e. Meanwhile, the remaining portion of the liquid refrigerant that is discharged from the primary-side passage of the second refrigerant-heat exchanger 34 flows into the second relay expansion valve 35, where the remaining portion is depressurized and expanded into low-pressure gas refrigerant and flows into the branch pipe 107. Hence, the low-pressure gas refrigerant contributes to the subcooling of the refrigerant flowing from the gas-liquid separator 31 through to the first refrigerant-heat exchanger 32 and the second refrigerant-heat exchanger 34.

[0061] The portion of the liquid refrigerant that is received by the indoor unit 20a is depressurized and expanded by the indoor expansion valve 21 into low-temperature and low-pressure two-phase gas-liquid refrigerant or low-temperature and low-pressure liquid refrigerant and flows into the indoor heat exchanger 22. The low-temperature and low-pressure two-phase gas-liquid refrigerant or the low-temperature and low-pressure liquid refrigerant received by the indoor heat exchanger 22 exchanges heat with indoor air and thus receives heat from the indoor air and evaporates, thereby cooling the indoor air. Consequently, the refrigerant turns into low-pressure gas refrigerant and is discharged from the indoor heat exchanger 22. The low-pressure gas refrigerant discharged from the indoor heat exchanger 22 is then discharged from the indoor unit 20a and flows into the relay unit 30.

[0062] Likewise, the other portions of the liquid refrigerant that are received by the respective indoor units 20b to 20e each turn into low-pressure gas refrigerant are discharged from the respective indoor units 20b to 20e, and flow into the relay unit 30.

[0063] The gas refrigerant portions received by the relay unit 30 flow through the respective three-way linear expansion valves 37a to 37e and are collected into the low-pressure pipe 102. The collected low-pressure gas refrigerant in the low-pressure pipe 102 merges with the refrigerant discharged from the primary-side passage of the second refrigerant-heat exchanger 34 and flowing through the second relay expansion valve 35, the second refrigerant-heat exchanger 34, and the first refrigerant-heat exchanger 32 into the branch pipe 107. Then, the low-pressure gas refrigerant is discharged from the relay unit 30 and flows into the outdoor unit 10.

[0064] The low-pressure gas refrigerant received by the outdoor unit 10 flows through the check valve 15d, the refrigerant-flow switching device 12, and the accumulator 16 and is sucked into the compressor 11. Thereafter, the above cycle is repeated.

(Heating Only Operation Mode)

[0065] Fig. 6 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in the heating only operation mode. In the heating only operation mode, all of the indoor units 20a to 20e perform heating operations. In Fig. 6, bold lines represent the refrigerant passages in the heating only operation mode, and arrows represent the direction in which the refrigerant flows in the refrigerant passages.

[0066] In the heating only operation mode, the refrigerant-flow switching device 12 of the outdoor unit 10 is first controlled such that the discharge side of the compressor 11 is connected to the gas-liquid separator 31 of the relay unit 30 while the suction side of the compressor 11 is connected to the outdoor heat exchanger 13. Furthermore, the three-way linear expansion valves 37a to 37e are each controlled such that the gas pipe 105 is connected to the corresponding indoor unit 20.

[0067] Low-temperature and low-pressure refrigerant is compressed by the compressor 11 into high-temperature and high-pressure gas refrigerant, which is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant-flow switching device 12 and the check valve 15b, is discharged from the outdoor unit 10, and flows into the relay unit 30. The high-temperature and high-pressure gas refrigerant received by the relay unit 30 flows through the gas-liquid separator 31 and the three-way linear expansion valves 37a to 37e, is discharged from the relay unit 30, and flows into the indoor units 20a to 20e.

[0068] A portion of the high-temperature and high-pressure gas refrigerant that is received by the indoor unit 20a flows into the indoor heat exchanger 22, exchanges heat with indoor air and thus transfers heat to the indoor air and condenses, thereby heating the indoor air. Consequently, the refrigerant turns into high-pressure liquid refrigerant and is discharged from the indoor heat exchanger 22. The high-pressure liquid refrigerant discharged from the indoor heat exchanger 22 is depressurized and expanded by the indoor expansion valve 21 into medium-pressure liquid refrigerant, which is discharged from the indoor unit 20a and then flows into the relay unit 30.

[0069] Likewise, the other portions of the high-temperature and high-pressure gas refrigerant that are received by the respective indoor units 20b to 20e each turn into medium-pressure liquid refrigerant are discharged from the indoor units 20b to 20e, and flow into the relay unit 30.

[0070] The medium-pressure liquid refrigerant portions received by the relay unit 30 flow through the respective check valves 36a1, 36b1, 36c1, 36d1, and 36e1 and are collected into the merging pipe 108. Subsequently, the collected medium-pressure liquid refrigerant flows through the second refrigerant-heat exchanger 34 and flows through the second relay expansion valve 35, thereby turning into low-pressure liquid refrigerant. The low-pressure liquid refrigerant then flows through the first refrigerant-heat exchanger 32 and reaches the low-pressure pipe 102. The low-pressure liquid refrigerant received by the low-pressure pipe 102 is then discharged from the relay unit 30 and flows into the outdoor unit 10.

[0071] The low-pressure liquid refrigerant received by the outdoor unit 10 flows through the check valve 15c and the outdoor expansion valve 14 and flows into the outdoor heat exchanger 13. The low-pressure liquid refrigerant received by the outdoor heat exchanger 13 exchanges heat with outdoor air and thus receives heat from the outdoor air and evaporates. Consequently, the refrigerant turns into low-temperature and low-pressure gas refrigerant and is discharged from the outdoor heat exchanger 13. The low-temperature and low-pressure gas refrigerant discharged from the outdoor heat exchanger 13 flows through the refrigerant-flow switching device 12 and the accumulator 16 and is sucked into the compressor 11. Thereafter, the above cycle is repeated.

(Cooling Main Operation Mode)

[0072] Fig. 7 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in the cooling main operation mode. The following description relates to an exemplary case where the indoor units 20a to 20d perform cooling operations while the indoor unit 20e performs a heating operation. In Fig. 7, bold lines represent the refrigerant passages in the cooling main operation mode, and arrows represent the direction in which the refrigerant flows in the refrigerant passages.

[0073] In the cooling main operation mode, the refrigerant-flow switching device 12 of the outdoor unit 10 is first controlled such that the discharge side of the compressor 11 is connected to the outdoor heat exchanger 13 while the suction side of the compressor 11 is connected to the low-pressure pipe 102. Furthermore, the three-way linear expansion valves 37a to 37d are each controlled such that the corresponding indoor unit 20 is connected to the low-pressure pipe 102. The three-way linear expansion valve 37e is controlled such that the gas pipe 105 is connected to the corresponding indoor unit 20.

[0074] Low-temperature and low-pressure refrigerant is compressed by the compressor 11 into high-temperature and high-pressure gas refrigerant, which is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant-flow switching device 12 and flows into the outdoor heat exchanger 13. The high-temperature and high-pressure gas refrigerant received by the outdoor heat exchanger 13 exchanges heat with outdoor air and thus transfers heat to the outdoor air and condenses into high-pressure two-phase gas-liquid refrigerant, which is discharged from the outdoor heat exchanger 13. The high-pressure two-phase gas-liquid refrigerant discharged from the outdoor heat exchanger 13 flows through the check valve 15a, is discharged from the outdoor unit 10, and flows into the relay unit 30.

[0075] The high-pressure two-phase gas-liquid refrigerant received by the relay unit 30 flows into the gas-liquid separator 31, thereby being separated into high-pressure gas refrigerant and high-pressure liquid refrigerant. The high-pressure liquid refrigerant obtained in the gas-liquid separator 31 flows into the primary-side passage of the first refrigerant-heat exchanger 32.

[0076] The liquid refrigerant received by the primary-side passage of the first refrigerant-heat exchanger 32 is subcooled by the refrigerant flowing in the secondary-side passage of the first refrigerant-heat exchanger 32 and is discharged from the primary-side passage of the first refrigerant-heat exchanger 32. The liquid refrigerant discharged from the primary-side passage of the first refrigerant-heat exchanger 32 flows through the first relay expansion valve 33 into the primary-side passage of the second refrigerant-heat exchanger 34. The medium-pressure liquid refrigerant received by the primary-side passage of the second refrigerant-heat exchanger 34 is further subcooled by the refrigerant flowing in the secondary-side passage of the second refrigerant-heat exchanger 34 and is discharged from the primary-side passage of the second refrigerant-heat exchanger 34.

[0077] The liquid refrigerant discharged from the primary-side passage of the second refrigerant-heat exchanger 34 is split into portions, some of which flow through the check valves 36a2, 36b2, 36c2, and 36d2 and are discharged from the relay unit 30. The portions of the liquid refrigerant that are discharged from the relay unit 30 flow into the respective indoor units 20a to 20d. Meanwhile, the remaining portion of the liquid refrigerant that is discharged from the primary-side passage of the second refrigerant-heat exchanger 34 flows into the second relay expansion valve 35, where the remaining portion is depressurized and expanded into low-pressure gas refrigerant and flows into the branch pipe 107. Hence, the low-pressure gas refrigerant contributes to the subcooling of the refrigerant flowing from the gas-liquid separator 31 through to the first refrigerant-heat exchanger 32 and the second refrigerant-heat exchanger 34.

[0078] The portion of the liquid refrigerant that is received by the indoor unit 20a is depressurized and expanded by the indoor expansion valve 21 into low-temperature and low-pressure two-phase gas-liquid refrigerant or low-temperature and low-pressure liquid refrigerant and flows into the indoor heat exchanger 22. The low-temperature and low-pressure two-phase gas-liquid refrigerant or low-temperature and low-pressure liquid refrigerant received by the indoor heat exchanger 22 exchanges heat with indoor air and thus receives heat from the indoor air and evaporates, thereby cooling the indoor air. Consequently, the refrigerant turns into low-pressure gas refrigerant and is discharged from the indoor heat exchanger 22. The low-pressure gas refrigerant discharged from the indoor heat exchanger 22 is then discharged from the indoor unit 20a and flows into the relay unit 30.

[0079] Likewise, the other portions of the liquid refrigerant that are received by the respective indoor units 20b to 20d each turn into low-pressure gas refrigerant are discharged from the indoor units 20b to 20e, and flow into the relay unit 30. The portions of the refrigerant that are received by the relay unit 30 flow through the respective three-way linear expansion valves 37a to 37d and are collected into the low-pressure pipe 102.

[0080] Meanwhile, the high-pressure gas refrigerant obtained in the gas-liquid separator 31 flows through the three-way linear expansion valve 37e, is discharged from the relay unit 30, and flows into the indoor unit 20e that performs a heating operation. The high-temperature and high-pressure gas refrigerant received by the indoor unit 20e flows into the indoor heat exchanger 22, exchanges heat with indoor air and thus transfers heat to the indoor air and condenses, thereby heating the indoor air. Consequently, the refrigerant turns into high-pressure liquid refrigerant and is discharged from the indoor heat exchanger 22. The high-pressure liquid refrigerant discharged from the indoor heat exchanger 22 is depressurized and expanded by the indoor expansion valve 21 into liquid refrigerant, which is discharged from the indoor unit 20e and then flows into the relay unit 30.

