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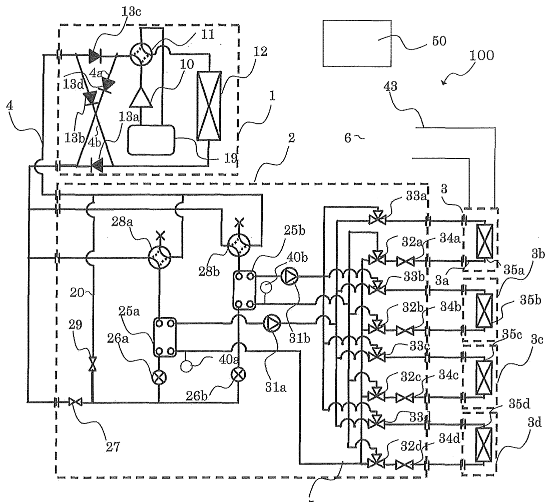
(54) AIR CONDITIONER

(57) In a case where frost is deposited a heat-source-side heat exchanger during a heating operation mode, an air-conditioning apparatus 100 executes either a "heat recovery defrosting operation mode" using a heat capacity held in a heat medium or a "bypass defrosting operation mode" not using the heat capacity held in the heat medium.

F I G. 2



EP 2 960 602 A1

Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus applied to, for example, a multi-air-conditioning apparatus for buildings.

Background Art

[0002] A conventional air-conditioning apparatus such as a multi-air-conditioning apparatus for buildings, for example, causes refrigerant to circulate between an outdoor unit, which is a heat source unit arranged outside a structure, and an indoor unit arranged inside the structure. The refrigerant transfers or receives heat, and the heated or cooled air causes air-conditioning target space to be cooled or heated. As a refrigerant used for such an air-conditioning apparatus, for example, an HFC (hydrofluorocarbon) refrigerant is often used. Furthermore, use of a natural refrigerant such as carbon dioxide (CO_2) has also been proposed.

[0003] Furthermore, in an air-conditioning apparatus called a chiller, a heat source unit arranged outside a structure generates cooling energy or heating energy. Then, a heat exchanger arranged inside the heat source unit heats or cools water, antifreeze, or the like, and the heated or cooled water, antifreeze, or the like is conveyed to a fan coil unit, a panel heater, or the like, which is an indoor unit, thereby performing cooling or heating (see, for example, Patent Literature 1).

[0004] An apparatus called an exhaust heat recovery-type chiller has also been available in which four water pipes are connected between a heat source unit and an indoor unit, cooled or heated water or the like is simultaneously supplied, and cooling or heating can be freely selected in the indoor unit (see, for example, Patent Literature 2).

[0005] An apparatus has also been available which is configured such that heat exchangers for a primary refrigerant and a secondary refrigerant are arranged in the vicinity of each indoor unit and the secondary refrigerant is conveyed to the indoor unit (see, for example, Patent Literature 3).

[0006] Furthermore, an apparatus has also been available which is configured such that an outdoor unit and a branch unit that includes a heat exchanger are connected by two pipes and a secondary refrigerant is conveyed to an indoor unit (see, for example, Patent Literature 4).

[0007] Moreover, an air-conditioning apparatus such as a multi-air-conditioning apparatus for buildings has also been available which is configured such that by causing refrigerant to circulate from an outdoor unit to a relay unit and causing a heat medium such as water to circulate from the relay unit to an indoor unit, the heat medium such as water may be caused to circulate to the indoor unit (see, for example, Patent Literature 5).

Citation List

Patent Literatures

[0008]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2005-140444 (P. 4, Fig. 1 etc.)

Patent Literature 2: Japanese Unexamined Patent Application Publication No. 5-280818 (P. 4 to 5, Fig. 1 etc.)

Patent Literature 3: Japanese Unexamined Patent Application Publication No. 2001-289465 (P. 5 to 8, Fig. 1, Fig. 2, etc.)

Patent Literature 4: Japanese Unexamined Patent Application Publication No. 2003-343936 (P. 5, Fig. 1)

Patent Literature 5: International Publication No. WO 2010/050002 (P. 11 to 15, Fig. 8 etc.)

Summary of Invention

Technical Problem

[0009] In conventional multi-air-conditioning apparatuses for buildings, since refrigerant is caused to circulate to an indoor unit, the refrigerant may be leaked to an indoor space or the like. On the other hand, in the air-conditioning apparatuses described in Patent Literature 1 and Patent Literature 2, refrigerant does not pass through an indoor unit. However, in the air-conditioning apparatuses described in Patent Literature 1 and Patent Literature 2, there is a need to heat or cool a heat medium at a heat source unit outside a structure and to convey the heated or cooled heat medium to an indoor unit side. Therefore, the length of the circulation passage for a heat medium increases. In conveying heat which functions to heat or cool an object to a certain extent using a heat medium, the energy consumption by the conveyance force or the like of the heat medium becomes greater than that of refrigerant. Therefore, the increase in the length of the circulation passage greatly increases the conveyance force. As is clear for the above, in the air-conditioning apparatuses, effectively controlling circulation of a heat medium achieves an energy saving effect.

[0010] In the air-conditioning apparatus described in Patent Literature 2, four pipes need to be used to connect an outdoor side to an indoor side so that cooling or heating may be selected for each indoor unit, thereby the workability being degraded. In the air-conditioning apparatus described in Patent Literature 3, a secondary medium circulation unit such as a pump needs to be provided for individual indoor units. Therefore, not only does the system become expensive, noise also increases. Thus, such an air-conditioning apparatus has not been practical. In addition, since a heat exchanger is provided in the vicinity of an indoor unit, it has been possible to eliminate the possibility that refrigerant may be leaked at a place near the indoor unit.

[0011] The air-conditioning apparatus described in Patent Literature 4 has a configuration which is wasteful in terms of energy since a primary refrigerant after being subjected to heat exchange flows into the same flow passage as that for a primary refrigerant before being subjected to heat exchange and each of a plurality of indoor units thus cannot exhibit the maximum performance when the plurality of indoor units are connected. Furthermore, the configuration in which the connection between a branch unit and an extension pipe is achieved using four pipes in total, that is, two pipes for cooling and two pipes for heating, is consequently similar to the configuration of the system in which an outdoor unit and a branch unit are connected by four pipes, thereby degrading the workability.

[0012] Moreover, in a known air-conditioning apparatus such as a multi-air-conditioning apparatus for buildings, frosting occurs on the surface of an outdoor heat exchanger by heat exchange with outdoor air at an outdoor unit during execution of a heating operation. Therefore, it is necessary to periodically execute a defrosting operation mode. However, during execution of a defrosting operation, a high-temperature, high-pressure refrigerant which is necessary for an indoor unit to perform a heating operation cannot be conveyed to the indoor unit. Therefore, a heating operation according to a required indoor-side heating load cannot be performed.

[0013] Moreover, even with an air-conditioning apparatus which has a function for taking in outdoor air and conveying the outdoor air toward an indoor space for the purpose of ventilation, during a defrosting operation, a blower device is stopped in order to prevent cold air from flowing toward the indoor space in accordance with the intake of the outdoor air. In the above way, a heating operation cannot be performed in accordance with the required indoor-side heating load.

[0014] In the air-conditioning apparatus described in Patent Literature 5, a reduction in the room temperature may be suppressed by causing a secondary heat medium to circulate to an indoor unit during a defrosting operation. However, continuation of a heating operation by an indoor unit including ventilation by intake of outdoor air is not taken into consideration.

[0015] The present invention has been made to solve the above problem, and an object of the present invention is to provide an air-conditioning apparatus that has a plurality of defrosting operation modes to achieve maintenance of comfort. Solution to Problem

[0016] An air-conditioning apparatus according to the present invention includes a refrigerant circulation circuit to circulate therein a heat-source-side refrigerant, the refrigerant circulation circuit connecting, by refrigerant pipes, a compressor, a heat-source-side heat exchanger, a plurality of expansion devices, refrigerant-side flow passages of a plurality of intermediate heat exchangers, and a plurality of refrigerant flow switching devices to switch a refrigerant circulation passage; a heat medium circulation circuit to circulate therein a heat medium, the heat medium circuit connecting, by heat medium conveyance pipes, a plurality of heat medium conveyance devices provided in association with the plurality of intermediate heat exchangers, a plurality of use-side heat exchangers, and heat-medium-side flow passages for the plurality of intermediate heat exchangers; and a bypass pipe installed so as to return the heat-source-side refrigerant to the compressor by bypassing at least the intermediate heat exchangers, the plurality of intermediate heat exchangers exchanging heat between the heat-source-side refrigerant and the heat medium, the air-conditioning apparatus being configured to execute a heating operation mode switching the refrigerant flow switching devices to a side of heating operation, heating the heat medium by at least one of the intermediate heat exchangers, operating at least one of the heat medium conveyance devices, and supplying the heated heat medium to at least one of the use-side heat exchangers, a heat recovery defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching, during the heating operation mode, the refrigerant flow switching devices to a side of cooling operation, operating at least one of the heat medium conveyance devices, and causing the heat-source-side refrigerant to receive heat of the heat medium by at least one of the intermediate heat exchangers, and a bypass defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching, during the heating operation mode, the refrigerant flow switching devices to the side of cooling operation and causing part or whole of the heat-source-side refrigerant to flow to the bypass pipe.

Advantageous Effects of Invention

[0017] An air-conditioning apparatus according to the present invention has, as a defrosting operation mode, a "heat recovery defrosting operation mode" and a "bypass defrosting operation mode". Therefore, either one of the defrosting operation modes may be executed, and maintenance of comfort may thus be achieved.

Brief Description of Drawings

[0018]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an exemplary installation of an air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 2] Fig. 2 is a schematic circuit configuration diagram illustrating an example of a circuit configuration of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 3] Fig. 3 is a refrigerant circuit diagram illustrating the flow of refrigerant in a cooling only operation mode of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 4] Fig. 4 is a refrigerant circuit diagram illustrating the flow of refrigerant in a heating only operation mode of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 5] Fig. 5 is a refrigerant circuit diagram illustrating the flow of refrigerant in a cooling and heating mixed operation mode of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 6] Fig. 6 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in a "first heat recovery defrosting operation mode (1)" of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 7] Fig. 7 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in a "first heat recovery defrosting operation mode (2)" of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 8] Fig. 8 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in a "second heat recovery defrosting operation mode" of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 9] Fig. 9 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in a "first bypass defrosting operation mode" of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 10] Fig. 10 is a graph illustrating an example of the relationship between the air volume of a fan for each temperature to which the temperature of a heat medium may be reduced and the time during which the heat medium temperature may be maintained in the case where a heating operation continues to be performed with the air volume.

[Fig. 11] Fig. 11 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in a "second bypass defrosting operation mode" of the air-conditioning apparatus according to Embodiment of the present invention.

Description of Embodiments

[0019] Hereinafter, Embodiment of the present invention will be explained with reference to the drawings.

[0020] Fig. 1 is a schematic diagram illustrating an exemplary installation of an air-conditioning apparatus according to Embodiment of the present invention. An exemplary installation of an air-conditioning apparatus will be explained with reference to Fig. 1. In the air-conditioning apparatus, by using a refrigeration cycle (a refrigerant circulation circuit A, a heat medium circulation circuit B) through which refrigerant (a heat-source-side refrigerant, a heat medium) circulates, each indoor unit can freely select, as an operation mode, a cooling mode or a heating mode. Fig. 1 schematically illustrates the overall configuration of an air-conditioning apparatus including a plurality of indoor units 3 connected. In the drawings provided below including Fig. 1, the size relationship of individual component members may differ from the actual size relationship.

[0021] In Fig. 1, the air-conditioning apparatus according to Embodiment includes an outdoor unit (heat source unit) 1, a plurality of indoor units 3, and a relay unit 2 which is arranged between the outdoor unit 1 and the indoor units 3. The relay unit 2 exchanges heat between a heat-source-side refrigerant and a heat medium. The outdoor unit 1 and the relay unit 2 are connected by refrigerant pipes 4 through which the heat-source-side refrigerant flows. The relay unit 2 and the indoor units 3 are connected by pipes (heat medium conveyance pipes) 5 through which the heat medium flows. Cooling energy or heating energy generated at the outdoor unit 1 is delivered to the indoor units 3 via the relay unit 2.

[0022] The outdoor unit 1 is normally placed in an outdoor space 6, which is a space (for example, a rooftop etc.) outside a structure 9 such as a building, and supplies cooling energy or heating energy to the indoor units 3 via the relay unit 2. The indoor units 3 are placed at positions from which cooling air or heating air may be supplied to an indoor space 7, which is a space (for example, a living room etc.) inside the structure 9, and supplies the cooling air or the heating air to the indoor space 7 serving as an air-conditioning target space. The relay unit 2 is configured to be installed at a position which is different from the outdoor space 6 and the indoor space 7 as a housing which is different from the outdoor unit 1 and the indoor units 3. The relay unit 2 is connected to the outdoor unit 1 and the indoor units 3 by the refrigerant pipes 4 and the pipes 5, respectively, and transmits to the indoor units 3 the cooling energy or heating energy supplied from the outdoor unit 1.

[0023] An operation of the air-conditioning apparatus according to Embodiment of the present invention will be briefly explained below.

[0024] A heat-source-side refrigerant is conveyed from the outdoor unit 1 to the relay unit 2 via the refrigerant pipes 4. The conveyed heat-source-side refrigerant exchanges heat with a heat medium at an intermediate heat exchanger (an intermediate heat exchanger 25 described later) inside the relay unit 2 to heat or cool the heat medium. That is, hot water or cold water is generated at the intermediate heat exchanger. The hot water or the cold water generated at the relay unit 2 is conveyed by a heat medium conveyance device (a pump 31 described later) to the indoor units 3 via the pipes 5, and is used at the indoor units 3 for a heating operation (may be an operation state requiring hot water) or a cooling operation (may be an operation state requiring cold water) for the indoor space 7.

[0025] As a heat-source-side refrigerant, for example, a single-component refrigerant such as R-22, R-134a, or R-32, a near-azeotropic refrigerant mixture such as R-

410A or R-404A, a non-azeotropic refrigerant mixture such as R-407C, a refrigerant having a relatively small global warming potential, such as $CF_3CF = CH_2$, which has a double bond in its chemical formula or a mixture of such refrigerants, or a natural refrigerant such as CO_2 or propane, may be used.

[0026] In contrast, as a heat medium, for example, water, antifreeze, a liquid mixture of antifreeze and water, a liquid mixture of water and an additive having high anticorrosion effect, or the like may be used.

[0027] As illustrated in Fig. 1, in the air-conditioning apparatus according to Embodiment, the outdoor unit 1 and the relay unit 2 are connected by the two refrigerant pipes 4, and the relay unit 2 and each of the indoor units 3 are connected by the two pipes 5. As described above, in the air-conditioning apparatus according to Embodiment, by connecting the individual units (the outdoor unit 1, the indoor units 3, and the relay unit 2) by the two pipes (the refrigerant pipes 4, the pipes 5), easy construction can be achieved.

[0028] In Fig. 1, a state is illustrated as an example in which the relay unit 2 is installed in a space (hereinafter, simply referred to as a space 8) such as a space above a ceiling, which is a space that is within the structure 9 but is different from the indoor space 7. Therefore, the relay unit 2 may be installed in any place other than the space above the ceiling as long as it is a space ventilated to the outside to some extent and is not a living space. For example, the relay unit 2 may be installed in a space which is ventilated to the outside, such as a common space in which an elevator or the like is located, or the like. Furthermore, the relay unit 2 may be installed at a position near the outdoor unit 1. However, when the distance from the relay unit 2 to the indoor units 3 is too long, the heat medium conveyance force is significantly large. Therefore, it should be noted that an energy saving effect is reduced.

[0029] In Fig. 1, the case where the outdoor unit 1 is installed in the outdoor space 6 is illustrated as an example. However, the outdoor unit 1 is not necessarily installed as described above. For example, the outdoor unit 1 may be installed in an enclosed space, such as a machine room with a ventilation opening. The outdoor unit 1 may be installed inside the structure 9 as long as waste heat can be exhausted outside the structure 9 via an exhaust duct. Alternatively, an outdoor unit 1 of a water-cooled type may be installed inside the structure 9. When the outdoor unit 1 is installed in such a place, there will be no particular problem.

[0030] In Fig. 1, the case where the indoor units 3 are of a ceiling cassette type is illustrated as an example. However, the indoor units 3 are not necessarily of the above type. The indoor units 3 may be of any type such as a ceiling concealed type or ceiling suspended type as long as they are able to blow heating air or cooling air to the indoor space 7 directly or through a duct or the like.

[0031] Furthermore, the number of connected outdoor units 1, indoor units 3, and relay units 2 is not limited to that illustrated in Fig. 1. The number of connected outdoor units 1, indoor units 3, and relay units 2 may be determined in accordance with the structure 9 in which the air-conditioning apparatus according to Embodiment is installed.

[0032] In the case where the plurality of relay units 2 are connected to the single outdoor unit 1, the plurality of relay units 2 may be installed in different positions in a common space in a structure such as a building or a space such as a space above a ceiling. By installing the plurality of relay units 2 as described above, an intermediate heat exchanger inside each of the relay units 2 is able to cover an air-conditioning load. Furthermore, the indoor units 3 may be installed at a distance or a height within an allowable conveyance range of the heat medium conveyance device in the individual relay units 2, and an arrangement for the entire structure such as a building can be attained.

[0033] Fig. 2 is a schematic circuit configuration diagram illustrating an example of a circuit configuration of the air-conditioning apparatus (hereinafter, referred to as an air-conditioning apparatus 100) according to Embodiment of the present invention. The configuration of the air-conditioning apparatus 100, that is, the workings of individual actuators forming a refrigerant circuit, will be explained in detail with reference to Fig. 2. As illustrated in Fig. 2, the outdoor unit 1 and the relay unit 2 are connected by the refrigerant pipes 4 via an intermediate heat exchanger (refrigerant-water heat exchanger) 25a and an intermediate heat exchanger (refrigerant-water heat exchanger) 25b which are provided in the relay unit 2. Furthermore, the relay unit 2 and the indoor units 3 are connected by the pipes 5 via the intermediate heat exchanger 25a and the intermediate heat exchanger 25b.

[Outdoor unit 1]

[0034] In the outdoor unit 1, a compressor 10, a first refrigerant flow switching device 11 such as a four-way valve, a heat-source-side heat exchanger 12, and an accumulator 19 are provided by being connected in series by the refrigerant pipes 4. The outdoor unit 1 also includes a refrigerant connection pipe 4a, a refrigerant connection pipe 4b, a check valve 13a, a check valve 13b, a check valve 13c, and a check valve 13d. By providing the refrigerant connection pipe 4a, the refrigerant connection pipe 4b, the check valve 13a, the check valve 13b, the check valve 13c, and the check valve 13d, the flow of a heat-source-side refrigerant which is to be caused to flow into the relay unit 2 may be fixed to a certain direction, irrespective of the operation required by the indoor units 3.

[0035] The compressor 10 sucks a heat-source-side refrigerant, compresses the heat-source-side refrigerant into a high-temperature and high-pressure state, and conveys the heat-source-side refrigerant to the refrigerant circulation circuit A. The compressor 10 may be, for example, an inverter compressor whose capacity can be controlled. The first refrigerant flow switching device 11 switches between providing the flow of a heat-source-side refrigerant in a heating operation mode (in a heating only operation mode and a heating main operation mode) and providing the flow of a heat-source-side refrigerant in cooling operation mode (in a cooling only operation mode and a cooling main operation mode).

[0036] The heat-source-side heat exchanger 12 serves as an evaporator during a heating operation and serves as a condenser (or a radiator) during a cooling operation. The heat-source-side heat exchanger 12 exchanges heat between fluid such as air supplied from a blower device such as a fan, which is not illustrated in the drawing, and a heat-source-side refrigerant to evaporate and gasify or condense and liquefy the heat-source-side refrigerant. The accumulator 19 is provided on the suction side of the compressor 10, and stores excess refrigerant caused by a difference between the heating operation time and the cooling operation time or excess refrigerant with respect to a transient change in the operation.

[0037] The check valve 13c is provided at a position of the refrigerant pipe 4 between the relay unit 2 and the first refrigerant flow switching device 11, and allows a heat-source-side refrigerant to flow only in a specific direction (direction from the relay unit 2 to the outdoor unit 1). The check valve 13a is provided at a position of the refrigerant pipe 4 between the heat-source-side heat exchanger 12 and the relay unit 2, and allows a heat-source-side refrigerant to flow only in a specific direction (direction from the outdoor unit 1 to the relay unit 2). The check valve 13d is provided at the refrigerant connection pipe 4a, and causes the heat-source-side refrigerant discharged from the compressor 10 to flow to the relay unit 2 during a heating operation. The check valve 13b is provided at the refrigerant connection pipe 4b, and causes the heat-source-side refrigerant returned from the relay unit 2 to flow to the suction side of the compressor 10 during a heating operation.

[0038] The refrigerant connection pipe 4a allows connection between a portion of the refrigerant pipe 4 between the first refrigerant flow switching device 11 and the check valve 13c and a portion of the refrigerant pipe 4 between the check valve 13a and the relay unit 2 in the outdoor unit 1. The refrigerant connection pipe 4b allows connection between a portion of the refrigerant pipe 4 between the check valve 13c and the relay unit 2 and a portion of the refrigerant pipe 4 between heat-source-side heat exchanger 12 and the check valve 13a in the outdoor unit 1. In Fig. 2, the case where the refrigerant connection pipe 4a, the refrigerant connection pipe 4b, the check valve 13a, the check valve 13b, the check valve 13c, and the check valve 13d are provided is illustrated as an example. However, the configuration is not limited to the above. The above components are not necessarily provided.

[Indoor unit 3]

[0039] In each of the indoor units 3, a use-side heat exchanger 35 is provided. The use-side heat exchangers 35 are connected to heat medium flow control devices 34 and second heat medium flow switching devices 33 of the relay unit 2 by the pipes 5. The use-side heat exchangers 35 exchange heat between air which is supplied from a blower device such as a fan, which is not illustrated in the drawing, and a heat medium, and generate heating air or cooling air to be supplied to the indoor space 7.

[0040] Furthermore, in the indoor units 3, a duct 43 or the like is attached to the use-side heat exchangers 35. By using the blower device, which is not illustrated in the drawing, outdoor air is taken into the indoor space 7 via the duct 43, and ventilation may thus be attained.

[0041] In Fig. 2, the case where the four indoor units 3 are connected to the relay unit 2 is illustrated as an example, and the indoor units 3 are illustrated as an indoor unit 3a, an indoor unit 3b, an indoor unit 3c, and an indoor unit 3d in this order from the top side of the drawing. Similarly, in association with the indoor units 3a to 3d, the use-side heat exchangers 35 are illustrated as a use-side heat exchanger 35a, a use-side heat exchanger 35b, a use-side heat exchanger 35c, and a use-side heat exchanger 35d in this order from the top side of the drawing. Similarly to the case of Fig. 1, the number of connected indoor units 3 is not necessarily four as illustrated in Fig. 2. Furthermore, although the state in which the duct 43 is connected to the indoor unit 3a is illustrated as an example in Fig. 2, the number of indoor units 3 with which the duct 43 may be connected is not necessarily the indoor unit. The duct 43 may be connected to any of the indoor units 3b to 3d.

[Relay unit 2]

[0042] In the relay unit 2, the at least two or more intermediate heat exchangers 25, two expansion devices 26, two opening and closing devices (an opening and closing device 27 and an opening and closing device 29), two second refrigerant flow switching devices 28, two heat medium conveyance devices (hereinafter, referred to as the pumps 31), four first heat medium flow switching devices 32, the four second heat medium flow switching devices 33, and the four heat medium flow control devices 34 are provided.

[0043] The two intermediate heat exchangers 25 (the intermediate heat exchanger 25a and the intermediate heat exchanger 25b) function as condensers (radiators) when supplying heating energy to an indoor unit 3 that is performing a heating operation and function as evaporators when supplying cooling energy to an indoor unit 3 that is performing a cooling operation, exchange heat between a heat-source-side refrigerant and a heat medium, and transmit cooling energy or heating energy generated at the outdoor unit 1 and stored in the heat-source-side refrigerant to the heat medium. The intermediate heat exchanger 25a is provided between the expansion device 26a and the second refrigerant flow switching device 28a in the refrigerant circulation circuit A and is used for cooling a heat medium in a cooling and heating mixed operation mode. The intermediate heat exchanger 25b is provided between the expansion device 26b and the second refrigerant flow switching device 28b in the refrigerant circulation circuit A and is used for heating a heat medium in a cooling and heating mixed operation mode.

[0044] The two expansion devices 26 (the expansion device 26a and the expansion device 26b) function as pressure reducing valves or expansion valves to decompress and expanse a heat-source-side refrigerant. The expansion device 26a is provided on the upstream side of the intermediate heat exchanger 25a in the flow of a heat-source-side refrigerant for a cooling operation. The expansion device 26b is provided on the upstream side of the intermediate heat exchanger 25b in the flow of a heat-source-side refrigerant for a cooling operation. The two expansion devices 26 may be devices whose opening degree may be controlled in a variable manner, such as electronic expansion valves.

[0045] The two opening and closing devices (the opening and closing device 27 and the opening and closing device 29) are solenoid valves which may be opened and closed by electrical connection, and open and close the refrigerant pipes 4. That is, the two opening and closing devices are controlled to be opened and closed in accordance with an operation mode, and switch the flow passage of a heat-source-side refrigerant. The opening and closing device 27 is provided at a portion of the refrigerant pipe 4 on a heat-source-side refrigerant inlet side (a portion of the refrigerant pipe 4 that connects the outdoor unit 1 with the relay unit 2 and that is located at the most bottom side in the drawing). The opening and closing device 29 is provided at a pipe (bypass pipe 20) which connects the portion of the refrigerant pipe 4 on the heat-source-side refrigerant inlet side with a portion of the refrigerant pipe 4 on a heat-source-side refrigerant outlet side. Devices whose opening degree may be controlled in a variable manner, such as electrical expansion valves, may be used as the opening and closing device 27 and the opening and closing device 29, as long as the devices may switch a refrigerant flow passage.

[0046] The two second refrigerant flow switching devices 28 (the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b) are, for example, four-way valves, and switch the flow of a heat-source-side refrigerant such that the intermediate heat exchangers 25 operate as condensers or evaporators in accordance with the operation mode. The second refrigerant flow switching device 28a is provided on the downstream side of the intermediate heat exchanger 25a in the flow of a heat-source-side refrigerant for a cooling operation. The second refrigerant flow switching device 28b is provided on the downstream side of the intermediate heat exchanger 25b in the flow of a heat-source-side refrigerant for a cooling only operation mode.

[0047] The two pumps 31 (the pump 31 a and the pump 31 b) cause a heat medium that flows through the pipes 5 to circulate to the heat medium circulation circuit B. The pump 31 a is provided at a portion of the pipe 5 between the intermediate heat exchanger 25a and the second heat medium flow switching devices 33. The pump 31 b is provided at a portion of the pipe 5 between the intermediate heat exchanger 25b and the second heat medium flow switching devices 33. The two pumps 31 are, for example, pumps whose capacity can be controlled, and may be configured such that the flow rate of the pumps can be adjusted according to the size of the load in the indoor units 3.

[0048] The four first heat medium flow switching devices 32 (the first heat medium flow switching devices 32a to 32d) are three-way valves or the like, and switch the flow passage of a heat medium between the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. The number of first heat medium flow switching devices 32 provided corresponds to the number of indoor units 3 installed (in this case, four). The first heat medium flow switching devices 32 are provided on the outlet side of the heat medium flow passages for the use-side heat exchangers 35 in such a manner that one of the three ways is connected to the intermediate heat exchanger 25a, another one of the three ways is connected to the intermediate heat exchanger 25b, and the other one of the three ways is connected to the heat medium flow control devices 34. In association with the indoor units 3, they are illustrated as the first heat medium flow switching device 32a, the first heat medium flow switching device 32b, the first heat medium flow switching device 32c, and the first heat medium flow switching device 32d in this order from the top side of the drawing. Furthermore, switching of a heat medium flow passage includes partial switching from one side to the other side as well as full switching from one side to the other side.

[0049] The four second heat medium flow switching devices 33 (the second heat medium flow switching devices 33a to 33d) are three-way valves or the like, and switch the flow passage of a heat medium between the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. The number of second heat medium flow switching devices 33 provided corresponds to the number of indoor units 3 installed (in this case, four). The second heat medium flow switching devices 33 are provided on the inlet side of the heat medium flow passages for the use-side heat exchangers 35 in such a manner that one of the three ways is connected to the intermediate heat exchanger 25a, another one of the three ways is connected to the intermediate heat exchanger 25b, and the other one of the three ways is connected to the heat medium flow control devices 35. In association with the indoor units 3, they are illustrated as the second heat medium flow switching device 33a, the second heat medium flow switching device 33b, the second heat medium flow switching device 33c, and the second heat medium flow switching device 33d in this order from the top side of the drawing. Furthermore, switching of a heat medium flow passage includes partial switching from one side to the other side as well as full switching from one side to the other side.