[0081] The refrigerant received by the relay unit 30 flows through the check valve 36e1 into the merging pipe 108. Then, the refrigerant flows through the second refrigerant-heat exchanger 34, the second relay expansion valve 35, and the first refrigerant-heat exchanger 32 and reaches the low-pressure pipe 102.

[0082] The portions of the refrigerant that are discharged from the indoor units 20a to 20d that perform cooling operations and from the indoor unit 20e that performs a heating operation as above merge together at the low-pressure pipe 102. The merged refrigerant is discharged from the relay unit 30 and then flows into the outdoor unit 10. The low-pressure gas refrigerant received by the outdoor unit 10 flows through the check valve 15d, the refrigerant-flow switching device 12, and the accumulator 16 and is sucked into the compressor 11. Thereafter, the above cycle is repeated.

(Heating Main Operation Mode)

[0083] Fig. 8 schematically illustrates the flow of refrigerant in the refrigerating and air-conditioning apparatus illustrated in Fig. 1 in a heating main operation mode. The following description relates to an exemplary case where the indoor units 20a to 20d perform heating operations while the indoor unit 20e performs a cooling operation. In Fig. 8, bold lines represent the refrigerant passages in the heating main operation mode, and arrows represent the direction in which the refrigerant flows in the refrigerant passages.

[0084] In the heating main operation mode, the refrigerant-flow switching device 12 of the outdoor unit 10 is first controlled such that the discharge side of the compressor 11 is connected to the gas-liquid separator 31 of the relay unit 30 while the suction side of the compressor 11 is connected to the outdoor heat exchanger 13. Furthermore, the three-way linear expansion valves 37a to 37d are each controlled such that the gas pipe 105 is connected to the corresponding indoor unit 20. The three-way linear expansion valve 37e is controlled such that the corresponding indoor unit 20 is connected to the low-pressure pipe 102.

[0085] Low-temperature and low-pressure refrigerant is compressed by the compressor 11 into high-temperature and high-pressure gas refrigerant, which is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 11 flows through the refrigerant-flow switching device 12 and the check valve 15b, is discharged from the outdoor unit 10, and flows into the relay unit 30. The high-temperature and high-pressure gas refrigerant received by the relay unit 30 flows through the gas-liquid separator 31 and the three-way linear expansion valves 37a to 37d, is discharged from the relay unit 30, and flows into the indoor units 20a to 20d.

[0086] A portion of the high-temperature and high-pressure gas refrigerant that is received by the indoor unit 20a flows into the indoor heat exchanger 22, exchanges heat with indoor air and thus transfers heat to the indoor air and condenses, thereby heating the indoor air. Consequently, the refrigerant turns into high-pressure liquid refrigerant and is discharged from the indoor heat exchanger 22. The high-pressure liquid refrigerant discharged from the indoor heat exchanger 22 is depressurized and expanded by the indoor expansion valve 21 into medium-pressure liquid refrigerant, which is discharged from the indoor unit 20a and then flows into the relay unit 30.

[0087] Likewise, the other portions of the high-temperature and high-pressure gas refrigerant that are received by the respective indoor units 20b to 20d each turn into medium-pressure liquid refrigerant are discharged from the indoor units 20b to 20d, and flow into the relay unit 30.

[0088] The medium-pressure liquid refrigerant portions received by the relay unit 30 flow through the respective check valves 36a1, 36b1, 36c1, and 36d1 and are collected into the merging pipe 108. Then, the collected refrigerant flows into the primary-side passage of the second refrigerant-heat exchanger 34. The low-pressure liquid refrigerant received by the primary-side passage of the second refrigerant-heat exchanger 34 is subcooled by the refrigerant flowing in the secondary-side passage of the second refrigerant-heat exchanger 34 and is discharged from the primary-side passage of the second refrigerant-heat exchanger 34.

[0089] The medium-pressure liquid refrigerant discharged from the primary-side passage of the second refrigerant-heat exchanger 34 is split into portions, one of which flows through the check valve 36e2 and is discharged from the relay unit 30. The portion of the liquid refrigerant that is discharged from the relay unit 30 flows into the corresponding indoor unit 20e that performs a cooling operation. Meanwhile, the remaining portion of the medium-pressure liquid refrigerant that is discharged from the primary-side passage of the second refrigerant-heat exchanger 34 flows through the branch pipe 107 into the secondary-side passage of the second refrigerant-heat exchanger 34.

[0090] The portion of the low-pressure liquid refrigerant that is received by the indoor unit 20e is depressurized and expanded by the indoor expansion valve 21 into low-pressure two-phase gas-liquid refrigerant or low-pressure liquid refrigerant and flows into the indoor heat exchanger 22. The low-pressure two-phase gas-liquid refrigerant or the low-pressure liquid refrigerant received by the indoor heat exchanger 22 exchanges heat with indoor air and thus receives heat from the indoor air and evaporates, thereby cooling the indoor air. Consequently, the refrigerant turns into low-pressure gas refrigerant and is discharged from the indoor heat exchanger 22. The low-pressure gas refrigerant discharged from the indoor heat exchanger 22 is then discharged from the indoor unit 20e and flows into the relay unit 30. The gas refrigerant received by the relay unit 30 flows through the three-way linear expansion valve 37e and reaches into the low-pressure pipe 102.

[0091] The low-pressure gas refrigerant in the low-pressure pipe 102 merges with the refrigerant discharged from the primary-side passage of the second refrigerant-heat exchanger 34 and flowing through the second relay expansion valve 35, the second refrigerant-heat exchanger 34, and the first refrigerant-heat exchanger 32 into the branch pipe 107. Then, the low-pressure gas refrigerant is discharged from the relay unit 30 and flows into the outdoor unit 10.

[0092] The low-pressure gas refrigerant received by the outdoor unit 10 flows through the check valve 15c and the outdoor expansion valve 14 and flows into the outdoor heat exchanger 13. The low-pressure gas refrigerant received by the outdoor heat exchanger 13 exchanges heat with outdoor air and thus receives heat from the outdoor air and evaporates, thereby being further gasified. Then, the refrigerant is discharged from the outdoor heat exchanger 13. The low-temperature and low-pressure gas refrigerant discharged from the outdoor heat exchanger 13 flows through the refrigerant-flow switching device 12 and the accumulator 16 and is sucked into the compressor 11. Thereafter, the above cycle is repeated.

[Evaporating-temperature-adjusting Process]

[0093] The evaporating-temperature-adjusting process according to Embodiment 1 will be described below. In a refrigerating and air-conditioning apparatus, to prevent the freezing of the pipes of the indoor units, factors such as the driving frequency of the compressor and the opening degrees of the expansion valves are usually controlled such that the evaporating temperatures become 0 degrees C. On the other hand, as the length of the pipe provided between each indoor unit and the outdoor unit increases, the pressure loss increases, which raises the evaporating temperature of the indoor unit. Therefore, in the operation modes of the refrigerating and air-conditioning apparatus that involve cooling operations; particularly, in the heating main operation, an indoor unit that is connected to the outdoor unit by the shortest pipe among those indoor units that perform cooling operations marks the lowest evaporating temperature compared with the evaporating temperatures of the other indoor units, and the lowest evaporating temperature may be below 0 degrees C. When the evaporating temperature of any indoor unit is below 0 degrees C, the pipe connected to the indoor unit is frozen and may be damaged.

[0094] To prevent the occurrence of such freezing of the pipe, in a known refrigerating and air-conditioning apparatus, the opening degree of the expansion valve included in the outdoor unit is adjusted according to the evaporating temperature of the indoor unit that has the shortest connection pipe among those indoor units that perform cooling operations. However, such a configuration raises the evaporating temperatures of the other indoor units that perform cooling operations. Consequently, the cooling capacity may become short when the cooling load is high, resulting in incapability of satisfactory cooling of the indoor spaces.

[0095] In Embodiment 1, when a plurality of indoor units 20 perform cooling operations, the evaporating-temperature-adjusting process is thus executed in which the evaporating temperatures of the indoor units 20 are individually adjusted by controlling the opening degrees of the three-way linear expansion valves 37 provided in the relay unit 30.

[0096] Fig. 9 is a flow chart illustrating an exemplary flow of the evaporating-temperature-adjusting process according to Embodiment 1. In step S1, the controller 40 checks whether the current operation is any of the heating main operation, the cooling main operation, and the cooling only operation. When the current operation is any of the heating main operation, the cooling main operation, and the cooling only operation (YES in step S1), the valve control circuitry 44 of the controller 40 sets in step S2 the opening degrees of all of the three-way linear expansion valves 37a to 37e to respective initial opening degrees. The initial opening degrees of the three-way linear expansion valves 37a to 37e are predetermined opening degrees and are set according to the capacities of the respective three-way linear expansion valves 37a to 37e.

[0097] When the current operation is none of the heating main operation, the cooling main operation, and the cooling only operation; that is, when the current operation is the heating only operation (NO in step S1), the process ends.

[0098] In step S3, the indoor-side pressure sensors 23 provided in the respective indoor units 20a to 20e detect respective indoor-side pressures. The information acquisition circuitry 41 acquires the indoor-side pressures detected by the indoor-side pressure sensors 23. The pressures thus acquired are regarded as being equivalent to the evaporating pressures of the corresponding indoor heat exchangers 22.

[0099] For example, under an atmospheric pressure of 1 or below, water boils at 100 degrees C and reaches a two-phase gas-liquid state. It is known that the pressure and the temperature in the two-phase gas-liquid state usually have a correlation with each other. In the two-phase gas-liquid state, one of the pressure and the temperature can be derived from the other. The arithmetic circuitry 42 thus utilizes such a relationship between the pressure and the temperature to derive evaporating temperatures from the evaporating pressures.

[0100] In step S4, for those indoor units 20 that are in cooling operation, the arithmetic circuitry 42 converts each of the pressures acquired as the evaporating pressures in step S3 into an evaporating temperature of a corresponding one of the indoor heat exchangers 22. Thus, the evaporating temperature is derived.

[0101] In step S5, the comparison circuitry 43 checks whether the evaporating temperature of the indoor heat exchanger 22 of each of those indoor units 20 that are in cooling operation is higher than or equal to a corresponding one of the predetermined set evaporating temperatures. When the evaporating temperature is below the set evaporating temperature (NO in step S5), the process proceeds to step S6, in which the valve control circuitry 44 reduces by a set opening degree the opening degree of a corresponding one of the three-way linear expansion valves 37 such that the evaporating temperature approaches the set evaporating temperature.

[0102] For example, when the indoor unit 20a is in cooling operation and the evaporating temperature of the indoor heat exchanger 22 of the indoor unit 20a is lower than the set evaporating temperature, the valve control circuitry 44 reduces by a set opening degree the opening degree of the three-way linear expansion valve 37a corresponding to the indoor unit 20a. The set opening degree in such a case is predetermined according to any factor such as the capacity of the corresponding indoor unit 20. When the evaporating temperature is higher than or equal to the set evaporating temperature (YES in step S5), the process proceeds to step S7.