[0050] The four heat medium flow control devices 34 (the heat medium flow control devices 34a to 34d) are two-way valves or the like whose opening area can be controlled, and control the flow rate of a heat medium flowing in the pipes 5. The number of heat medium flow control devices 34 provided corresponds to the number of indoor units 3 installed (in this case, four). The heat medium flow control devices 34 are provided on the outlet side of the heat medium flow passages for the use-side heat exchangers 35 in such a manner that one of the two ways is connected to the use-side heat exchangers 35 and the other one of the two ways is connected to the first heat medium flow switching devices 32. That is, the heat medium flow control devices 34 adjust the amount of heat medium flowing into the indoor units 3 in accordance with the temperature of the heat medium flowing into and flowing out of the indoor units 3 and may thus supply to the indoor units 3 an optimal amount of heat medium for the indoor load.

[0051] In association with the indoor units 3, they are illustrated as the heat medium flow control device 34a, the heat medium flow control device 34b, the heat medium flow control device 34c, and the heat medium flow control device 34d in this order from the top side of the drawing. The heat medium flow control devices 34 may be provided on the inlet side of the heat medium flow passages for the use-side heat exchangers 35. Furthermore, the heat medium flow control devices 34 may be provided at a portion that is on the inlet side of the heat medium flow passages for the use-side heat exchangers 35 and that is between the second heat medium flow switching devices 33 and the use-side heat exchangers 35. Moreover, when an indoor unit 3 requires no load, such as during stoppage or thermo-OFF, the supply of a heat medium to the indoor unit 3 may be stopped by fully closing the heat medium flow control devices 34.

[0052] If devices having functions of the heat medium flow control devices 34 are used as the first heat medium flow switching devices 32 or the second heat medium flow switching devices 33, the heat medium flow control devices 34 may be omitted.

[0053] Furthermore, in the relay unit 2, temperature sensors 40 (a temperature sensor 40a and a temperature sensor 40b) for detecting the temperature of a heat medium on the outlet side of the intermediate heat exchanger 25 are provided. Information (temperature information) detected by the temperature sensors 40 is sent to a controller 50 that performs overall control of the operation of the air-conditioning apparatus 100, and is used for control of the driving frequency of the compressor 10, the rotation speed of a blower device, which is not illustrated in the drawing, switching of the first refrigerant flow switching device 11, the driving frequency of the pumps 31, switching of the second refrigerant flow switching devices 28, switching of the flow passage of a heat medium, adjustment of the flow rate of a heat medium in the indoor units 3, and the like. Although the case where the controller 50 is provided separately from the individual units is illustrated as an example, the configuration is not limited to this. The controller 50 may be provided so as to be able to communicate with at least one of the outdoor unit 1, the indoor units 3, and the relay unit 2 or with the individual units.

[0054] Furthermore, the controller 50 is composed of a microcomputer or the like. The controller 50 controls the individual actuators (driving parts including the pumps 31, the first heat medium flow switching devices 32, the second heat medium flow switching devices 33, the expansion devices 26, and the second refrigerant flow switching devices 28), such as the driving frequency of the compressor 10, the rotation speed of the blower device (including ON/OFF), switching of the first refrigerant flow switching device 11, driving of the pumps 31, the opening degree of the expansion devices 26, opening and closing of the opening and closing devices (the opening and closing device 27 and the opening and closing device 29), switching of the second refrigerant flow switching devices 28, switching of the first heat medium flow switching devices 32, switching of the second heat medium flow switching devices 33, and driving of the heat medium flow control devices 34, in accordance with detection information from the various detection units and instructions from a remote controller.

[0055] The pipes 5 through which a heat medium flows include a pipe which is connected to the intermediate heat exchanger 25a and a pipe which is connected to the intermediate heat exchanger 25b. Each of the pipes 5 branches out into branch pipes (in this example, four branches) in accordance with the number of indoor units 3 connected to the relay unit 2. The pipes 5 are connected to the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33. The first heat medium flow switching devices 32 and the second heat medium flow switching devices 33 are controlled to determine whether a heat medium from the intermediate heat exchanger 25a or a heat medium from the intermediate heat exchanger 25b is to be caused to flow into the use-side heat exchangers 35.

[0056] In the air-conditioning apparatus 100, the refrigerant circulation circuit A is formed by connecting the compressor 10, the first refrigerant flow switching device 11, the heat-source-side heat exchanger 12, the opening and closing device 27, the opening and closing device 29, the second refrigerant flow switching devices 28, the refrigerant flow passages for the intermediate heat exchangers 25, the expansion devices 26, and the accumulator 19 by the refrigerant pipes 4. Furthermore, the heat medium circulation circuit B is formed by connecting the heat medium flow passages for the intermediate heat exchangers 25, the pumps 31, the first heat medium flow switching devices 32, the heat medium flow control devices 34, the use-side heat exchangers 35, and the second heat medium flow switching devices 33 by the pipes 5. That is, the plurality of use-side heat exchangers 35 are connected in parallel to each of the intermediate heat exchangers 25 to form the heat medium circulation circuit B as multiple systems.

[0057] Therefore, in the air-conditioning apparatus 100, the outdoor unit 1 and the relay unit 2 are connected via the intermediate heat exchanger 25a and the intermediate heat exchanger 25b which are provided in the relay unit 2, and the relay unit 2 and the indoor units 3 are connected via the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. That is, in the air-conditioning apparatus 100, heat is exchanged at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b between a heat-source-side refrigerant which circulates through the refrigerant circulation circuit A and a heat medium which circulates through the heat medium circulation circuit B. With the use of the above configuration, the air-conditioning apparatus 100 achieves an optimal cooling operation or an optimal heating operation for the indoor load.

[Operation mode]

[0058] Individual operation modes executed by the air-conditioning apparatus 100 will be explained below. In accordance with an instruction from each of the indoor units 3, the air-conditioning apparatus 100 is able to cause the indoor unit 3 to perform a cooling operation or a heating operation. That is, the air-conditioning apparatus 100 is configured such that not only may all of the indoor units 3 perform the same operation but also the indoor units 3 may perform different operations.

[0059] Operation modes executed by the air-conditioning apparatus 100 include a heating only operation mode in which all of the driving indoor units 3 perform a heating operation, a cooling only operation mode in which all of the driving indoor units 3 perform a cooling operation, a heating main operation mode, which is a cooling and heating mixed operation mode in which the heating load is larger than the cooling load, and a cooling main operation mode, which is a cooling and heating mixed operation mode in which the cooling load is larger than heating load. Furthermore, in the heating only operation mode and the heating main operation mode, a defrosting operation mode is available for removing frost attached at the heat-source-side heat exchanger 12 as a result of heat exchange with the outdoor air at the heat-source-side heat exchanger 12. The individual operation modes will be described below in accordance with the flow of a heat-source-side refrigerant and a heat medium.

[Cooling only operation mode]

[0060] Fig. 3 is a refrigerant circuit diagram illustrating the flow of refrigerant in the cooling only operation mode of the air-conditioning apparatus 100. With reference to Fig. 3, the cooling only operation mode will be explained in accordance with an example of the case where a cooling load is generated at all of the use-side heat exchangers 35a to 35d. In Fig. 3, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant flows. Furthermore, in Fig. 3, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0061] In the cooling only operation mode illustrated in Fig. 3, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0062] In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b are switched to the side of cooling operation, the opening and closing device 27 is opened, and the opening and closing device 29 is closed.

[0063] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0064] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11 through the heat-source-side heat exchanger 12, is subjected to heat exchange with air in the outdoor space 6 (hereinafter, referred to as outdoor air), turns into a high-temperature and high-pressure liquid or two-phase refrigerant, passes through the check valve 13a, flows through the refrigerant connection pipe 4a, and flows out of the outdoor unit 1. The high-temperature and high-pressure liquid or two-phase refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0065] The high-temperature and high-pressure liquid or two-phase refrigerant which has flowed into the relay unit 2 passes through the opening and closing device 27, is split, and is expanded at the expansion device 26a and the expansion device 26b into low-temperature and low-pressure two-phase refrigerant flows. The two-phase refrigerant flows flow into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, evaporate and liquefy while receiving heat from a heat medium circulating in the heat medium circulation circuit B, and turn into low-temperature gas refrigerant. The gas refrigerant flows which have flowed out of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b pass through the second refrigerant flow switching device

28a and the second refrigerant flow switching device 28b, flow out of the relay unit 2, flow through the refrigerant pipe 4, pass through the check valve 13c, and are sucked again to the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0066] At this time, the opening degree of the expansion devices 26 is controlled such that the superheat (degree of superheat) obtained as a difference between the value obtained by converting the pressure of a heat-source-side refrigerant flowing between the intermediate heat exchangers 25 and the expansion devices 26 into saturation temperature and the temperature on the outlet side of the intermediate heat exchangers 25 is constant. If the temperature at the intermediate position of the intermediate heat exchangers 25 can be measured, the saturation temperature obtained by conversion of the temperature at the intermediate position may be used instead. In this case, there is no need to install a pressure sensor, and the system can be configured at low cost.

[0067] Next, the flow of a heat medium in the heat medium circulation circuit B will be explained.

[0068] In the cooling only operation mode, the cooling energy of a heat-source-side refrigerant is transferred to a heat medium at both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, the cooled heat medium is pressurized at and flows out of the pump 31 a and the pump 31 b, and flows into the use-side heat exchangers 35a to 35d via the second heat medium flow switching devices 33a to 33d. Then, the heat medium receives heat from the indoor air at the use-side heat exchangers 35a to 35d, and cooling of the indoor space 7 is thus performed.

[0069] After that, the heat medium flows out of the use-side heat exchangers 35a to 35d, and flows into the heat medium flow control devices 34a to 34d. At this time, due to the operation of the heat medium flow control devices 34a to 34d, the flow rate of a heat medium is controlled to a flow rate necessary for an air-conditioning load required for the indoor space, and the heat medium is thus caused to flow into the use-side heat exchangers 35a to 35d. The heat medium which has flowed out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d, flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, delivers to a refrigerant side the amount of heat received from the indoor space 7 through the indoor units 3, and is sucked again into the pump 31 a and the pump 31 b.

[0070] In the pipes 5 for the use-side heat exchangers 35, a heat medium flows in the direction from the second heat medium flow switching devices 33 via the heat medium flow control devices 34 to the first heat medium flow switching devices 32. Furthermore, the air-conditioning load required for the indoor space 7 may be carried by controlling the temperature detected by the temperature sensors 40 or the difference between the temperature detected by the temperature sensors 40 and the temperature of a heat medium flowing out of the use-side heat exchangers 35 to be maintained at a target value. As the outlet temperature of the intermediate heat exchangers 25, any one of the temperature of the temperature sensor 40a and the temperature of the temperature sensor 40b or the average of these temperatures may be used.

[0071] At this time, the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33 may be controlled to intermediate opening degrees or opening degrees corresponding to the heat medium temperature at the outlet of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b so that the flow passages for the flow to both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b are secured. Originally, the use-side heat exchangers 35 should be controlled based on the temperature difference between the inlet and outlet thereof. However, since the heat medium temperature on the inlet side of the use-side heat exchangers 35 is substantially the same as the temperature detected by the temperature sensors 40. Therefore, with the use of the temperature sensors 40, the number of temperature sensors may be reduced, and the system may thus be configured at low cost.

[0072] In executing the cooling only operation mode, there is no need to cause a heat medium to flow to the use-side heat exchangers 35 with no thermal load. Therefore, the flow passages are closed by the heat medium flow control devices 34, so that no heat medium flows to the use-side heat exchangers 35. In Fig. 3, since there is a thermal load in all of the use-side heat exchangers 35a to 35d, a heat medium is caused to flow to the use-side heat exchangers 35a to 35d. However, if no thermal load exists in any of the use-side heat exchangers 35a to 35d, the corresponding heat medium flow control device 34 may be fully closed. If a thermal load is generated again, the corresponding heat medium flow control device 34 is opened, so that a heat medium may be caused to circulate. This also applies to the other operation modes which will be described later.

[Heating only operation mode]

[0073] Fig. 4 is a refrigerant circuit diagram illustrating the flow of refrigerant in the heating only operation mode of the air-conditioning apparatus 100. With reference to Fig. 4, the heating only operation mode will be explained in accordance with an example of the case where a heating load is generated at all of the use-side heat exchangers 35a to 35d. In Fig. 4, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant flows. Furthermore, in Fig. 4, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0074] In the heating only operation mode illustrated in Fig. 4, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the relay unit 2 without passing through the heat-source-side heat exchanger 12. In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b are switched to the side of heating operation, the opening and closing device 27 is closed, and the opening and closing device 29 is opened.

[0075] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0076] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, flows through the refrigerant connection pipe 4a, passes through the check valve 13d, and flows out of the outdoor unit 1. The high-temperature and high-pressure gas refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2. The high-temperature and high-pressure gas refrigerant which has flowed into the relay unit 2 is split. The split gas refrigerant flows pass through the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b, and flow into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b.

[0077] The high-temperature and high pressure gas refrigerant flows which have flowed into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b condense and liquefy while transferring heat to a heat medium circulating in the heat medium circulation circuit B, and turn into high-pressure liquid refrigerant flows. The liquid refrigerant flows that have flowed out of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b are expanded at the expansion device 26a and the expansion device 26b into low-temperature and low-pressure, two-phase refrigerant flows. These two-phase refrigerant flows are merged together. The merged two-phase refrigerant passes through the opening and closing device 29, flows out of the relay unit 2, passes through the refrigerant pipe 4, and flows into the outdoor unit 1 again. The refrigerant which has flowed into the outdoor unit 1 flows through the refrigerant connection pipe 4b, passes through the check valve 13b, and flows into the heat-source-side heat exchanger 12 operating as an evaporator.

[0078] The heat-source-side refrigerant which has flowed into the heat-source-side heat exchanger 12 receives heat from the outdoor air at the heat-source-side heat exchanger 12, and turns into a low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant which has flowed out of the heat-source-side heat exchanger 12 is sucked into the compressor 10 again via the first refrigerant flow switching device 11 and the accumulator 19.

[0079] At this time, the opening degree of the expansion devices 26 is controlled such that the subcooling (degree of subcooling) obtained as a difference between the value obtained by converting the pressure of a heat-source-side refrigerant flowing between the intermediate heat exchangers 25 and the expansion devices 26 into saturation temperature and the temperature on the outlet side of the intermediate heat exchangers 25 is constant. If the temperature at the intermediate position of the intermediate heat exchangers 25 can be measured, the temperature at the intermediate position may be used instead of the converted saturation temperature. In this case, there is no need to install a pressure sensor, and the system can be configured at low cost.

[0080] Next, the flow of a heat medium in the heat medium circulation circuit B will be explained.

[0081] In the heating only operation mode, the heating energy of a heat-source-side refrigerant is transferred to a heat medium at both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and the heated heat medium is caused by the pump 31 a and the pump 31 b to flow in the pipes 5. The heat medium which has been pressurized at and flowed out of the pump 31 a and the pump 31 b flows into the use-side heat exchangers 35a to 35d via the second heat medium flow switching devices 33a to 33d. Then, the heat medium transfers heat to the indoor air at the use-side heat exchangers 35a to 35d, and heating of the indoor space 7 is thus performed.