[0103] In step S7, the comparison circuitry 43 checks whether the evaporating temperature of the indoor heat exchanger 22 of each of those indoor units 20 that are in cooling operation is equal to the corresponding set evaporating temperature. When the evaporating temperature is equal to the set evaporating temperature (YES in step S7), the process returns to step S3.

[0104] When the evaporating temperature is not equal to the set evaporating temperature (NO in step S7), the process proceeds to step S8, in which the valve control circuitry 44 increases by a set opening degree the opening degree of the corresponding three-way linear expansion valve 37 such that the evaporating temperature approaches the set evaporating temperature. Then, the process returns to step S3.

[0105] As described above, the opening degree of each of the three-way linear expansion valves 37 is controlled such that the evaporating temperature becomes equal to the set evaporating temperature. Thus, the evaporating temperatures of the indoor heat exchangers 22 provided in the respective indoor units 20 are individually adjustable. Therefore, cooling operations are performable according to respective air-conditioning loads that are set for individual rooms provided with the indoor units 20, avoiding a situation in the above known art that leads to incapability of satisfactory cooling of the indoor spaces.

[0106] In a heating main operation, for example, cooling operations may be performed in a room with a low air-conditioning load such as a server room and in a room with a high air-conditioning load such as a residential space, while heating operations may be performed in the other rooms. Even in such a case, cooling operations suited for the air-conditioning loads of the individual rooms are achieved through the execution of the evaporating-temperature-adjusting process. The above opening-degree control is applicable not only to the heating main operation but also to the cooling main operation and to the cooling only operation.

[0107] While the present example relates to a case where the evaporating temperatures of the indoor heat exchangers 22 are derived from the indoor-side pressures detected by the indoor-side pressure sensors 23, such a method is not the only example. For example, a thermocouple may be placed inside the pipe of each indoor heat exchanger 22 to directly detect refrigerant temperature regarded as evaporating temperature. Alternatively, for example, a thermocouple may be pasted to the outer wall of the pipe to detect refrigerant temperature.

[Liquid-carryover-prevention Process]

[0108] The liquid-carryover-prevention process will be described below. When the refrigerating and air-conditioning apparatus 100 causes a liquid carryover in which liquid refrigerant is sucked into the compressor 11 provided in the outdoor unit 10, the compressor 11 may fail.

[0109] In Embodiment 1, the liquid-carryover-prevention process is thus executed in which suction of liquid refrigerant into the compressor 11 is prevented. In the liquid-carryover-prevention process, a first liquid-carryover-prevention process is executed when the operation mode of the refrigerating and air-conditioning apparatus 100 is the heating main operation or the heating only operation, whereas a second liquid-carryover-prevention process is executed when the operation mode is the cooling main operation or the cooling only operation.

[0110] Fig. 10 is a flow chart illustrating an exemplary flow of the liquid-carryover-prevention process according to Embodiment 1. In step S100, the controller 40 checks whether the operation mode of the refrigerating and air-conditioning apparatus 100 is the heating main operation or the heating only operation.

[0111] When the operation mode is the heating main operation or the heating only operation (YES in step S100), the controller 40 executes the first liquid-carryover-prevention process in step S10. When the operation mode is neither the heating main operation nor the heating only operation; that is, when the operation mode is the cooling main operation or the cooling only operation (NO in step S100), the controller 40 executes the second liquid-carryover-prevention process in step S30.

(First Liquid-carryover-prevention Process)

[0112] Fig. 11 is a flow chart illustrating an exemplary flow of the first liquid-carryover-prevention process illustrated in Fig. 10. In step S11, the outdoor-side pressure sensor 17 provided in the outdoor unit 10 detects a suction pressure P17 of the refrigerant that is sucked into the compressor 11. The information acquisition circuitry 41 acquires the suction pressure P17 detected by the outdoor-side pressure sensor 17. When the operation mode is the heating main operation or the heating only operation, the suction pressure P17 thus acquired is regarded as being equivalent to the evaporating pressure of the outdoor heat exchanger 13.

[0113] In step S12, the outdoor-side temperature sensor 18 provided in the outdoor unit 10 detects a suction temperature T18 of the refrigerant that is sucked into the compressor 11. The information acquisition circuitry 41 acquires the suction temperature T18 detected by the outdoor-side temperature sensor 18.

[0114] In step S13, the arithmetic circuitry 42 converts the suction pressure P17 acquired as the evaporating pressure in step S11 into an evaporating temperature Te of the outdoor heat exchanger 13. Thus, the evaporating temperature Te is derived. In step S14, the arithmetic circuitry 42 calculates a degree of superheat SH1 (= T18 - Te) of the refrigerant that is sucked into the compressor 11 from the suction temperature T18 acquired in step S12 and the evaporating temperature Te derived in step S13.

[0115] In step S15, the comparison circuitry 43 checks whether the degree of superheat SH1 is lower than or equal to the set degree of superheat. When the degree of superheat SH1 is lower than or equal to the set degree of superheat (YES in step S15), the process proceeds to step S16. When the degree of superheat SH1 is below the set degree of superheat (NO in step S15), the process returns to step S11.

[0116] In step S16, the valve control circuitry 44 reduces by a set opening degree the opening degree of the three-way linear expansion valve 37 corresponding to each of those indoor units 20 that are in cooling operation such that a liquid carryover of the refrigerant to be sucked into the compressor 11 does not occur. The set opening degree in such a case is predetermined according to any factors such as the amount of refrigerant in the refrigerating and air-conditioning apparatus 100, the outdoor-air temperature, the refrigerant pressure, and the refrigerant temperature.

[0117] In step S17, the outdoor-side pressure sensor 17 detects a suction pressure P17, and the information acquisition circuitry 41 acquires the suction pressure P17 detected by the outdoor-side pressure sensor 17. In step S18, the outdoor-side temperature sensor 18 detects a suction temperature T18, and the valve control circuitry 44 acquires the suction temperature T18 detected by the outdoor-side temperature sensor 18.

[0118] In step S19, the arithmetic circuitry 42 converts the suction pressure P17 acquired in step S17 into an evaporating temperature Te of the outdoor heat exchanger 13. Thus, the evaporating temperature Te is derived. In step S20, the arithmetic circuitry 42 calculates a degree of superheat SH1 from the suction temperature T18 acquired in step S18 and the evaporating temperature Te derived in step S19.

[0119] In step S21, the comparison circuitry 43 checks whether the degree of superheat SH1 is lower than or equal to the set degree of superheat. When the degree of superheat SH1 is lower than or equal to the set degree of superheat (YES in step S21), the process proceeds to step S22. When the degree of superheat SH1 is below the set degree of superheat (NO in step S21), the process returns to step S11.

[0120] In step S22, the valve control circuitry 44 reduces by a set opening degree the opening degree of the outdoor expansion valve 14 provided in the outdoor unit 10 such that a liquid carryover of the refrigerant that is to be sucked into the compressor 11 does not occur. Then, the process returns to step S11.

[0121] As described above, in Embodiment 1, when the heating main operation or the heating only operation is being performed, the first liquid-carryover-prevention process is executed. Thus, the liquid refrigerant is assuredly gasified before the refrigerant is sucked into the compressor 11. Therefore, the occurrence of a failure of the compressor 11 is prevented.

[0122] In the heating main operation or the heating only operation, the first liquid-carryover-prevention process is executed simultaneously with the above-described evaporating-temperature-adjusting process. In such a case, the two processes each include a step of controlling the opening degrees of the three-way linear expansion valves 37. When the degree of superheat SH1 of the refrigerant that is sucked into the compressor 11 is below the set degree of superheat, priority is given to the protection of the compressor 11. That is, priority is given to the control of the opening degrees of the three-way linear expansion valves 37 in step S16 of the first liquid-carryover-prevention process.

(Second Liquid-carryover-prevention Process)

[0123] Fig. 12 is a flow chart illustrating an exemplary flow of the second liquid-carryover-prevention process illustrated in Fig. 10. In step S31, the outdoor-side pressure sensor 17 provided in the outdoor unit 10 detects a suction pressure P17 of the refrigerant that is sucked into the compressor 11. The information acquisition circuitry 41 acquires the suction pressure P17 detected by the outdoor-side pressure sensor 17.

[0124] In step S32, the outdoor-side temperature sensor 18 provided in the outdoor unit 10 detects a suction temperature T18 of the refrigerant that is sucked into the compressor 11. The information acquisition circuitry 41 acquires the suction temperature T18 detected by the outdoor-side temperature sensor 18.

[0125] In step S33, the arithmetic circuitry 42 converts the suction pressure P17 acquired in step S11 into an evaporating temperature Te of the outdoor heat exchanger 13. Thus, the evaporating temperature Te is derived. In step S34, the arithmetic circuitry 42 calculates a degree of superheat SH2 (= T18 - Te) of the refrigerant that is sucked into the compressor 11 from the suction temperature T18 acquired in step S12 and the evaporating temperature Te derived in step S13.

[0126] In step S35, the comparison circuitry 43 checks whether the degree of superheat SH2 is lower than or equal to the set degree of superheat. When the degree of superheat SH2 is lower than or equal to the set degree of superheat (YES in step S35), the process proceeds to step S36. When the degree of superheat SH2 is below the set degree of superheat (NO in step S35), the process returns to step S31.

[0127] In step S36, the valve control circuitry 44 reduces by a set opening degree the opening degree of the indoor expansion valve 21 of each of those indoor units 20 that are in heating operation such that a liquid carryover of the refrigerant that is to be sucked into the compressor 11 does not occur.

[0128] In step S37, the outdoor-side pressure sensor 17 detects a suction pressure P17, and the information acquisition circuitry 41 acquires the suction pressure P17 detected by the outdoor-side pressure sensor 17. In step S38, the outdoor-side temperature sensor 18 detects a suction temperature T18, and the information acquisition circuitry 41 acquires the suction temperature T18 detected by the outdoor-side temperature sensor 18.

[0129] In step S39, the arithmetic circuitry 42 converts the suction pressure P17 acquired in step S37 into an evaporating temperature Te of the outdoor heat exchanger 13. Thus, the evaporating temperature Te is derived. In step S40, the arithmetic circuitry 42 calculates a degree of superheat SH2 from the suction temperature T18 acquired in step S38 and the evaporating temperature Te derived in step S39.

[0130] In step S41, the comparison circuitry 43 checks whether the degree of superheat SH2 is lower than or equal to the set degree of superheat. When the degree of superheat SH2 is lower than or equal to the set degree of superheat (YES in step S41), the process proceeds to step S42. When the degree of superheat SH2 is below the set degree of superheat (NO in step S41), the process returns to step S31.

[0131] In step S42, the valve control circuitry 44 reduces by a set opening degree the opening degree of the three-way linear expansion valve 37 corresponding to each of those indoor units 20 that are in cooling operation such that a liquid carryover of the refrigerant that is to be sucked into the compressor 11 does not occur. Then, the process returns to step S31.