[0082] After that, the heat medium flows out of the use-side heat exchangers 35a to 35d, and flows into the heat medium flow control devices 34a to 34d. At this time, due to the operation of the heat medium flow control devices 34a to 34d, the flow rate of a heat medium is controlled to a flow rate necessary for an air-conditioning load required for an indoor space, and the heat medium is thus caused to flow into the use-side heat exchangers 35a to 35d. The heat medium which has flowed out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d, flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, receives the amount of heat supplied to the indoor space 7 through the indoor units 3, and is sucked again into the pump 31 a and the pump 31 b.

[0083] In the pipes 5 for the use-side heat exchangers 35, a heat medium flows in the direction from the second heat medium flow switching devices 33 via the heat medium flow control devices 34 to the first heat medium flow switching devices 32. Furthermore, the air-conditioning load required for the indoor space 7 may be carried by performing control so that the temperatures detected by the temperature sensors 40 or the difference between the temperatures detected by the temperature sensors 40 and the temperature of a heat medium flowing out of the use-side heat exchangers 35 to be maintained at a target value. As the outlet temperature of the intermediate heat exchangers 25, any one of the temperature of the temperature sensor 40a and the temperature of the temperature sensor 40b or the average of these temperatures may be used.

[0084] At this time, the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33 may be controlled to intermediate opening degrees or opening degrees corresponding to the heat medium temperature at the outlet of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b so that the flow passages for the flow to both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b are secured. Originally, the use-side heat exchangers 35 should be controlled based on the temperature difference between the inlet and outlet thereof. However, since the heat medium temperature on the inlet side of the use-side heat exchangers 35 is substantially the same as the temperature detected by the temperature sensors 40. Therefore, with the use of the temperature sensors 40, the number of temperature sensors may be reduced, and the system may thus be configured at low cost.

[Cooling and heating mixed operation mode]

[0085] Fig. 5 is a refrigerant circuit diagram illustrating the flow of refrigerant in the cooling and heating mixed operation mode of the air-conditioning apparatus 100. With reference to Fig. 5, the heating main operation mode of a cooling and heating mixed operation in which a heating load is generated in some of the use-side heat exchangers 35 and a cooling load is generated in the rest of use-side heat exchangers 35 will be explained. In Fig. 5, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 5, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0086] In the heating main operation mode illustrated in Fig. 5, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the relay unit 2 without passing through the heat-source-side heat exchanger 12. In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between the intermediate heat exchanger 25a and the use-side heat exchanger 35 at which the cooling load is generated and between the intermediate heat exchanger 25b and the use-side heat exchanger 35 at which the heating load is generated. Furthermore, the second refrigerant flow switching device 28a is switched to the side of cooling operation, the second refrigerant flow switching device 28b is switched to the side of heating operation, the expansion device 26a is fully opened, the opening and closing device 27 is closed, and the opening and closing device 29 is closed.

[0087] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0088] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, flows through the refrigerant connection pipe 4a, passes through the check valve 13d, and flows out of the outdoor unit 1. The high-temperature and high-pressure gas refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2. The high-temperature and high-pressure gas refrigerant which has flowed into the relay unit 2 passes through the second refrigerant flow switching device 28b, and flows into the intermediate heat exchanger 25b that operates as a condenser.

[0089] The gas refrigerant which has flowed into the intermediate heat exchanger 25b condenses and liquefies while transferring heat to a heat medium circulating in the heat medium circulation circuit B, and turns into a liquid refrigerant. The liquid refrigerant that has flowed out of the intermediate heat exchanger 25b is expanded at the expansion device 26b into a low-pressure, two-phase refrigerant. The low-pressure, two-phase refrigerant passes through the expansion device 26a and flows into the intermediate heat exchanger 25a that operates as an evaporator. The low-pressure, two-phase refrigerant that has flowed into the intermediate heat exchanger 25a evaporates by receiving heat from a heat medium circulating in the heat medium circulation circuit B, and thus cools the heat medium. The low-pressure, two-phase refrigerant flows out of the intermediate heat exchanger 25a, passes through the second refrigerant flow switching device 28a, flows out of the relay unit 2, passes through the refrigerant pipe 4, and flows into the outdoor unit 1 again.

[0090] The low-temperature and low-pressure, two-phase refrigerant which has flowed into the outdoor unit 1 passes through the check valve 13b, and flows into the heat-source-side heat exchanger 12 that operates as an evaporator. Then, the refrigerant which has flowed into the heat-source-side heat exchanger 12 receives heat from the outdoor air at the heat-source-side heat exchanger 12, and turns into a low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant which has flowed out of the heat-source-side heat exchanger 12 is sucked into the compressor 10 again via the first refrigerant flow switching device 11 and the accumulator 19.

[0091] The opening degree of the expansion device 26b is controlled such that the subcooling (the degree of subcooling) of the refrigerant at the outlet of the intermediate heat exchanger 25b is a target value. By fully opening the expansion device 26b, subcooling may be controlled using the expansion device 26a.

[0092] Next, the flow of a heat medium in the heat medium circulation circuit B will be explained.

[0093] In the heating main operation mode, the heating energy of a heat-source-side refrigerant is transferred to a heat medium at the intermediate heat exchanger 25b, and the heated heat medium is caused by the pump 31 b to flow in the pipe 5. Furthermore, in the heating main operation mode, the cooling energy of a heat-source-side refrigerant is transferred to a heat medium at the intermediate heat exchanger 25a, and the cooled heat medium is caused by the pump 31a to flow in the pipe 5. The cooled heat medium which has been pressurized by and flowed out of the pump 31 a flows via the second heat medium flow switching device 33 into the use-side heat exchanger 35 at which the cooling load is generated, and the heat medium which has been pressurized by and flowed out of the pump 31 b flows via the second heat medium flow switching device 33 into the use-side heat exchanger 35 at which the heating load is generated.

[0094] At this time, the second heat medium flow switching device 33 is switched to a direction in which the intermediate heat exchanger 25b and the pump 31 b are connected when the connected indoor unit 3 is in the heating operation mode, and is switched to a direction in which the intermediate heat exchanger 25a and the pump 31 a are connected when the connected indoor unit 3 is in the cooling operation mode. That is, the second heat medium flow switching devices 33 allow a heat medium to be supplied to the indoor units 3 to be used for heating or cooling.

[0095] The use-side heat exchangers 35 perform a cooling operation for the indoor space 7 by causing a heat medium to receive heat from the indoor air or a heating operation for the indoor space 7 by causing a heat medium to transfer heat to the indoor space. At this time, due to the operation of the heat medium flow control devices 34, the flow rate of a heat medium is controlled to a flow rate necessary for an air-conditioning load required for an indoor space, and the heat medium is thus caused to flow into the use-side heat exchangers 35.

[0096] The heat medium whose temperature is slightly increased by being used for a cooling operation and passing through the use-side heat exchanger 35, passes through the heat medium flow control device 34 and the first heat medium flow switching device 32, flows into the intermediate heat exchanger 25a, and is sucked into the pump 31 a again. The heat medium whose temperature is slightly decreased by being used for a heating operation and passing through the use-side heat exchanger 35, passes through the heat medium flow control device 34 and the first heat medium flow switching device 32, flows into the intermediate heat exchanger 25b, and is sucked into the pump 31 a again. At this time, the first heat medium flow switching device 32 is switched to a direction in which the intermediate heat exchanger 25b and the pump 31 b are connected when the connected indoor unit 3 is in the heating operation mode, and is switched to a direction in which the intermediate heat exchanger 25a and the pump 31 a are connected when the connected indoor unit 3 is in the cooling operation mode.

[0097] During this time, the hot heat medium and the cold heat medium are not mixed together by the operation of the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33, and are introduced to the use-side heat exchangers 35 at which the heating load and the cooling load exist. Accordingly, the heat medium that has been used for the heating operation mode is caused to flow into the intermediate heat exchanger 25b at which a refrigerant transfers heat for heating, and the heat medium that has been used for the cooling operation mode is caused to flow into the intermediate heat exchanger 25a at which a refrigerant receives heat for cooling. Then, each of the heat media is subjected to heat exchange with a refrigerant, and is transferred to the pump 31 a and the pump 31 b.

[0098] In the pipes 5 for the use-side heat exchangers 35, for both the side of heating operation and the side of cooling operation, a heat medium flows in the direction from the second heat medium flow switching devices 33 via the heat medium flow control devices 34 to the first heat medium flow switching devices 32. Furthermore, the air-conditioning load required for the indoor space 7 may be carried by controlling, for the side of heating operation, the difference between the temperature detected by the temperature sensor 40b and the temperature of a heat medium which has flowed out of the use-side heat exchanger 35, and for the side of cooling operation, the difference between the temperature of a heat medium which has flowed out of the use-side heat exchanger 35 and the temperature detected by the temperature sensor 40a to be maintained at a target value.

[0099] Moreover, in the cooling and heating mixed operation mode of the air-conditioning apparatus 100 in Fig. 5, also in the cooling main operation mode of a mixed operation in which a cooling load is generated in some of the use-side heat exchangers 35 and a heating load is generated in the rest of use-side heat exchangers 35, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A and the flow of a heat medium in the heat medium circulation circuit B are similar to those in the heating main operation mode.

[Defrosting operation mode]

[0100] As described above, in the air-conditioning apparatus 100, when the heating only operation mode or the heating main operation mode is executed, the heat-source-side heat exchanger 12 in the outdoor unit 1 operates as an evaporator to exchange heat with the outdoor air. Therefore, if the outdoor air temperature is low, the evaporating temperature of the heat-source-side heat exchanger 12 decreases, and frosting occurs to the surface of the heat-source-side heat exchanger 12 due to the moisture of the outdoor air. Consequently, the performance of heat exchange may be degraded. In the air-conditioning apparatus 100, for example, the outdoor unit 1 detects evaporating temperature. When the detected evaporating temperature becomes too low, the defrosting operation mode for removing frost on the surface of the heat-source-side heat exchanger 12 is executed. The heating only operation mode and the heating main operation mode correspond to the "heating operation mode" in the present invention.

[0101] In the air-conditioning apparatus 100, in execution of the defrosting operation mode, the heat capacity that has been held by a heat medium in the heating operation may be used. That is, during the heating operation mode, the air-conditioning apparatus 100 can melt frost formed around the heat-source-side heat exchanger 12 by switching the first refrigerant flow switching device 11 to the side of cooling operation, causing at least one of the pumps 31 to operate, and causing a refrigerant to receive heat held by a heat medium in at least one of the intermediate heat exchangers 25 (heat recovery defrosting operation mode). With the above operation, the air-conditioning apparatus 100 is able to remove frost on the surface of the heat-source-side heat exchanger 12 more quickly than conventional techniques. Meanwhile, the air-conditioning apparatus 100 is able to continue execution of the heating operation mode in the use-side heat exchangers 35.

[0102] Furthermore, the air-conditioning apparatus 100 has a bypass defrosting operation mode for melting frost formed around the heat-source-side heat exchanger 12 by switching the first refrigerant flow switching device 11 to the side of cooling operation to cause part or whole of the refrigerant to flow to the bypass pipe 20 during the heating operation mode.

[0103] In order to perform the operation mentioned above, the air-conditioning apparatus 100 increases the temperature of a heat medium through the intermediate heat exchangers 25 during the heating operation mode immediately before execution of the defrosting operation mode. Then, after detecting that the temperature of the heat medium whose temperature has been increased and which is detected by the temperature sensors 40 is higher than a setting temperature (for example, 43 degrees Centigrade), the air-conditioning apparatus 100 executes the defrosting operation mode. With the above operation, the air-conditioning apparatus 100 may ensure the heat capacity to be used for the defrosting operation mode and the amount of heat for continuing the heating operation mode.

[0104] Specifically, when the temperature of a heat medium detected by the temperature sensors 40 is higher than the setting temperature (for example, 43 degrees Centigrade), the air-conditioning apparatus 100 executes the "heat recovery defrosting operation mode" which utilizes the heat capacity held by the heat medium. In contrast, when the temperature of the heat medium detected by the temperature sensors 40 is lower than the setting temperature (for example, 43 degrees Centigrade), the air-conditioning apparatus 100 executes the "bypass defrosting operation mode" which does not utilize the heat capacity held by the heat medium. The setting temperature may be changed to any temperature. However, it is desirable to provide a use-side air temperature sensor for detecting the temperature of air blown to the use-side heat exchangers 35 and set the setting temperature to a value equal to or higher than the temperature detected by the use-side air temperature sensor. By setting to the above temperature, either the "heat recovery defrosting operation mode" or the "bypass defrosting operation mode" can be executed while maintaining comfort.

[0105] As described above, the defrosting operation mode executed by the air-conditioning apparatus 100 includes two types of defrosting operation modes (the "heat recovery defrosting operation mode" and the "bypass defrosting operation mode") according to the flow of a heat-source-side refrigerant.

[0106] The "heat recovery defrosting operation mode" that is executed during the heating only operation mode will be referred to as a "first heat recovery defrosting operation mode".

[0107] The "heat recovery defrosting operation mode" that is executed during the heating main operation mode will be referred to as a "second heat recovery defrosting operation mode".

[0108] The "bypass defrosting operation mode" that is executed during the heating only operation mode will be referred to as a "first bypass defrosting operation mode".

[0109] The "bypass defrosting operation mode" that is executed during the heating main operation mode will be referred to as a "second bypass defrosting operation mode".

[First heat recovery defrosting operation mode]

[0110] The "first heat recovery defrosting operation mode" executed during the heating only operation mode of the air-conditioning apparatus 100 further includes two types of defrosting operation modes (a "first heat recovery defrosting operation mode (1)" and a "first heat recovery defrosting operation mode (2)") according to the flow of a heat-source-side refrigerant.

(First heat recovery defrosting operation mode (1))

[0111] Fig. 6 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in the "first heat recovery defrosting operation mode (1)" of the air-conditioning apparatus 100. In Fig. 6, the "first heat recovery defrosting operation mode (1)" will be explained. In Fig. 6, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 6, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0112] The "first heat recovery defrosting operation mode (1)" is a defrosting operation mode to be executed during the heating only operation mode of the air-conditioning apparatus 100 when frosting occurs to the heat-source-side heat exchanger 12 in the outdoor unit 1 due to moisture of the outdoor air and the evaporating temperature decreases.

[0113] In the case of the "first heat recovery defrosting operation mode (1)" illustrated in Fig. 6, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0114] In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b are switched to the side of cooling operation, the opening and closing device 27 is opened, and the opening and closing device 29 is closed. Furthermore, the expansion device 26a and the expansion device 26b are fully opened. However, the expansion device 26a and the expansion device 26b are not necessarily strictly fully opened.

[0115] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0116] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, and flows into the heat-source-side heat exchanger 12. The refrigerant that has flowed into the heat-source-side heat exchanger 12 exchanges heat with a frosting part on the heat-source-side heat exchanger 12. The frosting part on the heat-source-side heat exchanger 12 is melted by the high-temperature, high-pressure refrigerant. The low-temperature and high-pressure refrigerant that has exchanged heat with the frosting part on the heat-source-side heat exchanger 12 passes through the check valve 13a, and then flows out of the outdoor unit 1. The low-temperature and high-pressure refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0117] The refrigerant which has flowed into the relay unit 2 passes through the opening and closing device 27, and is split. The split refrigerant flows pass through the expansion device 26a and the expansion device 26b and flow into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. The low-temperature and high-pressure refrigerant flows which have flowed into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b are subjected to heat exchange with a heat medium which has been used for heating and turn into high-temperature, high-pressure refrigerant flows. The refrigerant flows which have flowed out of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b pass through the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b, flow out of the relay unit 2, flow through the refrigerant pipe 4, pass through the check valve 13c, and are sucked again to the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

(First heat recovery defrosting operation mode (2))

[0118] Fig. 7 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in the "first heat recovery defrosting operation mode (2)" of the air-conditioning apparatus 100. In Fig. 7, the "first heat recovery defrosting operation mode (2)" will be explained. In Fig. 7, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 7, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0119] Similar to the "first heat recovery defrosting operation mode (1)", the "first heat recovery defrosting operation mode (2)" is a defrosting operation mode to be executed during the heating only operation mode of the air-conditioning apparatus 100 when frosting occurs to the heat-source-side heat exchanger 12 in the outdoor unit 1 due to moisture of the outdoor air and the evaporating temperature decreases. However, the flow of a heat-source-side refrigerant in the "first heat recovery defrosting operation mode (2)" differs from that in the "first heat recovery defrosting operation mode (1)". The air-conditioning apparatus 100 may select any one of the "first heat recovery defrosting operation mode (1)" and the "first heat recovery defrosting operation mode (2)".

[0120] In the case of the "first heat recovery defrosting operation mode (2)" illustrated in Fig. 7, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0121] In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, both of the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b maintain the opening direction on the side of heating operation, the opening and closing device 27 is closed, and the opening and closing device 29 is opened. Furthermore, the expansion device 26a and the expansion device 26b are fully opened. However, the expansion device 26a and the expansion device 26b are not necessarily strictly fully opened.

[0122] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0123] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, and flows into the heat-source-side heat exchanger 12. The refrigerant that has flowed into the heat-source-side heat exchanger 12 exchanges heat with a frosting part on the heat-source-side heat exchanger 12. The frosting part on the heat-source-side heat exchanger 12 is melted by the high-temperature, high-pressure refrigerant. The low-temperature and high-pressure refrigerant that has exchanged heat with the frosting part on the heat-source-side heat exchanger 12 passes through the check valve 13a, and then flows out of the outdoor unit 1. The low-temperature and high-pressure gas refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0124] The low-temperature and high-pressure gas refrigerant which has flowed into the relay unit 2 is split. The split gas refrigerant flows pass through the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b, and flow into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. The low-temperature and high-pressure refrigerant flows which have flowed into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b are subjected to heat exchange with a heat medium which has been used for heating and turn into high-temperature, high-pressure refrigerant flows. The refrigerant flows which have flowed out of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b pass through the expansion device 26a and the expansion device 26b, flow out of the relay unit 2 via the opening and closing device 29, flow through the refrigerant pipe 4, pass through the check valve 13c, and are sucked again to the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0125] Next, the flow of a heat medium in the heat medium circulation circuit B in the "first heat recovery defrosting operation mode" will be explained. The flow of a heat medium in the heat medium circulation circuit B is common between the "first heat recovery defrosting operation mode (1)" illustrated in Fig. 6 and the "first heat recovery defrosting operation mode (2)" illustrated in Fig. 7. Therefore, the flow of a heat medium will be explained below in accordance with an example of the "first heat recovery defrosting operation mode (2)".

[0126] In the "first heat recovery defrosting operation mode (2)", a heat medium is subjected to heat exchange with a low-temperature and high-pressure gas refrigerant at both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and turns into a low-temperature heat medium. The heat medium whose temperature has been decreased at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b is pressurized by the pump 31 a and the pump 31 b, and flows into the use-side heat exchangers 35a to 35d via the second heat medium flow switching devices 33a to 33d. At this time, the opening degree of the second heat medium flow switching devices 33 is controlled to an intermediate opening degree or an opening degree corresponding to the heat medium temperature at the outlet of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b so that the heat medium conveyed from both of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b may be supplied to the indoor units 3.

[0127] After that, the heat medium flows out of the use-side heat exchangers 35a to 35d, and flows into the heat medium flow control devices 34a to 34d. The heat medium which has flowed out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d. At this time, the same opening degree adjustment as the second heat medium flow switching devices 33 is performed on the first heat medium flow switching devices 32, and the heat medium flow control devices 34 are fully opened.

[0128] The heat medium which has passed through the first heat medium flow switching devices 32a to 32d flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and is subjected to heat exchange again with flows of refrigerant flowing in the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. After the amount of heat of the heat medium is supplied to the refrigerant side, the heat medium is sucked into the pump 31 a and the pump 31 b again.

[0129] The indoor unit 3 that has been performing a heating operation in the "first heat recovery defrosting operation mode" receives information indicating that the outdoor unit 1 is in the defrosting operation mode, and stops a blower device (hereinafter, simply referred to as a fan") for blowing air to the use-side heat exchanger 35. However, if the indoor air temperature and the indoor-unit blown-out air temperature may be detected, no problem occurs if the fan continues operating as far as the indoor unit blown-out air temperature is not lower than the indoor air temperature. Furthermore, the fan may continue to operate as long as the heat medium temperature at the outlet of the intermediate heat exchanger 25 detected by the temperature sensor 40 is not lower than the indoor air temperature.

[0130] Thus, by performing heat exchange with a heat medium at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b in the relay unit 2 during the execution of the "first heat recovery defrosting operation mode" of the outdoor unit 1, the amount of heat supplied from the heat medium to the refrigerant side may be supplied to the heat-source-side heat exchanger 12 of the outdoor unit 1. Therefore, the time for melting frost may be shortened.

[Second heat recovery defrosting operation mode]

[0131] Fig. 8 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in the "second heat recovery defrosting operation mode" of the air-conditioning apparatus 100. In Fig. 8, the "second heat recovery defrosting operation mode" will be explained. In Fig. 8, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 8, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0132] In the case of the "second heat recovery defrosting operation mode" illustrated in Fig. 8, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0133] In the relay unit 2, the pump 31 a and the pump 31 b are driven, the heat medium flow control device 34 for the indoor unit 3 that is performing a cooling operation is opened so that a heat medium may circulate between the intermediate heat exchanger 25a and the use-side heat exchanger 35 of the indoor unit 3 that is performing the cooling operation, and the heat medium flow control device 34 for the indoor unit 3 that is performing a heating operation so that a heat medium may circulate between the intermediate heat exchanger 25b and the use-side heat exchanger 35 of the indoor unit 3 that is performing the heating operation. Furthermore, both of the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b maintain the opening direction on the side of cooling operation, the opening and closing device 27 is opened, and the opening and closing device 29 is closed. Furthermore, the expansion device 26a is controlled such that the refrigerant at the outlet of the intermediate heat exchanger 25a becomes a gas state, and the expansion device 26b is fully opened. However, the expansion device 26b is not necessarily strictly fully opened.

[0134] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0135] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, and flows into the heat-source-side heat exchanger 12. The refrigerant that has flowed into the heat-source-side heat exchanger 12 exchanges heat with a frosting part on the heat-source-side heat exchanger 12. The frosting part on the heat-source-side heat exchanger 12 is melted by the high-temperature, high-pressure refrigerant. The low-temperature and high-pressure refrigerant that has exchanged heat with the frosting part on the heat-source-side heat exchanger 12 passes through the check valve 13a, and then flows out of the outdoor unit 1. The low-temperature and high-pressure refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0136] The refrigerant which has flowed into the relay unit 2 passes through the opening and closing device 27, and is split. The split refrigerant flows pass through the expansion device 26a and the expansion device 26b and flow into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. In the intermediate heat exchanger 25a, due to the operation of the expansion device 26a, heat exchange with a heat medium continues to be performed to generate a low-temperature heat medium for cooling, and the generated low-temperature heat medium for cooling is supplied to the indoor unit 3. Meanwhile, a heat-source-side refrigerant whose heat capacity has been lost by defrosting of the heat-source-side heat exchanger 12 is conveyed to the intermediate heat exchanger 25b. By performing heat exchange with a high-temperature heat medium which has been used for the heating operation, the heat capacity can be secured.

[0137] The refrigerant flows which have flowed out of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b pass through the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b, flow out of the relay unit 2, flow through the refrigerant pipe 4, pass through the check valve 13c, and are sucked again to the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0138] Next, the flow of a heat medium in the heat medium circulation circuit B in the "second heat recovery defrosting operation mode" will be explained.

[0139] In the "second heat recovery defrosting operation mode", the heat medium whose temperature has been decreased at the intermediate heat exchanger 25a and the heat medium whose temperature has been decreased at the intermediate heat exchanger 25b are pressurized by the pump 31 a and the pump 31 b, and flow into the use-side heat exchangers 35a to 35d via the second heat medium flow switching devices 33a to 33d. At this time, the second heat medium flow switching device 33 is switched to a direction in which the intermediate heat exchanger 25b and the pump 31 b are connected when the connected indoor unit 3 is in the heating operation mode, and is switched to a direction in which the intermediate heat exchanger 25a and the pump 31 a are connected when the connected indoor unit 3 is in the cooling operation mode.

[0140] For the indoor unit 3 that has been performing the cooling operation, the cooling operation continues to be performed by causing the heat medium which has been caused by the pump 31 a to flow into the indoor unit 3 to be subjected to heat exchange with the indoor air of the indoor space 7 at the use-side heat exchanger 35. Then, the heat medium which has been subjected to heat exchange at the use-side heat exchanger 35 is conveyed into the relay unit 2 via the heat medium pipe 5 and the heat medium flow control device 34. The flow rate of the heat medium which has been conveyed to each of the indoor units 3 is adjusted by the corresponding heat medium flow control device 34. The heat medium which has flowed out of the heat medium flow control device 34 passes through the first heat medium flow switching devices 32.

[0141] At this time, the flow rate is adjusted at the heat medium flow control device 34 based on a detected difference between the temperature immediately before the pump 31 a and the outlet temperature of the connected indoor unit 3. Furthermore, the first heat medium flow switching device 32 is switched to the direction in which the intermediate heat exchanger 25a and the pump 31 a are connected.

[0142] Meanwhile, the pump 31 b is driven, the fan of the indoor unit 3 that has been executing the heating operation mode is stopped, and the heating operation mode is thus stopped. Furthermore, the second heat medium flow switching device 33 that is connected to the indoor unit 3 that has been executing the heating operation mode is directed toward the opening direction in which the connected pump 31 b is connected. Moreover, the heat medium flow control device 34 after passing through the use-side heat exchanger 35 is fully opened, and the opening degree of the first heat medium flow switching device 32 is set to the same opening degree of the second heat medium flow switching device 33.

[0143] The heat medium that has been conveyed to the indoor unit 3 that has been executing the heating operation mode is conveyed to the intermediate heat exchanger 25b via the first heat medium flow switching device 32, without being subjected to heat exchange at the use-side heat exchanger 35. The heat medium that has flowed into the intermediate heat exchanger 25b is subjected to heat exchange again with a heat-source-side refrigerant that has flowed into the intermediate heat exchanger 25b, and supplies the heat to the refrigerant side. After that, the heat medium is sucked again into the pump 31 b.

[0144] The indoor unit 3 that has been performing a heating operation in the "second heat recovery defrosting operation mode" receives information indicating that the outdoor unit 1 is in the defrosting operation mode, and stops the fan. However, if the indoor air temperature and the indoor unit blown-out air temperature may be detected, no problem occurs if the fan continues operating as far as the indoor unit blown-out air temperature is not lower than the indoor air temperature. Furthermore, the fan may continue operating as long as the heat medium temperature at the outlet of the intermediate heat exchanger 25 detected by the temperature sensor 40 is not lower than the indoor air temperature.

[First bypass defrosting operation mode]

[0145] Fig. 9 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in the "first bypass defrosting operation mode" of the air-conditioning apparatus 100. In Fig. 9, the "first bypass defrosting operation mode" will be explained. In Fig. 9, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 9, solid arrows represent the flow direction of a heat-source-side refrigerant, and broken arrows represent the flow direction of a heat medium.

[0146] Similar to the "first heat recovery defrosting operation mode", the "first bypass defrosting operation mode" is a defrosting operation mode to be executed during the heating only operation mode of the air-conditioning apparatus 100 when frosting occurs to the heat-source-side heat exchanger 12 in the outdoor unit 1 due to moisture of the outdoor air and the evaporating temperature decreases. However, unlike the "first heat recovery defrosting operation mode", the refrigerant does not receive the heat capacity from the heat medium. The "first bypass defrosting operation mode" is executed during the execution of the "first heat recovery defrosting operation mode" by being switched according to a change in the setting temperature.

[0147] In the case of the "first bypass defrosting operation mode" illustrated in Fig. 9, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0148] In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b maintain a state being switched to the side of cooling operation, the opening and closing device 27 is opened, and the opening and closing device 29 is closed. Furthermore, the expansion device 26a and the expansion device 26b are fully closed.

[0149] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0150] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, and flows into the heat-source-side heat exchanger 12. The refrigerant that has flowed into the heat-source-side heat exchanger 12 exchanges heat with a frosting part on the heat-source-side heat exchanger 12. The frosting part on the heat-source-side heat exchanger 12 is melted by the high-temperature, high-pressure refrigerant. The low-temperature and high-pressure refrigerant that has exchanged heat with the frosting part on the heat-source-side heat exchanger 12 passes through the check valve 13a, and then flows out of the outdoor unit 1. The low-temperature and high-pressure refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0151] The refrigerant which has flowed into the relay unit 2 passes through the opening and closing device 27, and then passes through the opening and closing device 29. The expansion device 26a and the expansion device 26b are fully closed. Therefore, no refrigerant is conveyed to the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. The refrigerant which has passed through the opening and closing device 29 directly flows out of the relay unit 2, passes through the refrigerant pipe 4, and flows into the outdoor unit 1. The refrigerant which has flowed into the outdoor unit 1 passes through the check valve 13c, and is sucked into the compressor 10 again via the first refrigerant flow switching device 11 and the accumulator 19.

[0152] Next, the flow of a heat medium in the heat medium circulation circuit B in the "first bypass defrosting operation mode" will be explained.

[0153] The heat medium has been used for the heating operation, and as described above, the heat capacity is secured by temporarily increasing the temperature of the heat medium at the intermediate heat exchanger 25 before execution of the defrosting operation mode. Therefore, the heat medium maintains high temperature. Thus, even in the defrosting operation mode, a high-temperature heat medium may be conveyed to the use-side heat exchanger 35, that is, the heating operation may continue to be performed in the indoor unit 3.