[0132] As described above, in Embodiment 1, when the cooling main operation or the cooling only operation is being performed, the second liquid-carryover-prevention process is executed. Thus, the liquid refrigerant is assuredly gasified before the refrigerant is sucked into the compressor 11. Therefore, the occurrence of a failure of the compressor 11 is prevented.

[0133] In the cooling main operation or the cooling only operation, the second liquid-carryover-prevention process is executed simultaneously with the above-described evaporating-temperature-adjusting process. In such a case, the two processes each include a step of controlling the opening degrees of the three-way linear expansion valves 37. When the degree of superheat SH2 of the refrigerant that is sucked into the compressor 11 is below the set degree of superheat, priority is given to the protection of the compressor 11. That is, priority is given to the control of the opening degrees of the three-way linear expansion valves 37 in step S42 of the second liquid-carryover-prevention process.

[0134] As described above, in the refrigerating and air-conditioning apparatus 100 according to Embodiment 1, according to the indoor-side pressure of each of those indoor units 20 that are in cooling operation, the opening degree of a corresponding one of the three-way linear expansion valves 37 is controlled. Specifically, the indoor-side pressure of each of those indoor units 20 that are in cooling operation is used to derive an evaporating temperature, and the opening degree of a corresponding one of the three-way linear expansion valves 37 is controlled according to the result of comparison between the evaporating temperature and the set evaporating temperature. Hence, each of those indoor units 20 that are in cooling operation is subjected to adjustment of its evaporating temperature. Thus, the indoor units are controllable individually.

[0135] Furthermore, in the refrigerating and air-conditioning apparatus 100, the evaporating temperature is derived from the suction pressure, and the degree of superheat is calculated from the suction temperature and the evaporating temperature. Then, when the degree of superheat is lower than or equal to the constant degree of superheat, the opening degree of at least one of the corresponding three-way linear expansion valve 37, the outdoor expansion valve 14, and the corresponding indoor expansion valve 21 is controlled. Thus, the refrigerant that is sucked into the compressor 11 is superheated satisfactorily. Therefore, the occurrence of a liquid carryover into the compressor 11 is prevented.

Embodiment 2

[0136] Embodiment 2 will be described below. Embodiment 2 differs from Embodiment 1 in employing indoor units that are configured to take in outdoor air and to blow the outdoor air into respective rooms. In Embodiment 2, elements that are common to those described in Embodiment 1 are denoted by corresponding ones of the reference signs, and detailed description of such elements is omitted.

[Configuration of Refrigerating and Air-conditioning Apparatus 100A]

[0137] Fig. 13 is a circuit diagram illustrating an exemplary configuration of a refrigerating and air-conditioning apparatus according to Embodiment 2. A refrigerating and air-conditioning apparatus 100A according to Embodiment 2 includes an outdoor unit 10, a plurality of indoor units 120, a relay unit 30, and a controller 40. In the example illustrated in Fig. 13, the refrigerating and air-conditioning apparatus 100A includes one outdoor unit 10, five indoor units 120a to 120e, and one relay unit 30. In the refrigerating and air-conditioning apparatus 100, the outdoor unit 10, the relay unit 30, and the indoor units 120a to 120e are connected to one another by a high-pressure pipe 101 and a low-pressure pipe 102, whereby a refrigerant circuit is formed. The number of the indoor units 120 is not limited to the above and may be two or more and four or less, or six or more.

[0138] The plurality of indoor units 120a to 120e have the same configuration. Therefore, in Fig. 13, the indoor units 120c and 120d and a part of the circuit configuration of the relay unit 30 that is connected to the indoor units 120c and 120d are not illustrated. Furthermore, the circuit configurations of the indoor units 120b and 120e are the same as that of the indoor unit 120a and are therefore not illustrated.

[0139] Furthermore, the configurations of the outdoor unit 10, the relay unit 30, and the controller 40 of the refrigerating and air-conditioning apparatus 100A according to Embodiment 2 are the same as in Embodiment 1 and are not described herein.

[0140] The indoor units 120a to 120e are each configured to take in outdoor air, condition the air, and then blow the conditioned air into an indoor space, thereby cooling and heating, for example, a corresponding one of rooms 1a to 1e. Since the indoor units 120a to 120e are each configured to condition the outdoor air taken in the indoor unit and blow the conditioned air into an indoor space, the indoor units 120a to 120e are each capable of cooling or heating a corresponding one of the rooms 1a to 1e while ventilating the corresponding one of the rooms 1a to 1e.

[0141] The indoor units 120a to 120e each have an outdoor-air inlet 151, through which outdoor air is taken in; and an air outlet 152, through which air is blown out. The indoor units 120a to 120e each include an indoor expansion valve 21 and an indoor heat exchanger 122. The indoor units 120a to 120e each further include an indoor-side pressure sensor 23 and a blown-air temperature sensor 24. Hereinafter, the indoor units 120a to 120e are simply denoted as "indoor unit 120" as appropriate when the indoor units 120a to 120e do not need to be distinguished from one another.

[0142] The indoor heat exchanger 122 causes outdoor air and the refrigerant to exchange heat with each other. The outdoor air is supplied through the outdoor-air inlet 151 by an air-sending device such as a fan, which is not illustrated. Thus, heating air or cooling air to be supplied to each of the rooms 1a to 1e is generated.

[0143] The blown-air temperature sensor 24 is provided at the air outlet 152 of the indoor unit 120. The blown-air temperature sensor 24 is configured to detect a blown-air temperature, which is the temperature of air blown from the air outlet 152.

[0144] While the present example relates to a case where all indoor units included in the refrigerating and air-conditioning apparatus 100A each serve as the indoor unit 120 configured to taken in outdoor air, such a case is not the only example. For example, the refrigerating and air-conditioning apparatus 100A may include, among all the indoor units, at least one indoor unit serving as the indoor unit 120 configured to take in outdoor air, with the other indoor units each serving as the indoor unit 20 described in Embodiment 1.

[0145] In Embodiment 2, the controller 40 is configured to control the opening degrees of the indoor expansion valves 21 of the indoor units 120 and the three-way linear expansion valves 37 of the relay unit 30 such that the blown-air temperatures detected by the blown-air temperature sensors 24 of the respective indoor units 120 become equal to respective set temperatures.

[Operation of Refrigerating and Air-conditioning Apparatus 100A]

[0146] In the refrigerating and air-conditioning apparatus 100A according to Embodiment 1, the refrigerant behavior, the evaporating-temperature-adjusting process, and the liquid-carryover-prevention process are the same as in the refrigerating and air-conditioning apparatus 100 according to Embodiment 1 and are therefore not described herein.

[0147] As described above, the refrigerating and air-conditioning apparatus 100A according to Embodiment 2 includes the indoor units 120 each configured to take in outdoor air and blow the outdoor air. Thus, while the rooms provided with the indoor units 120 are ventilated, the same advantageous effects as in Embodiment 1 are produced.

Reference Signs List

[0148] 1a, 1b, 1c, 1d, 1e: room, 10: outdoor unit, 11: compressor, 12: refrigerant-flow switching device, 13: outdoor heat exchanger, 14: outdoor expansion valve, 15a, 15b, 15c, 15d, 15e: check valve, 16: accumulator, 17: outdoor-side pressure sensor, 18: outdoor-side temperature sensor, 20, 20a, 20b, 20c, 20d, 20e, 120, 120a, 120b, 120c, 120d, 120e: indoor unit, 21: indoor expansion valve, 22, 122: indoor heat exchanger, 23: indoor-side pressure sensor, 24: blown-air temperature sensor, 30: relay unit, 31: gas-liquid separator, 32: first refrigerant-heat exchanger, 33: first relay expansion valve, 34: second refrigerant-heat exchanger, 35: second relay expansion valve, 36, 36a1, 36a2, 36b1, 36b2, 36c1, 36c2, 36d1, 36d2, 36e1, 36e2: check valve, 37, 37a, 37b, 37c, 37d, 37e: three-way linear expansion valve, 40: controller, 41: information acquisition circuitry, 42: arithmetic circuitry, 43: comparison circuitry, 44: valve control circuitry, 45: storage circuitry, 51: processing circuit, 52: processor, 53: memory, 100, 100A: refrigerating and air-conditioning apparatus, 101: high-pressure pipe, 102: low-pressure pipe, 103: first connecting pipe, 104: second connecting pipe, 105: gas pipe, 106: liquid pipe, 107: branch pipe, 108: merging pipe, 151: outdoor-air inlet, 152: air outlet

Claims

1. A refrigerating and air-conditioning apparatus comprising:

   an outdoor unit including a compressor and an outdoor heat exchanger;
   a plurality of indoor units each including an indoor expansion valve and an indoor heat exchanger;
   a relay unit connected between the outdoor unit and the plurality of indoor units and including a plurality of three-way valves, the plurality of three-way valves each being configured to switch flows of refrigerant and to adjust a flow rate of the refrigerant that passes through the three-way valve, the plurality of three-way valves being provided in number relative to the number of the plurality of indoor units, the relay unit being configured to distribute the refrigerant in a low-temperature state to each of ones of the plurality of indoor units that perform cooling operations and the refrigerant in a high-

temperature state to each of ones of the plurality of indoor units that perform heating operations; and

a controller configured to control switching and opening degrees of the plurality of three-way valves,

the plurality of indoor units each including an indoor-side pressure sensor configured to detect an indoor-side pressure, the indoor-side pressure being a pressure of the refrigerant that passes through the indoor heat exchanger,

the controller being configured to control, with reference to the indoor-side pressure of each of ones of the plurality of indoor units that perform cooling operations, the opening degree of a corresponding three-way valve of the plurality of three-way valves such that the controller is configured to adjust the flow rate of the refrigerant passing through the corresponding three-way valve.

2. The refrigerating and air-conditioning apparatus of claim 1,
wherein the controller is configured to

derive from the indoor-side pressure of each of ones of the plurality of indoor units that perform cooling operations an evaporating temperature of the corresponding indoor heat exchanger,

reduce the opening degree of the corresponding three-way valve when the evaporating temperature exceeds a set evaporating temperature, which is predetermined, and

increase the opening degree of the corresponding three-way valve when the evaporating temperature is below the set evaporating temperature.

3. The refrigerating and air-conditioning apparatus of claim 1 or 2,
wherein the outdoor unit further includes

an outdoor expansion valve configured to depressurize and expand the refrigerant,

an outdoor-side pressure sensor configured to detect a suction pressure, the suction pressure being a pressure of the refrigerant that is sucked into the compressor, and

an outdoor-side temperature sensor configured to detect a suction temperature, the suction temperature being a temperature of the refrigerant that is sucked into the compressor, and

wherein the controller is configured to

derive an evaporating temperature from the suction pressure,

calculate a degree of superheat from the suction temperature and the evaporating temperature, and

control an opening degree of at least one of the corresponding three-way valve, the outdoor expansion valve, and the corresponding indoor expansion valve when the degree of superheat is lower than or equal to a set degree of superheat, which is predetermined.