[0154] Specifically, due to the operation of the pump 31 a and the pump 31 b that are connected to the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, the heat medium is conveyed. Furthermore, each of the second heat medium flow switching devices 33 that are connected to the corresponding indoor units 3 is set to have an intermediate opening degree. Moreover, the heat medium flow control devices 34 are controlled such that the outlet temperature of the intermediate heat exchangers 25 and the outlet temperature of the use-side heat exchangers 35 are constant. The first heat medium flow switching devices 32 are set to have the same opening degree of the second heat medium flow switching devices 33, and the heating operation by the conveyance of the heat medium may continue to be performed.

[0155] In addition, as illustrated in Fig. 9, even in the case where the indoor units 3 may be configured to perform ventilation, a high-temperature heat medium may flow into the use-side heat exchangers 35 during a defrosting operation, heat exchange with the outdoor air by the operation of the fans may be performed, and a heating operation by hot-air blowing may continue to be performed.

[0156] In the case where a heating operation continues to be performed by the operation of a fan, by making the air volume of the fan lower than the air volume (setting air volume) of the fan during a conventional heating operation, the heat capacity emitted to the indoor space by the use-side heat exchanger 35 may be limited, and the time during which the heat capacity of the heat medium is maintained may be extended. The setting air volume, which is the air volume of the fan during the conventional heating operation may be varied.

[0157] Fig. 10 is a graph illustrating an example of the relationship between the air volume of a fan for each temperature to which a heat medium may be reduced and the time during which the heat medium temperature may be maintained in the case where a heating operation continues to be performed with the air volume. As illustrated in Fig. 10, the emission amount and time of heat to the indoor space by blowing air from the fan may be estimated with respect to the heat capacity which may be held by the heat medium. By the above estimation, an appropriate air volume ratio and air volume maintenance time may be determined, and the heating operation mode may continue to be performed during the appropriate time at the appropriate temperature in the defrosting operation mode.

[Second bypass defrosting operation mode]

[0158] Fig. 11 is a refrigerant circuit diagram illustrating the flow of refrigerant and the flow of a heat medium in the "second bypass defrosting operation mode" of the air-conditioning apparatus 100. In Fig. 11, the "second bypass defrosting operation mode" will be explained. In Fig. 11, pipes indicated by thick lines represent pipes through which a heat-source-side refrigerant circulates. Furthermore, in Fig. 11, solid arrows represent the flow direction of a heat-source-side cooling, and broken arrows represent the flow direction of a heat medium. The "second bypass defrosting operation mode" is executed during the execution of the "second heat recovery defrosting operation mode" by being switched according to a change in the setting temperature.

[0159] In the case of the "second bypass defrosting operation mode" illustrated in Fig. 11, in the outdoor unit 1, the first refrigerant flow switching device 11 is switched to cause a heat-source-side refrigerant discharged from the compressor 10 to flow into the heat-source-side heat exchanger 12.

[0160] In the relay unit 2, the pump 31 a and the pump 31 b are driven and the heat medium flow control devices 34a to 34d are opened, so that a heat medium may circulate between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use-side heat exchangers 35a to 35d. Furthermore, the second refrigerant flow switching device 28a and the second refrigerant flow switching device 28b maintain a state being switched to the side of cooling operation, the opening and closing device 27 is opened, and the opening and closing device 29 is opened. Furthermore, the expansion device 26a is controlled such that the refrigerant at the outlet of the intermediate heat exchanger 25a becomes a gas state, and the expansion device 26b is fully closed.

[0161] First, the flow of a heat-source-side refrigerant in the refrigerant circulation circuit A will be explained.

[0162] A low-temperature and low-pressure refrigerant is compressed by the compressor 10 into a high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant which has been discharged from the compressor 10 passes via the first refrigerant flow switching device 11, and flows into the heat-source-side heat exchanger 12. The refrigerant that has flowed into the heat-source-side heat exchanger 12 exchanges heat with a frosting part on the heat-source-side heat exchanger 12. The frosting part on the heat-source-side heat exchanger 12 is melted by the high-temperature, high-pressure refrigerant. The low-temperature and high-pressure refrigerant that has exchanged heat with the frosting part on the heat-source-side heat exchanger 12 passes through the check valve 13a, and then flows out of the outdoor unit 1. The low-temperature and high-pressure gas refrigerant which has flowed out of the outdoor unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2.

[0163] The refrigerant which has flowed into the relay unit 2 passes through the opening and closing device 27, and is split. The split refrigerant flows pass through the opening and closing device 29 and the expansion device 26a. The refrigerant flows that have passed through the expansion device 26a flow into the intermediate heat exchanger 25a. In the intermediate heat exchanger 25a, due to the operation of the expansion device 26a, heat exchange with a heat medium continues to be performed to generate a low-temperature heat medium for cooling, and the generated low-temperature heat medium for cooling is supplied to the indoor unit 3. Meanwhile, no refrigerant is conveyed to the intermediate heat exchanger 25b, and heat exchange with a high-temperature heat medium which has been used for the heating operation is not performed.

[0164] The refrigerant flows that have passed through the intermediate heat exchanger 25a and the opening and closing device 29 are merged together. The merged refrigerant flows out of the relay unit 2. The refrigerant which has flowed out of the relay unit 2 passes through the refrigerant pipe 4, and flows into the outdoor unit. The refrigerant which has flowed into the outdoor unit 1 passes through the check valve 13c, and is sucked into the compressor 10 again via the first refrigerant flow switching device 11 and the accumulator 19.

[0165] Next, the flow of a heat medium in the heat medium circulation circuit B in the "second bypass defrosting operation mode" will be explained.

[0166] In the "second bypass defrosting operation mode", the heat medium whose temperature has been decreased at the intermediate heat exchanger 25a is pressurized by the pump 31 a, passes through a corresponding one of the second heat medium flow switching devices 33a to 33d that corresponds to the indoor unit 3 in the cooling operation mode, and flows into the corresponding one of the use-side heat exchangers 35a to 35d. For the indoor unit 3 that has been performing the cooling operation, the cooling operation continues to be performed by causing the heat medium which has been caused by the pump 31 a to flow into the indoor unit 3 to be subjected to heat exchange with the indoor air of the indoor space 7 at the use-side heat exchanger 35.

[0167] Then, the heat medium which has been subjected to heat exchange at the use-side heat exchanger 35 is conveyed into the relay unit 2 via the heat medium pipe 5 and the heat medium flow control device 34. The flow rate of the heat medium which has been conveyed to each of the indoor units 3 is adjusted by the corresponding heat medium flow control device 34. The heat medium which has flowed out of the heat medium flow control device 34 passes through the first heat medium flow switching device 32. The heat medium that has passed through the first heat medium flow switching device 32 is subjected to heat exchange again with a heat-source-side refrigerant that has flowed into the intermediate heat exchanger 25a, and supplies the heat to the refrigerant side. After that, the heat medium is sucked again into the pump 31 a.

[0168] In contrast, the heat medium flowing into the intermediate heat exchanger 25b has been used for the heating operation, and as described above, the heat capacity is secured by temporarily increasing the temperature of the heat medium at the intermediate heat exchanger before execution of the defrosting operation mode. Therefore, the heat medium still has a high temperature. Thus, even in the defrosting operation mode, a high-temperature heat medium may be conveyed to the use-side heat exchanger 35 by conveyance of the heat medium, that is, the heating operation may continue to be performed in the indoor unit 3.

[0169] Specifically, due to the operation of the pump 31 b that is connected to the intermediate heat exchanger 25b, the heat medium is conveyed. Furthermore, each of the second heat medium flow switching devices 33 that are connected to the corresponding indoor units 3 is directed toward the intermediate heat exchanger 25b. Moreover, the heat medium flow control devices 34 after passing through the use-side heat exchangers 35 are controlled such that the outlet temperature of the intermediate heat exchanger 25b and the outlet temperature of the use-side heat exchanger are constant. Furthermore, the first heat medium flow switching devices 32 are set to have the same opening degree of the second heat medium flow switching devices 33, and the heating operation by the conveyance of the heat medium may continue to be performed.

[0170] In addition, as illustrated in Fig. 11, even in the case where the indoor units 3 may perform ventilation, a high-temperature heat medium may flow into the use-side heat exchangers 35 during a defrosting operation, heat exchange with the outdoor air by the operation of the fans may be performed, and a heating operation by hot-air blowing may continue to be performed.

[0171] As described with reference to Fig. 10, in the case where a heating operation continues to be performed by the operation of a fan, by making the air volume of the fan smaller than a conventional heating operation, the heat capacity emitted to the indoor space by the use-side heat exchanger 35 may be limited, and the time during which the heat capacity of the heat medium is maintained may be extended.

[0172] As described above, the air-conditioning apparatus 100 exchanges heat between refrigerant and a heat medium via the relay unit 2 without causing the refrigerant to directly circulate in the indoor space in which the indoor units 3 are installed, and conveys the heat medium to the indoor units 3. Accordingly, a cooling operation and a heating operation can be achieved. Therefore, the air-conditioning apparatus 100 is able to avoid leakage of refrigerant into the indoor space. Furthermore, in the air-conditioning apparatus 100, refrigerant is conveyed from the outdoor unit 1 to the relay unit 2, and the relay unit 2 may thus be installed at an appropriate position. Therefore, the conveyance distance of a heat medium may be shortened, and the motive power of the pump 31 a and the pump 31 b may be reduced. Consequently, energy saving can be attained.

[0173] Furthermore, when the air-conditioning apparatus 100 performs a heating operation at a low outdoor air temperature, frosting occurs in the outdoor unit 1. The air-conditioning apparatus 100 has a defrosting operation mode for removing frost on the heat-source-side heat exchanger 12 of the outdoor unit 1 based on detection of the evaporating temperature or the like. In this defrosting operation mode, refrigerant which has been subjected to heat exchange by defrosting and whose temperature has been reduced is conveyed to the indoor units 3 during a heating operation. In addition, the refrigerant is subjected to heat exchange with a heat medium whose temperature has been increased to a high temperature immediately before a defrosting operation, and is conveyed to the outdoor unit 1. By performing the above processing, with the air-conditioning apparatus 100, the heat capacity held by a heat medium may be utilized for defrosting, and a defrosting operation time may be shortened.

[0174] Furthermore, in the defrosting operation mode, by reducing the air volume of a fan and setting a fan operation maintenance time corresponding to the air volume for the indoor unit 3 that has been performing a heating operation, the air-conditioning apparatus 100 is able to continue an appropriate heating operation. Furthermore, even when the indoor units 3 may take in the outdoor air, the air-conditioning apparatus 100 may exchange heat with a heat medium in the defrosting operation mode, and may continue to perform a heating operation, as described above.

[0175] The first heat medium flow switching devices 32 and the second heat medium flow switching devices 33 explained above in Embodiment may be devices which may switch a flow passage, such as a combination of three-way valves or the like which may switch three-way flow passages and opening and closing valves or the like which may open and close two-way flow passages. Furthermore, a combination of stepping-motor mixing valves or the like which may change the flow rate of three-way flow passages and electronic expansion valves or the like which may change the flow rate of two-way flow passages, or the like may be used as the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33. In this case, water hammer caused by sudden opening and closing of a flow passage may be prevented. Furthermore, although the case where the heat medium flow control devices 34 are two-way valves is explained as an example in Embodiment, the heat medium flow switching devices 34 may be configured as control valves having three-way flow passages and may be installed together with a bypass pipe for bypassing the use-side heat exchangers 35.

[0176] Furthermore, stepping-motor-driven devices which may control the flow rate of flowing in a flow passage may be used as the heat medium flow control devices 34. The devices may be two-way valves or three-way valves whose one end is closed. Furthermore, opening and closing valves or the like which open and close two-way flow passages may be used as the heat medium flow control devices 34, and the average flow rate may be controlled by repeatedly turning on and off.

[0177] Furthermore, although it is illustrated as if the second refrigerant flow switching devices 28 were four-way valves, the second refrigerant flow switching devices 28 are not limited to this. The second refrigerant flow switching devices 28 may be configured such that refrigerant flows in the same manner by using a plurality of two-phase flow passage switching valves or three-way flow passage switching valves.

[0178] Furthermore, needless to say, similar effects are achieved even when only one of the use-side heat exchangers 35 and the heat medium flow control devices 34 is connected, and there is no problem if a plurality of devices that perform the same operation are installed as the intermediate heat exchangers 25 and the expansion devices 26. Moreover, although the case where the heat medium flow control devices 34 are built in the relay unit 2 is explained as an example, the heat medium flow control devices 34 are not necessarily built in the relay unit 2. The heat medium flow control devices 34 may be built in the indoor units 3 or may be configured separately from the relay unit 2 and the indoor units 3.

[0179] As a heat medium, for example, brine (antifreeze), water, a liquid mixture of brine and water, a liquid mixture of water and an additive having high anticorrosion effect, or the like may be used. Therefore, in the air-conditioning apparatus 100, even if a heat medium is leaked into the indoor space 7 via the indoor units 3, the use of a heat medium with a high safety contributes to an improvement in the safety.

[0180] In Embodiment, although the case where the air-conditioning apparatus 100 includes the accumulator 19 has been explained as an example, the accumulator 19 is not necessarily provided. Furthermore, generally, blower devices are attached to the heat-source-side heat exchanger 12 and the use-side heat exchangers 35, and blowing air often prompts condensation and evaporation. However, the configuration is not limited to this. For example, panel heaters or the like which utilize radiation may be used as the use-side heat exchangers 35. Devices of a water-cooled type for moving heat by using water or antifreeze may be used as the heat-source-side heat exchanger 12. That is, devices of any type may be used as the heat-source-side heat exchanger 12 and the use-side heat exchangers 35 as long as they have a structure which may transfer heat or receive heat.