4. The refrigerating and air-conditioning apparatus of claim 3, wherein the controller is configured to, in a heating main operation or in a heating only operation, reduce, when the degree of superheat is lower than or equal to the set degree of superheat, the opening degree of the three-way valve corresponding to each of ones of the plurality of indoor units that perform cooling operations.

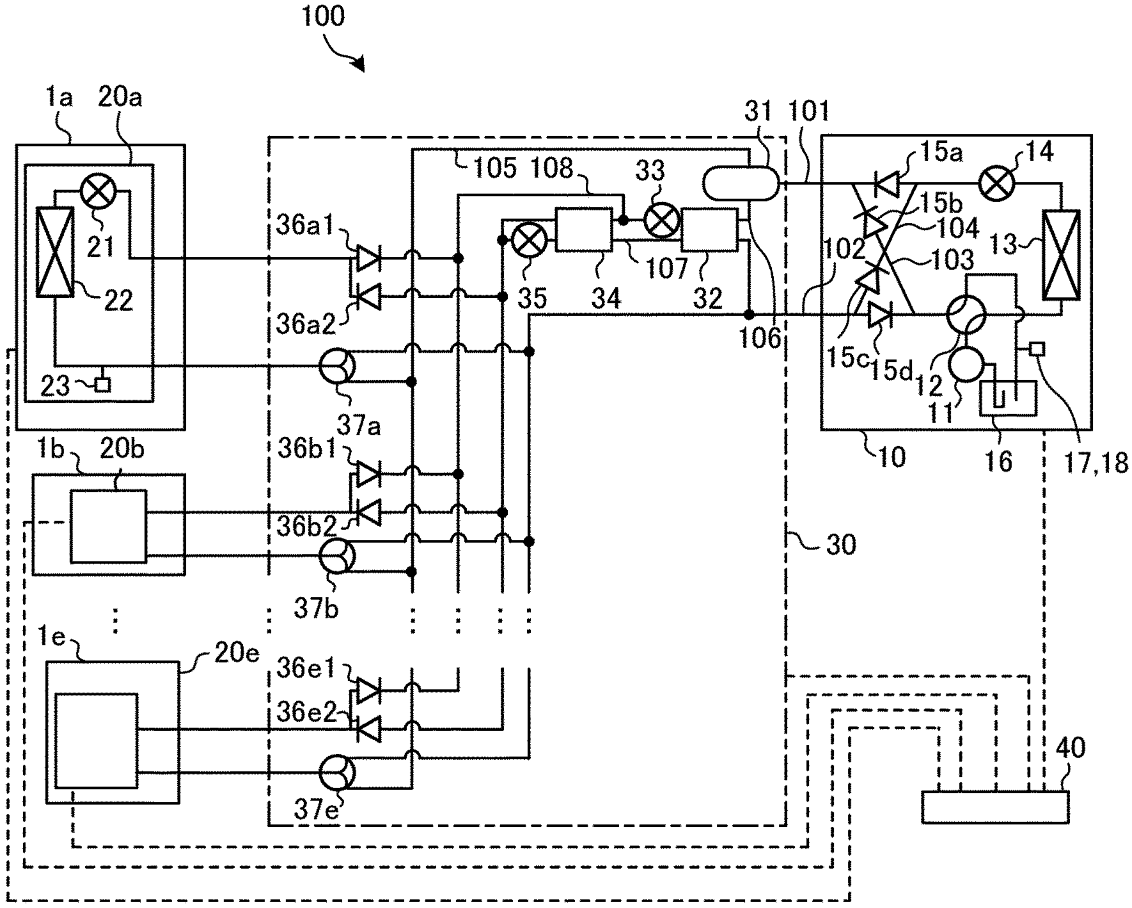
5. The refrigerating and air-conditioning apparatus of claim 4, wherein the controller is configured to reduce the opening degree of the outdoor expansion valve when the degree of superheat is lower than or equal to the set degree of superheat after the opening degree of the corresponding three-way valve is reduced.

6. The refrigerating and air-conditioning apparatus of claim 3, wherein the controller is configured to, in a cooling main operation or in a cooling only operation, reduce, when the degree of superheat is lower than or equal to the set degree of superheat, the opening degree of the indoor expansion valve of each of ones of the plurality of indoor units that perform heating operations.

7. The refrigerating and air-conditioning apparatus of claim 6, wherein the controller is configured to reduce, when the degree of superheat is lower than or equal to the set degree of superheat after the opening degree of the indoor expansion valve is reduced, the opening degree of the three-way valve corresponding to each of ones of the plurality of indoor units that perform cooling operations.

8. The refrigerating and air-conditioning apparatus of any one of claims 1 to 7, wherein at least one of the plurality of indoor units is configured to take in outdoor air and blow conditioned air to a corresponding one of the indoor spaces.

FIG. 1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20a
21
22
23
1b
20b
1e
20e
36a1
36a2
37a
36b1
36b2
37b
36e1
36e2
37e
105
108
33
31
101
35
34
107
32
106
30
15a
14
15b
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102
103
13
15c
15d
12
11
10
16
17,18
40

FIG. 2

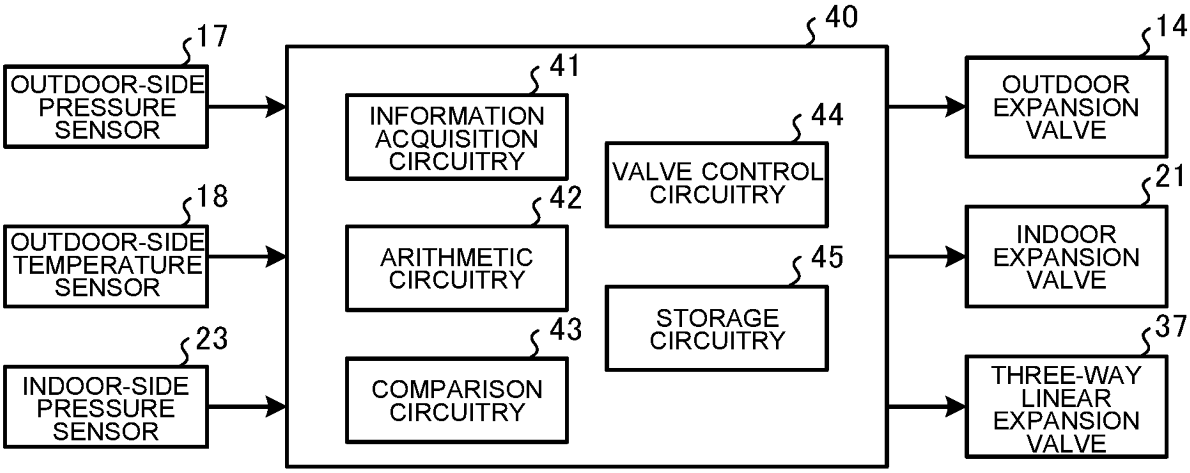

17
OUTDOOR-SIDE PRESSURE SENSOR
18
OUTDOOR-SIDE TEMPERATURE SENSOR
23
INDOOR-SIDE PRESSURE SENSOR
40
41
INFORMATION ACQUISITION CIRCUITRY
42
ARITHMETIC CIRCUITRY
43
COMPARISON CIRCUITRY
44
VALVE CONTROL CIRCUITRY
45
STORAGE CIRCUITRY
14
OUTDOOR EXPANSION VALVE
21
INDOOR EXPANSION VALVE
37
THREE-WAY LINEAR EXPANSION VALVE