[0181] Although the case where the four use-side heat exchangers 35 are provided is explained as an example in Embodiment, the number of use-side heat exchangers 35 is not particularly limited. Furthermore, although the case where the two intermediate heat exchanger 25a and the intermediate heat exchanger 25b are provided is explained as an example, obviously, the number of intermediate heat exchangers is not limited to this. Any number of intermediate heat exchangers may be installed as long as the intermediate heat exchangers are able to cool or/and heat a heat medium. Furthermore, each of the number of pumps 31 a and the number of pumps 31 b is not necessarily one. A plurality of compact pumps may be connected in parallel to one another. Reference Signs List

[0182] 1: outdoor unit, 2: relay unit, 3: indoor unit, 3a: indoor unit, 3b: indoor unit, 3c: indoor unit, 3d: indoor unit, 4: refrigerant pipe, 4a: refrigerant connection pipe, 4b: refrigerant connection pipe, 5: heat medium pipe, 6: outdoor space, 7: indoor space, 8: space, 9: structure, 10: compressor, 11: first refrigerant flow switching device, 12: heat-source-side heat exchanger, 13a: check valve, 13b: check valve, 13c: check valve, 13d: check valve, 19: accumulator, 20: bypass pipe, 25: intermediate heat exchanger, 25a: intermediate heat exchanger, 25b: intermediate heat exchanger, 26: expansion device, 26a: expansion device, 26b: expansion device, 27: opening and closing device, 28: second refrigerant flow switching device (refrigerant flow switching device), 28a: second refrigerant flow switching device (refrigerant flow switching device), 28b: second refrigerant flow switching device (refrigerant flow switching device), 29: opening and closing device, 31: pump, 31 a: pump, 31b: pump, 32: first heat medium flow switching device, 32a: first heat medium flow switching device, 32b: first heat medium flow switching device, 32c: first heat medium flow switching device, 32d: first heat medium flow switching device, 33: second heat medium flow switching device, 33a: second heat medium flow switching device, 33b: second heat medium flow switching device, 33c: second heat medium flow switching device, 33d: second heat medium flow switching device, 34: heat medium flow control device, 34a: heat medium flow control device, 34b: heat medium flow control device, 34c: heat medium flow control device, 34d: heat medium flow control device, 35: use-side heat exchanger, 35a: use-side heat exchanger, 35b: use-side heat exchanger, 35c: use-side heat exchanger, 35d: use-side heat exchanger, 40: temperature sensor (heat medium temperature sensor), 40a: temperature sensor (heat medium temperature sensor), 40b: temperature sensor (heat medium temperature sensor), 43: duct, 50: controller, 100: air-conditioning apparatus, A: refrigerant circulation circuit, B: heat medium circulation circuit.

Claims

1. An air-conditioning apparatus comprising:

a refrigerant circulation circuit to circulate therein a heat-source-side refrigerant, the refrigerant circulation circuit connecting, by refrigerant pipes, a compressor, a heat-source-side heat exchanger, a plurality of expansion devices, refrigerant-side flow passages of a plurality of intermediate heat exchangers, and a plurality of refrigerant flow switching devices to switch a refrigerant circulation passage;

a heat medium circulation circuit to circulate therein a heat medium, the heat medium circuit connecting, by heat medium conveyance pipes, a plurality of heat medium conveyance devices provided in association with the plurality of intermediate heat exchangers, a plurality of use-side heat exchangers, and heat-medium-side flow passages for the plurality of intermediate heat exchangers; and

a bypass pipe installed so as to return the heat-source-side refrigerant to the compressor by bypassing at least the intermediate heat exchangers,

the plurality of intermediate heat exchangers exchanging heat between the heat-source-side refrigerant and the heat medium,

the air-conditioning apparatus being configured to execute

a heating operation mode switching the refrigerant flow switching devices to a side of heating operation, heating the heat medium by at least one of the intermediate heat exchangers, operating at least one of the heat medium conveyance devices, and supplying the heated heat medium to at least one of the use-side heat ex-

changers,
a heat recovery defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching, during the heating operation mode, the refrigerant flow switching devices to a side of cooling operation, operating at least one of the heat medium conveyance devices, and causing the heat-source-side refrigerant to receive heat of the heat medium by at least one of the intermediate heat exchangers, and
a bypass defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching, during the heating operation mode, the refrigerant flow switching devices to the side of cooling operation and causing part or whole of the heat-source-side refrigerant to flow to the bypass pipe.

2. The air-conditioning apparatus of claim 1,
wherein in the heat recovery defrosting operation mode,
at least one of the intermediate heat exchangers to cause the heat-source-side refrigerant to receive the heat of the heat medium is
same as the at least one of the intermediate heat exchangers having heated the heat medium before execution of the heat recovery defrosting operation mode.

3. The air-conditioning apparatus of claim 1 or 2, further comprising:

a heat medium temperature sensor provided at any position of a flow passage on an outlet side of the heat medium of the intermediate heat exchangers,
wherein the heat recovery defrosting operation mode is executed when a temperature of the heat medium detected by the heat medium temperature sensor is higher than a setting temperature, and
wherein the bypass defrosting operation mode is executed when the temperature of the heat medium detected by the heat medium temperature sensor is lower than the setting temperature.

4. The air-conditioning apparatus of claim 3, further comprising:

a use-side air temperature sensor detecting a temperature of air flowing through the use-side heat exchangers,
wherein the setting temperature is
equal to or higher than the temperature detected by the use-side air temperature sensor.

5. The air-conditioning apparatus of any one of claims 1 to 4,
wherein the heating operation mode includes
a heating only operation mode switching the refrigerant flow switching devices to the side of heating operation, heating the heat medium by all of the intermediate heat exchangers, operating all of the heat medium conveyance devices, and delivering the hot heat medium to all of the use-side heat exchangers,
wherein the heat recovery defrosting operation mode includes
a first heat recovery defrosting operation mode melting frost formed around the heat-source-side heat exchanger, by switching, during the heating only operation mode, the refrigerant flow switching devices to the side of cooling operation, causing the cold heat medium to flow to all of the intermediate heat exchangers, and causing the heat-source-side refrigerant to receive heat held in the heat medium by all of the intermediate heat exchangers, and
wherein when the air-conditioning apparatus is switched from the heating only operation mode to the first heat recovery defrosting operation mode to perform defrosting, the plurality of expansion devices are fully opened in the first heat recovery defrosting operation mode.

6. The air-conditioning apparatus of claim 5,
wherein the bypass defrosting operation mode is configured to perform
a first bypass defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching the refrigerant flow switching devices to the side of cooling operation and causing the entire heat medium to flow to the bypass pipe, and
defrosting is performed by switching the air-conditioning apparatus from the first heat recovery defrosting operation mode to the first bypass defrosting mode.

7. The air-conditioning apparatus of any one of claims 1 to 4,
wherein the heating operation mode includes
a heating main operation mode switching the refrigerant flow switching devices to the side of heating operation, heating the heat medium by at least one of the intermediate heat exchangers, and cooling the heat medium by rest of intermediate heat exchangers,
wherein the heat recovery defrosting operation mode includes
a second heat recovery defrosting operation mode melting frost formed around the heat-source-side heat exchanger by switching the refrigerant flow switching devices to the side of cooling operation, causing the cold heat medium to flow to all of the intermediate heat exchangers, and causing the heat-source-side refrigerant to receive heat held in the

heat medium by at least one of the intermediate heat exchangers having executed heating during the heating main operation mode while causing at least one of the intermediate heat exchangers having executed cooling during the heating main operation mode to continue cooling, and
wherein when the air-conditioning apparatus is switched from the heating main operation mode to the second heat recovery defrosting operation mode to perform defrosting, each of the expansion devices corresponding to at least one of the intermediate heat exchangers having executed heating during the heating main operation mode is fully opened in the second heat recovery defrosting operation mode.

8. The air-conditioning apparatus of claim 7,
wherein the bypass defrosting operation mode includes
a second bypass defrosting operation mode for melting frost formed around the heat-source-side heat exchanger by switching the refrigerant flow switching devices to the side of cooling operation, causing the cold heat medium to flow to at least one of the intermediate heat exchangers, and causing part of the heat medium to flow to the bypass pipe while causing at least one of the intermediate heat exchangers having executed cooling during the heating main operation to continue cooling, and
defrosting is performed by switching the air-conditioning apparatus from the second heat recovery defrosting operation mode to the second bypass defrosting operation mode.

9. The air-conditioning apparatus of any one of claims 1 to 8,
wherein in the heat recovery defrosting operation mode,
a blower device blowing air to at least one of the use-side heat exchangers having executed a heating operation before starting a defrosting operation is stopped, and
a blower device blowing air to at least one of the use-side heat exchangers having executed a cooling operation before starting the defrosting operation is operated.

10. The air-conditioning apparatus of any one of claims 1 to 9, further comprising:

a plurality of indoor units accommodating each of the plurality of use-side heat exchangers;
at least one outdoor unit accommodating the compressor and the heat-source-side heat exchanger; and
at least one relay unit accommodating the plurality of intermediate heat exchangers, the plurality of expansion devices, the plurality of heat medium conveyance devices, and the plurality of refrigerant flow switching devices,
wherein the indoor units, the outdoor unit, and the relay unit are configured to be formed independently of one another and installed at positions separated from one another.

11. The air-conditioning apparatus of claim 1,
wherein in the bypass defrosting operation mode, the heating operation continues to be performed by using a heat capacity of the heat medium having been used for the heating operation.

12. The air-conditioning apparatus of claim 11,
wherein in continuing the heating operation,
an amount of air blown to one of the use-side heat exchangers that continues to perform the heating operation is reduced to be less than a setting air volume.

13. The air-conditioning apparatus of claim 12,
wherein even when air is blown by using outdoor air taken in for a purpose of ventilation, hot air is suppliable by performing a heating operation using the heat medium.

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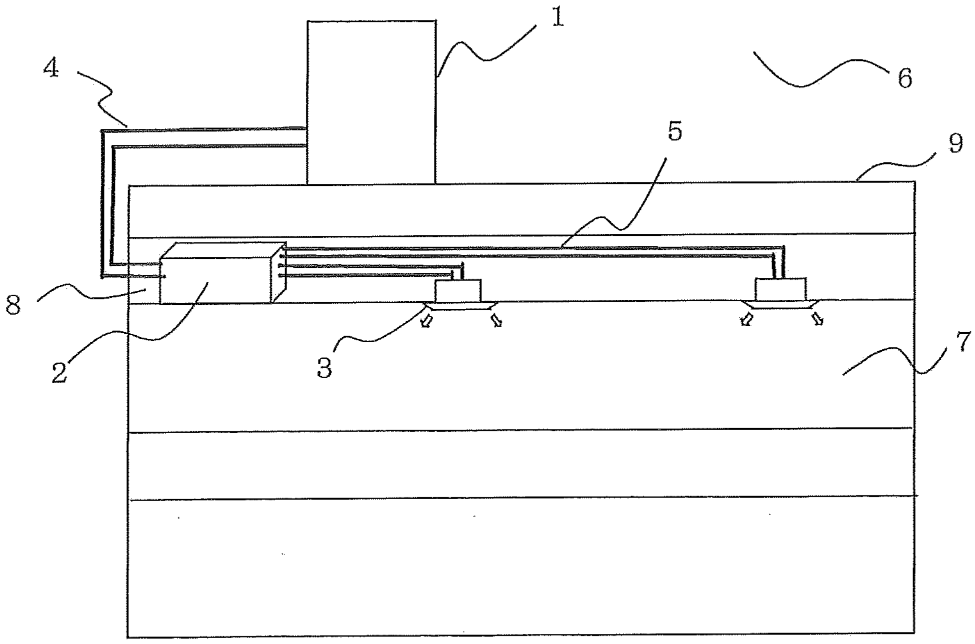
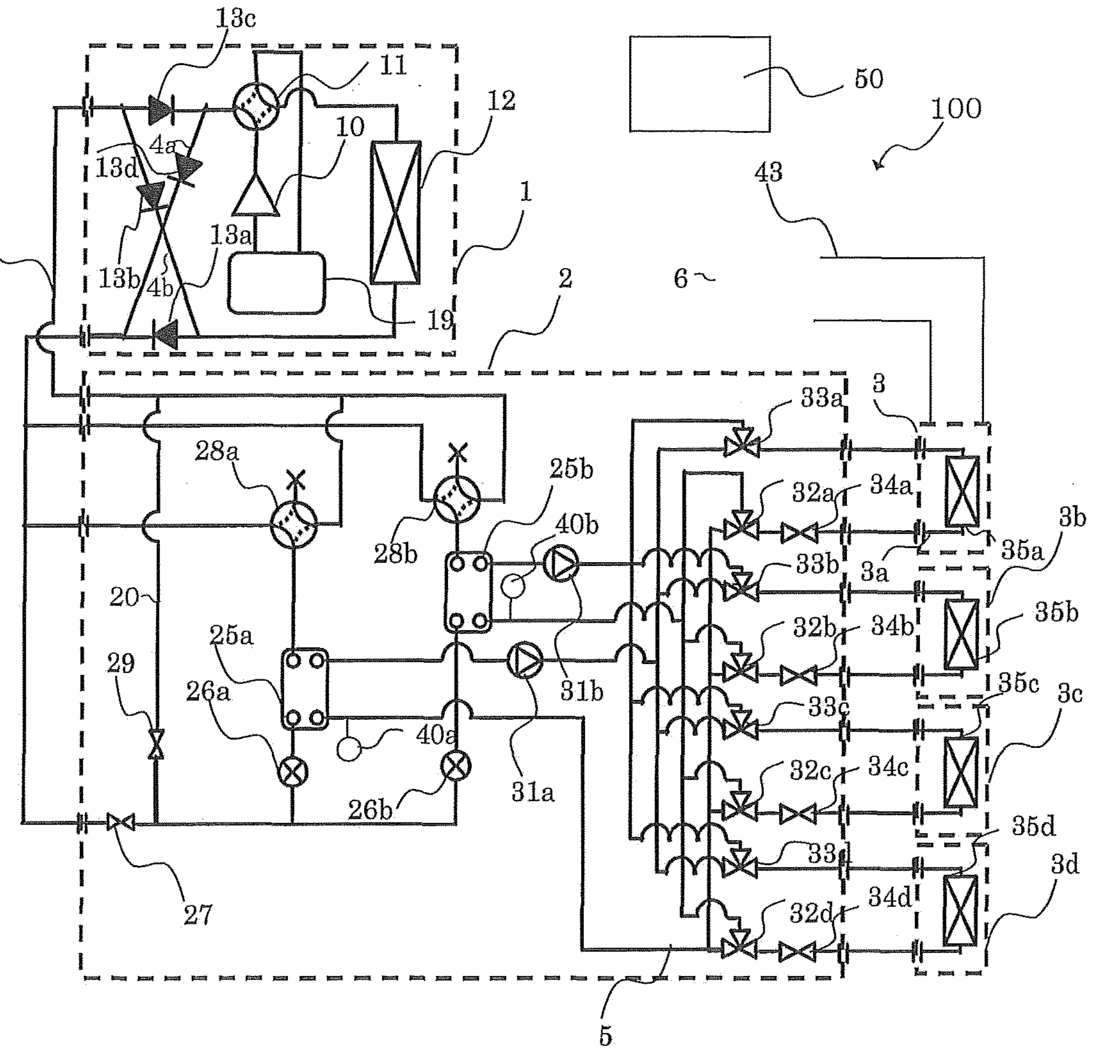