FIG. 3

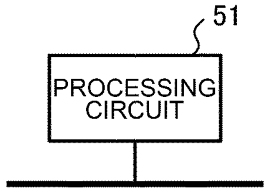


FIG. 4

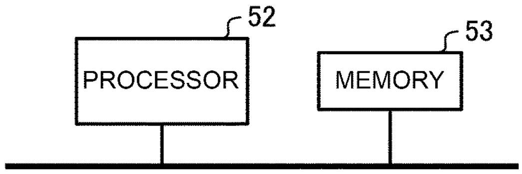


FIG. 5

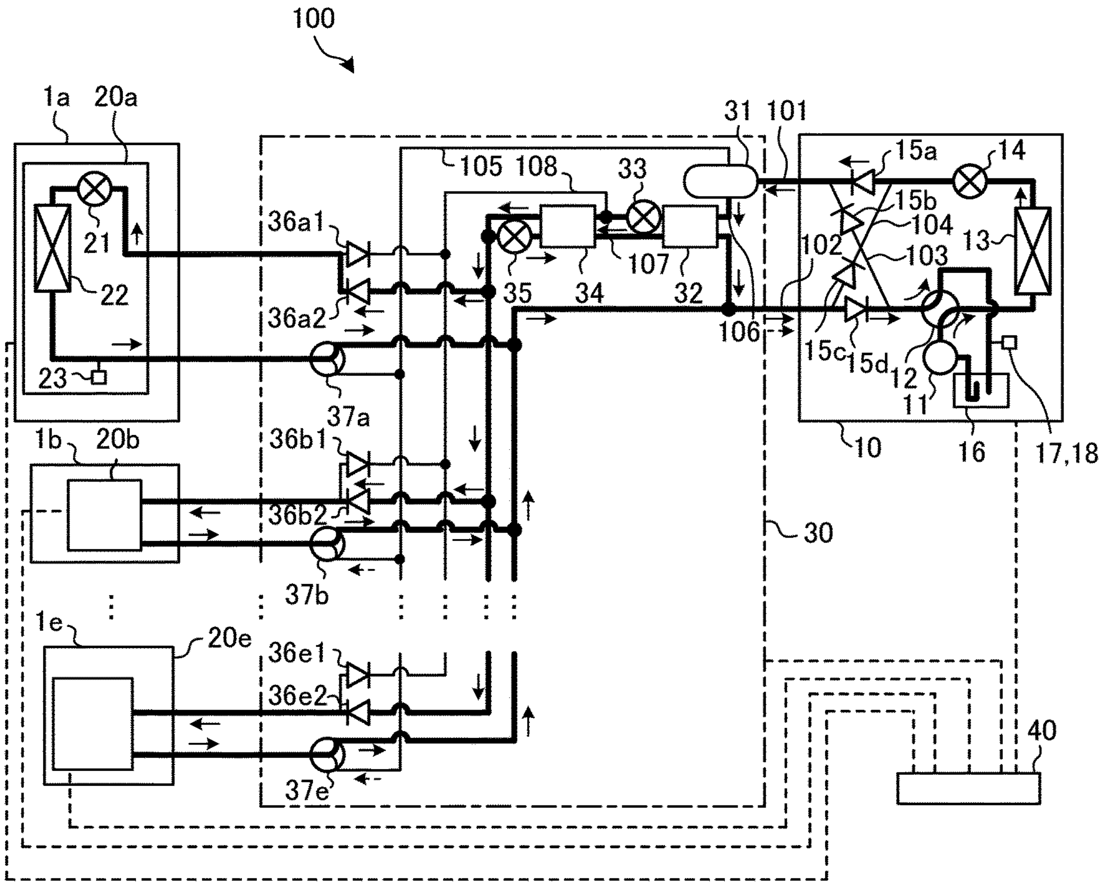
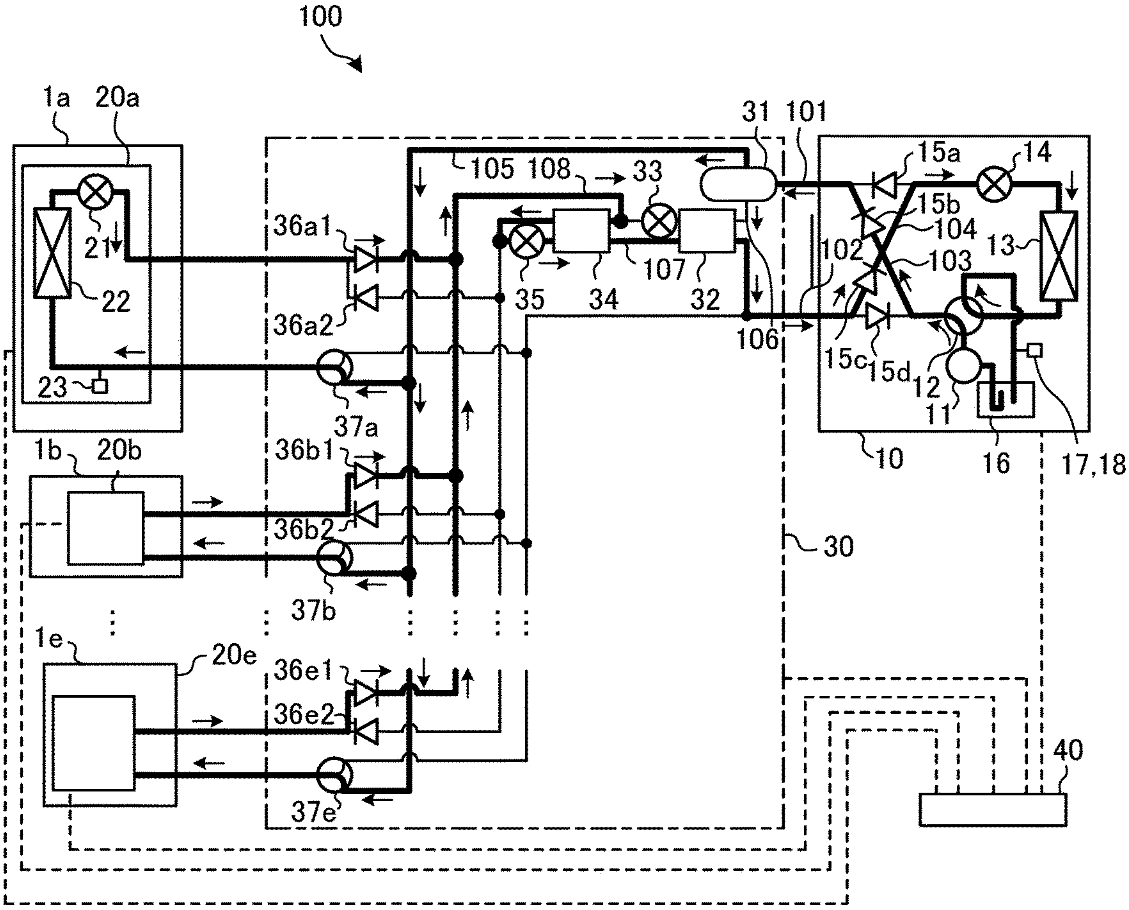


FIG. 6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36b1
36b2
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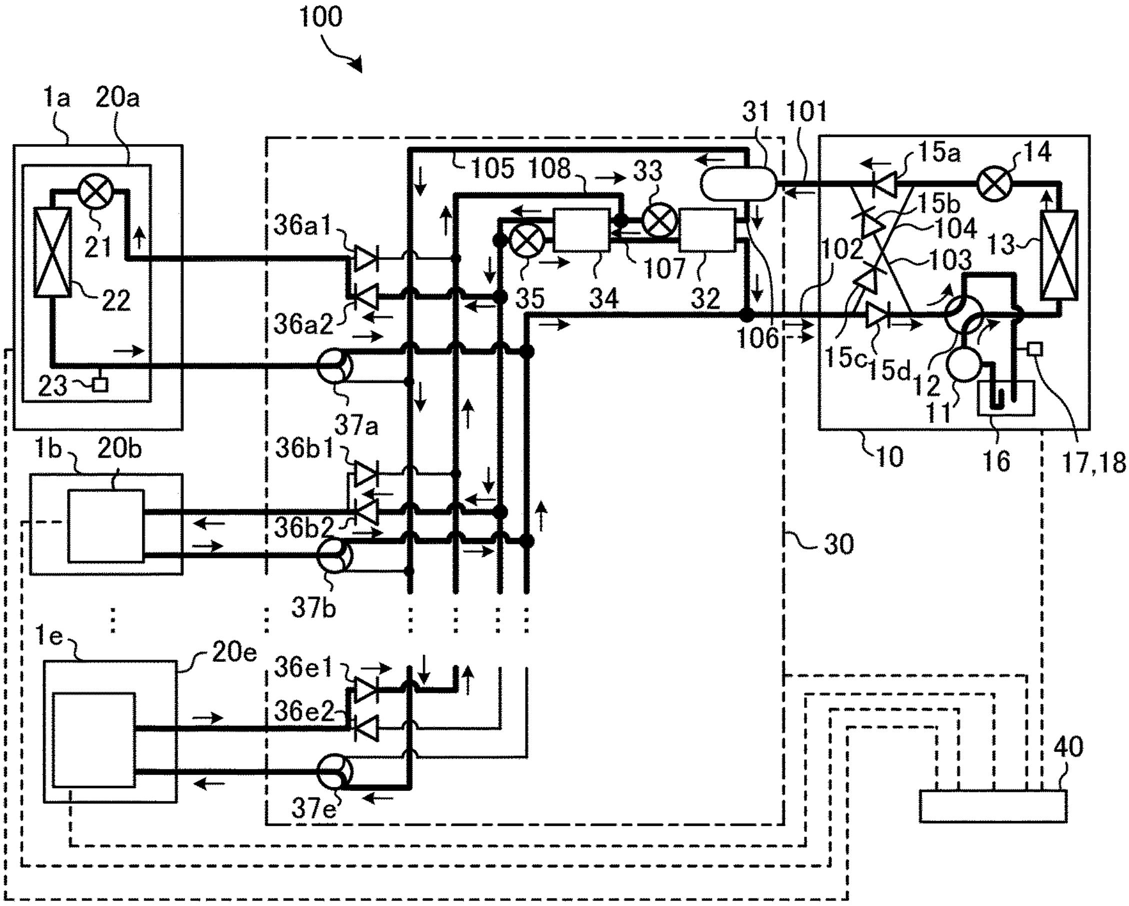
36e1
36e2
37e
105
108
33
31
101
35
34
107
32
106
30
15a
14
15b
104
102
103
13
15c
15d
12
11
10
16
17,18
40

FIG. 7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32
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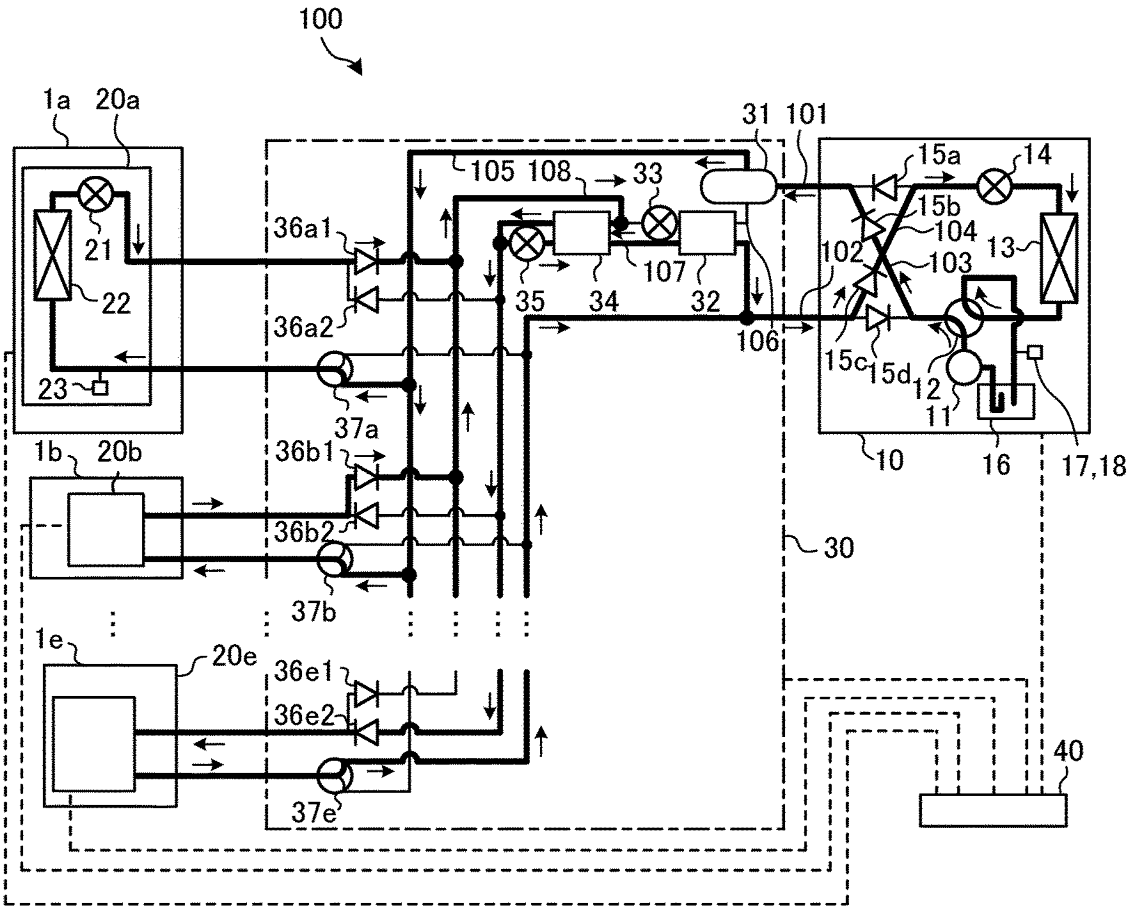
FIG. 8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32
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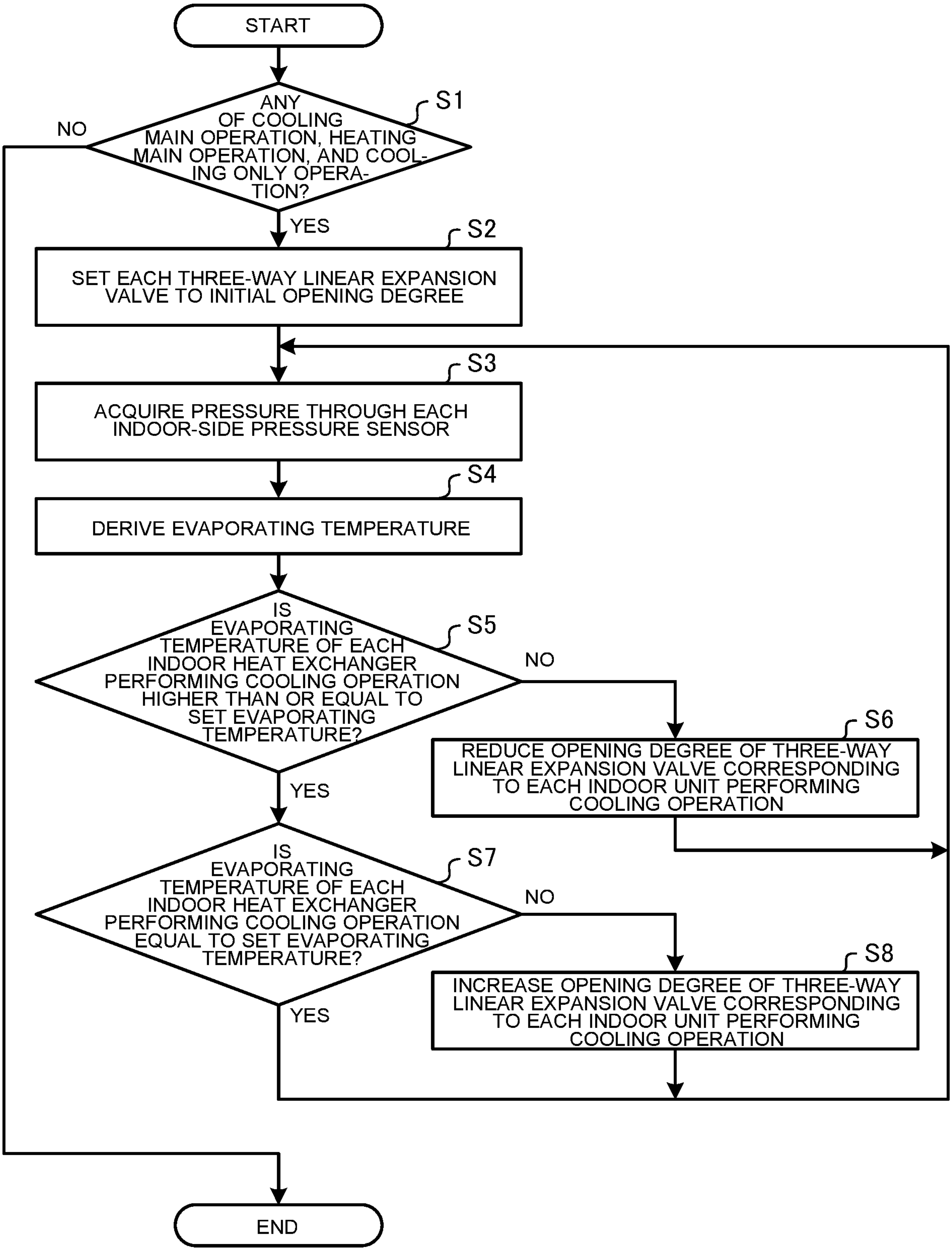
FIG. 9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ANY OF COOLING MAIN OPERATION, HEATING MAIN OPERATION, AND COOLING ONLY OPERATION?
S1
NO
YES
S2
SET EACH THREE-WAY LINEAR EXPANSION VALVE TO INITIAL OPENING DEGREE
S3
ACQUIRE PRESSURE THROUGH EACH INDOOR-SIDE PRESSURE SENSOR
S4
DERIVE EVAPORATING TEMPERATURE
IS EVAPORATING TEMPERATURE OF EACH INDOOR HEAT EXCHANGER PERFORMING COOLING OPERATION HIGHER THAN OR EQUAL TO SET EVAPORATING TEMPERATURE?
S5
NO
S6
REDUCE OPENING DEGREE OF THREE-WAY LINEAR EXPANSION VALVE CORRESPONDING TO EACH INDOOR UNIT PERFORMING COOLING OPERATION
YES
IS EVAPORATING TEMPERATURE OF EACH INDOOR HEAT EXCHANGER PERFORMING COOLING OPERATION EQUAL TO SET EVAPORATING TEMPERATURE?
S7
NO
S8
INCREASE OPENING DEGREE OF THREE-WAY LINEAR EXPANSION VALVE CORRESPONDING TO EACH INDOOR UNIT PERFORMING COOLING OPERATION
YES
END

FIG. 10

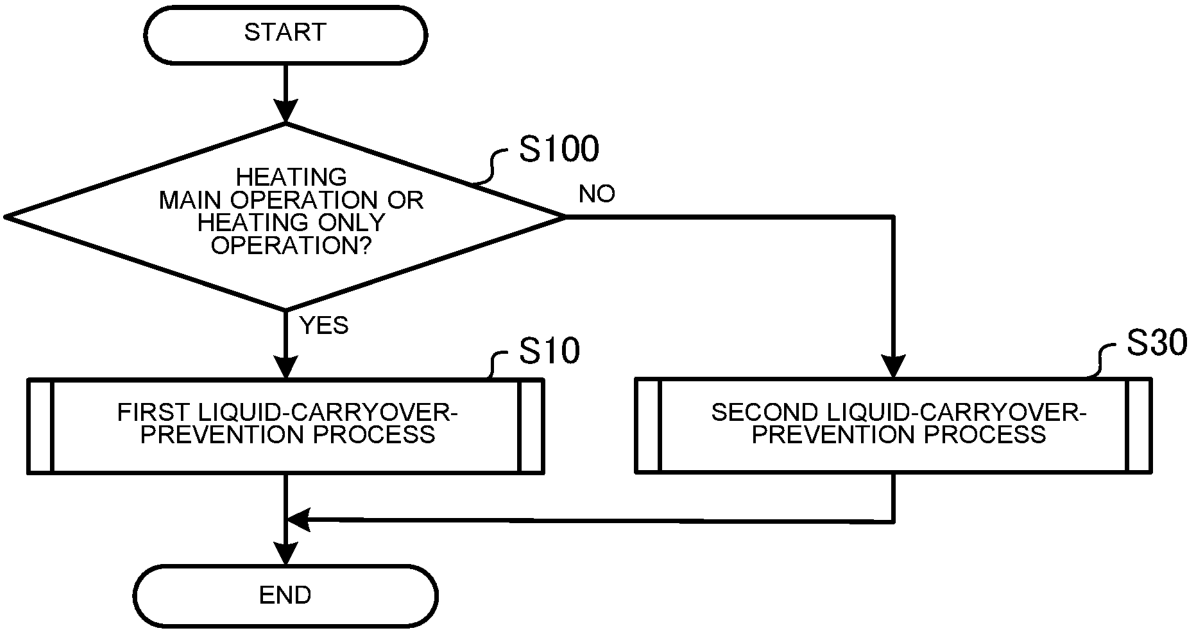
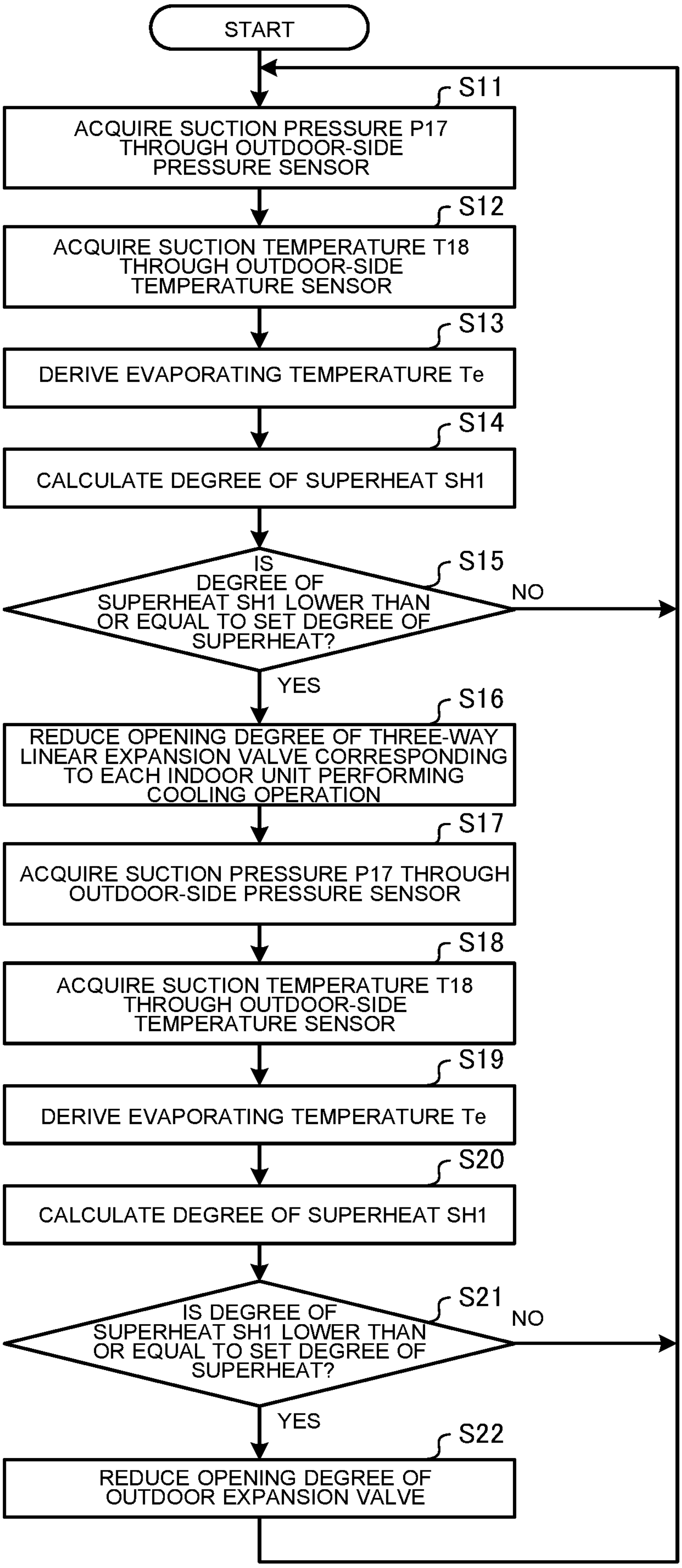

START
HEATING MAIN OPERATION OR HEATING ONLY OPERATION?
S100
NO
YES
S10
S30
FIRST LIQUID-CARRYOVER-PREVENTION PROCESS
SECOND LIQUID-CARRYOVER-PREVENTION PROCESS
END

FIG. 11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S11
ACQUIRE SUCTION PRESSURE P17 THROUGH OUTDOOR-SIDE PRESSURE SENSOR
S12
ACQUIRE SUCTION TEMPERATURE T18 THROUGH OUTDOOR-SIDE TEMPERATURE SENSOR
S13
DERIVE EVAPORATING TEMPERATURE Te
S14
CALCULATE DEGREE OF SUPERHEAT SH1
S15
IS DEGREE OF SUPERHEAT SH1 LOWER THAN OR EQUAL TO SET DEGREE OF SUPERHEAT?
NO
YES
S16
REDUCE OPENING DEGREE OF THREE-WAY LINEAR EXPANSION VALVE CORRESPONDING TO EACH INDOOR UNIT PERFORMING COOLING OPERATION
S17
ACQUIRE SUCTION PRESSURE P17 THROUGH OUTDOOR-SIDE PRESSURE SENSOR
S18
ACQUIRE SUCTION TEMPERATURE T18 THROUGH OUTDOOR-SIDE TEMPERATURE SENSOR
S19
DERIVE EVAPORATING TEMPERATURE Te
S20
CALCULATE DEGREE OF SUPERHEAT SH1
S21
IS DEGREE OF SUPERHEAT SH1 LOWER THAN OR EQUAL TO SET DEGREE OF SUPERHEAT?
NO
YES
S22
REDUCE OPENING DEGREE OF OUTDOOR EXPANSION VALVE

FIG. 12

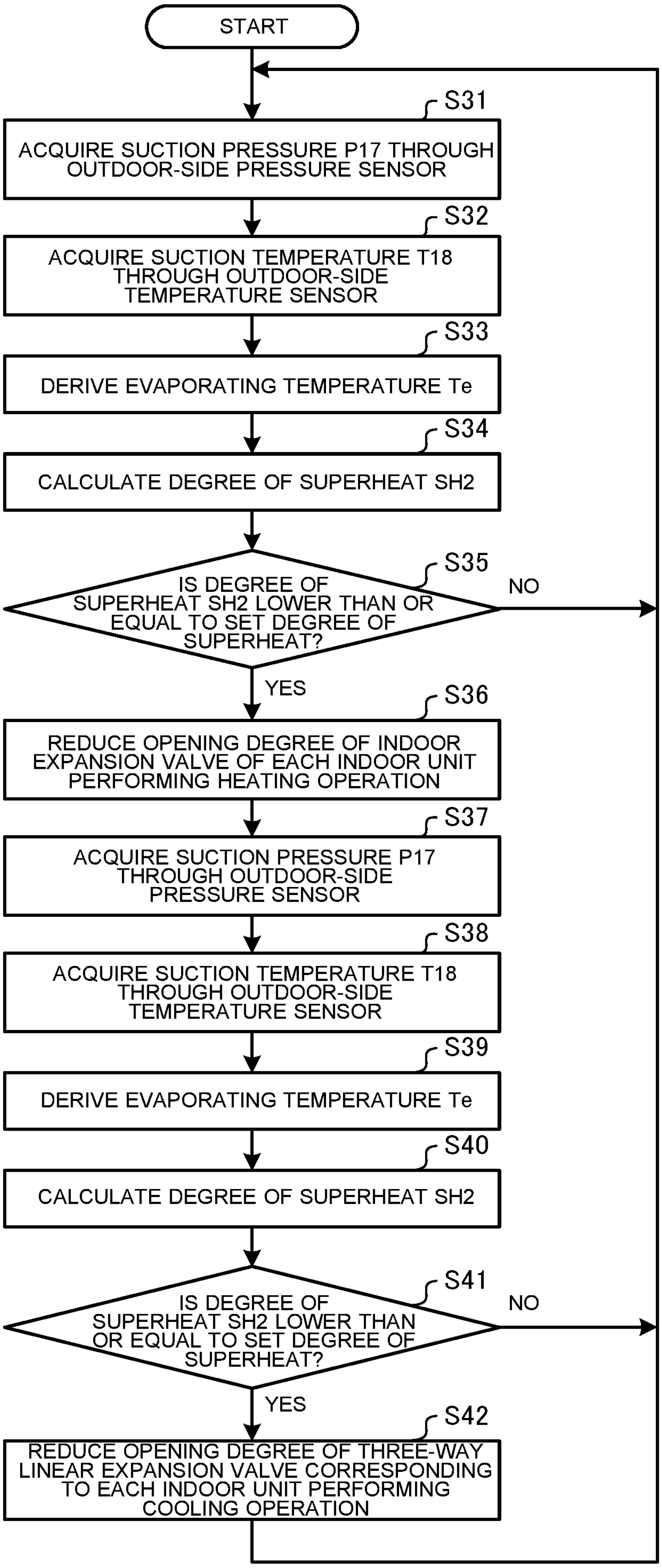
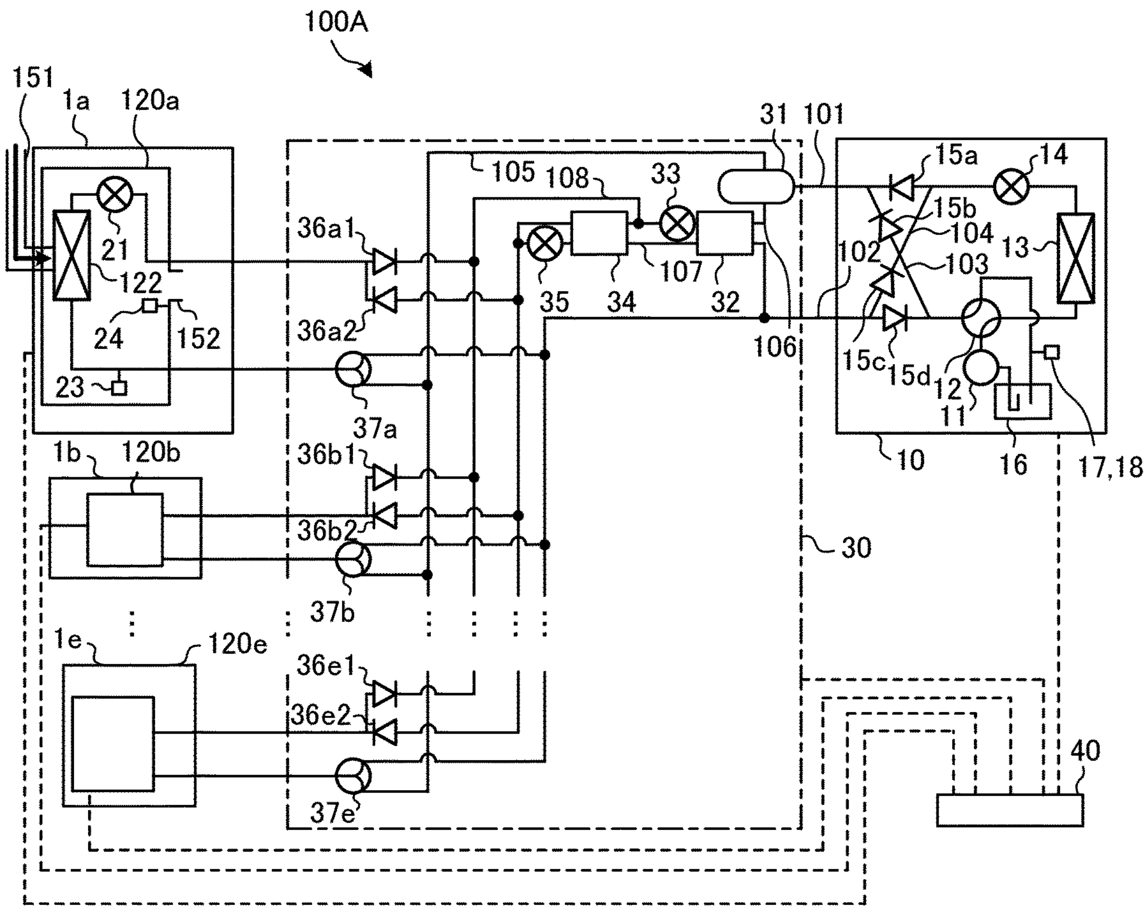

START
S31
ACQUIRE SUCTION PRESSURE P17 THROUGH OUTDOOR-SIDE PRESSURE SENSOR
S32
ACQUIRE SUCTION TEMPERATURE T18 THROUGH OUTDOOR-SIDE TEMPERATURE SENSOR
S33
DERIVE EVAPORATING TEMPERATURE Te
S34
CALCULATE DEGREE OF SUPERHEAT SH2
S35
IS DEGREE OF SUPERHEAT SH2 LOWER THAN OR EQUAL TO SET DEGREE OF SUPERHEAT?
NO
YES
S36
REDUCE OPENING DEGREE OF INDOOR EXPANSION VALVE OF EACH INDOOR UNIT PERFORMING HEATING OPERATION
S37
ACQUIRE SUCTION PRESSURE P17 THROUGH OUTDOOR-SIDE PRESSURE SENSOR
S38
ACQUIRE SUCTION TEMPERATURE T18 THROUGH OUTDOOR-SIDE TEMPERATURE SENSOR
S39
DERIVE EVAPORATING TEMPERATURE Te
S40
CALCULATE DEGREE OF SUPERHEAT SH2
S41
IS DEGREE OF SUPERHEAT SH2 LOWER THAN OR EQUAL TO SET DEGREE OF SUPERHEAT?
NO
YES
S42
REDUCE OPENING DEGREE OF THREE-WAY LINEAR EXPANSION VALVE CORRESPONDING TO EACH INDOOR UNIT PERFORMING COOLING OPERATION

FIG. 13


100A
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15c
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36b2
37b
30
1e
120e
36e1
36e2
37e
40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/001823

A. CLASSIFICATION OF SUBJECT MATTER

F25B 13/00(2006.01)i
FI: F25B13/00 104

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)

F25B13/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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.
Y	JP 2003-343936 A (MITSUBISHI ELECTRIC CORP.) 03 December 2003 (2003-12-03) paragraphs [0028]-[0030]	1-8
Y	JP 7-71839 A (MITSUBISHI ELECTRIC CORP.) 17 March 1995 (1995-03-17) paragraphs [0072], [0073]	1-8
Y	JP 59-89959 A (MATSUSHITA SEIKO KK) 24 May 1984 (1984-05-24) page 2, upper right column, line 4 to page 3, left column, line 1	2-8
Y	JP 8-145483 A (MATSUSHITA ELECTRIC IND. CO., LTD.) 07 June 1996 (1996-06-07) paragraphs [0017], [0018]	3-8
Y	JP 8-75226 A (DAIKIN IND., LTD.) 19 March 1996 (1996-03-19) paragraph [0003]	4-5, 8
Y	JP 7-305879 A (DAIKIN IND., LTD.) 21 November 1995 (1995-11-21) paragraph [0002]	6-8
Y	JP 10-325589 A (DAIKIN IND., LTD.) 08 December 1998 (1998-12-08) paragraphs [0090]-[0095]	8

☐ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
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Date of the actual completion of the international search	Date of mailing of the international search report
04 February 2022	**08 March 2022**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/001823

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