FIG. 2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F I G. 3

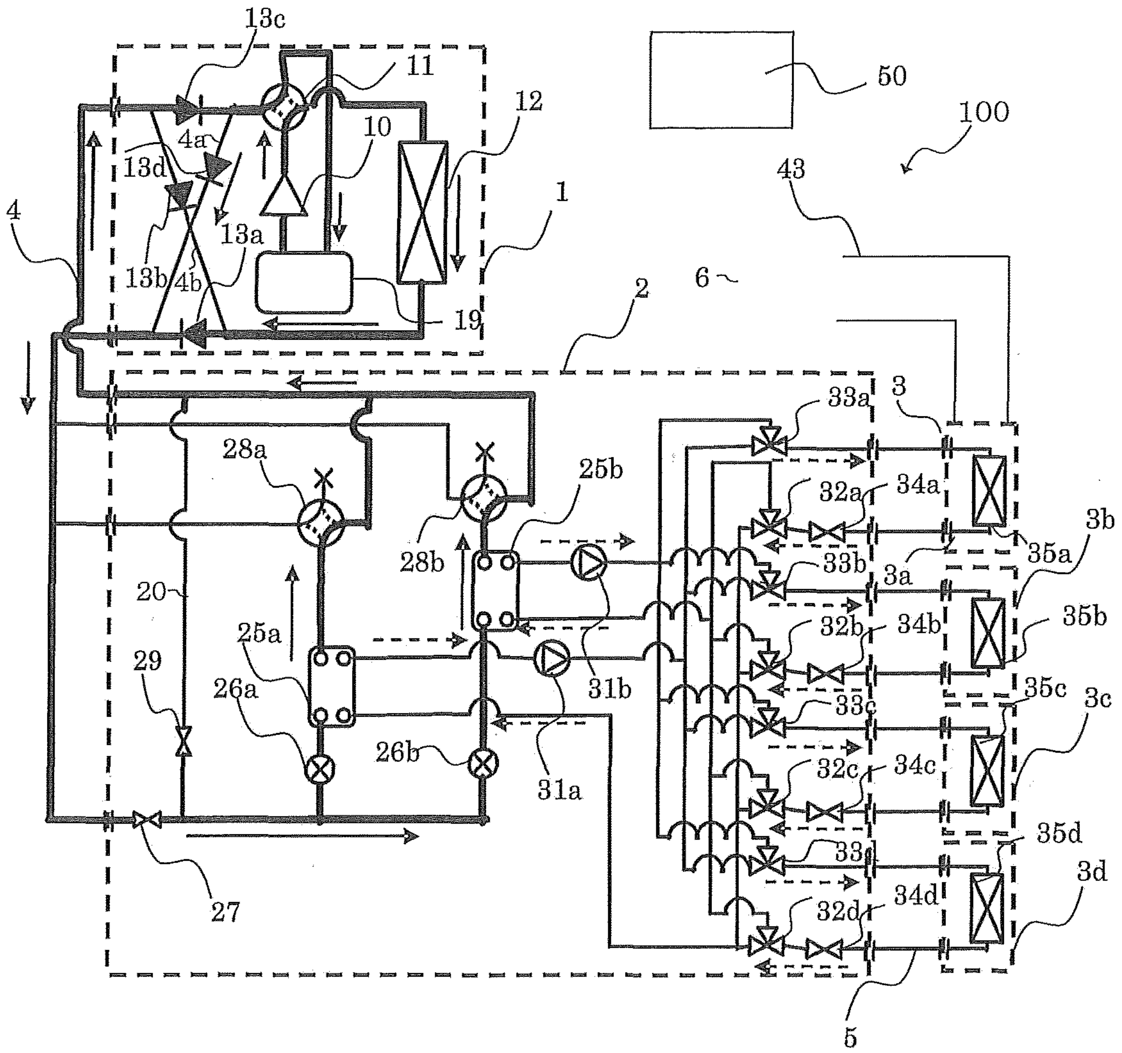
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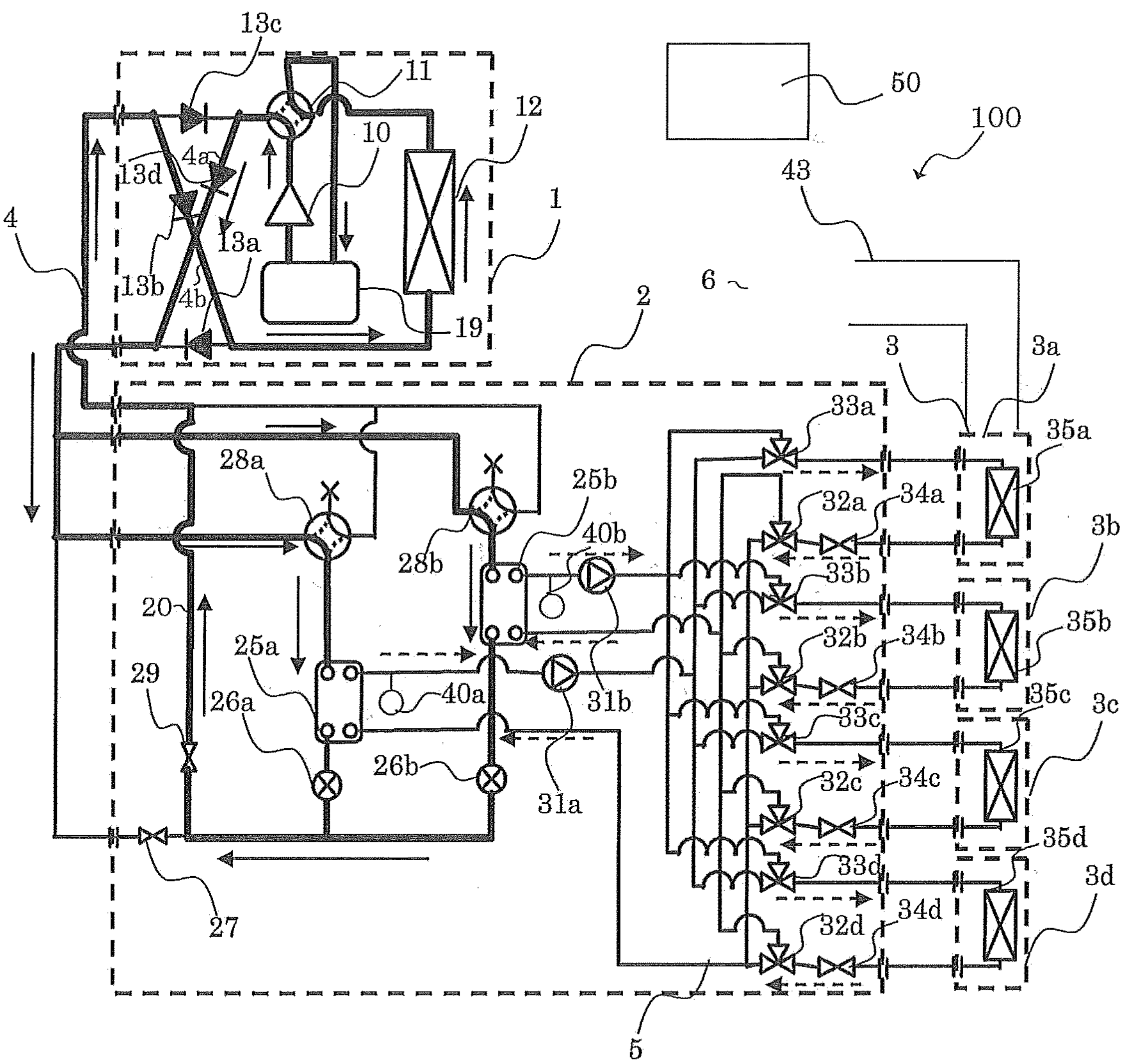
FIG. 4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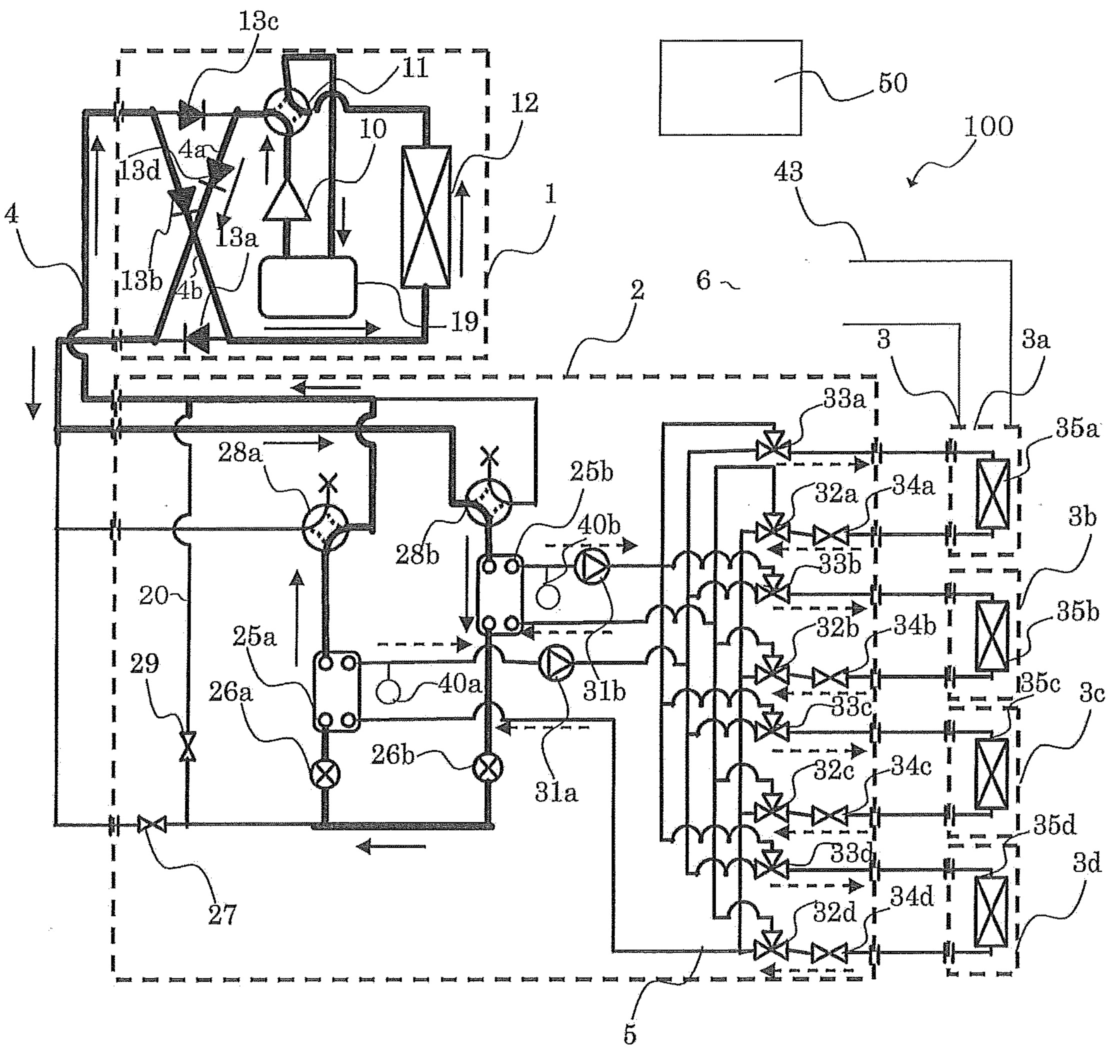
F I G. 5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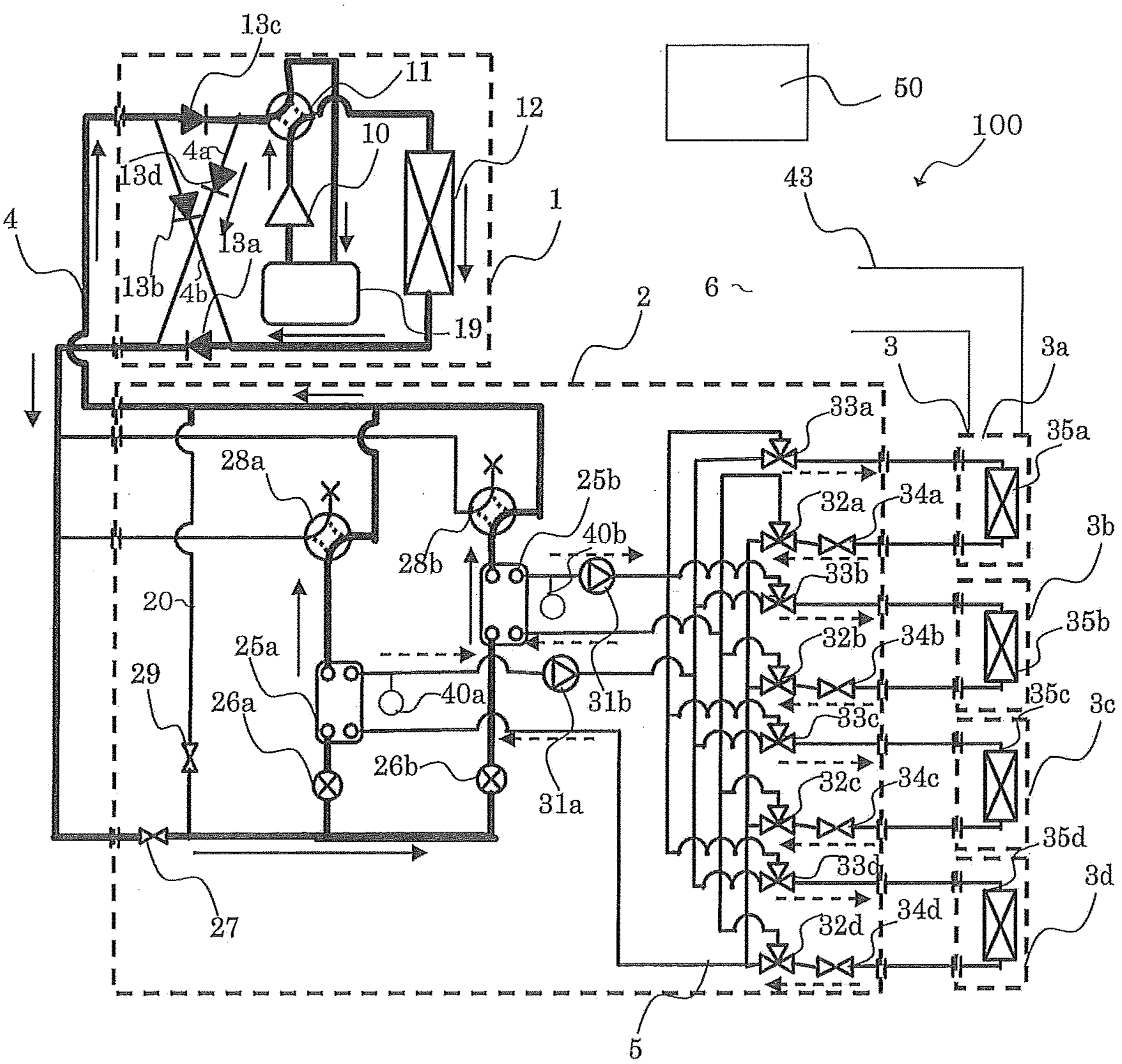
F I G. 6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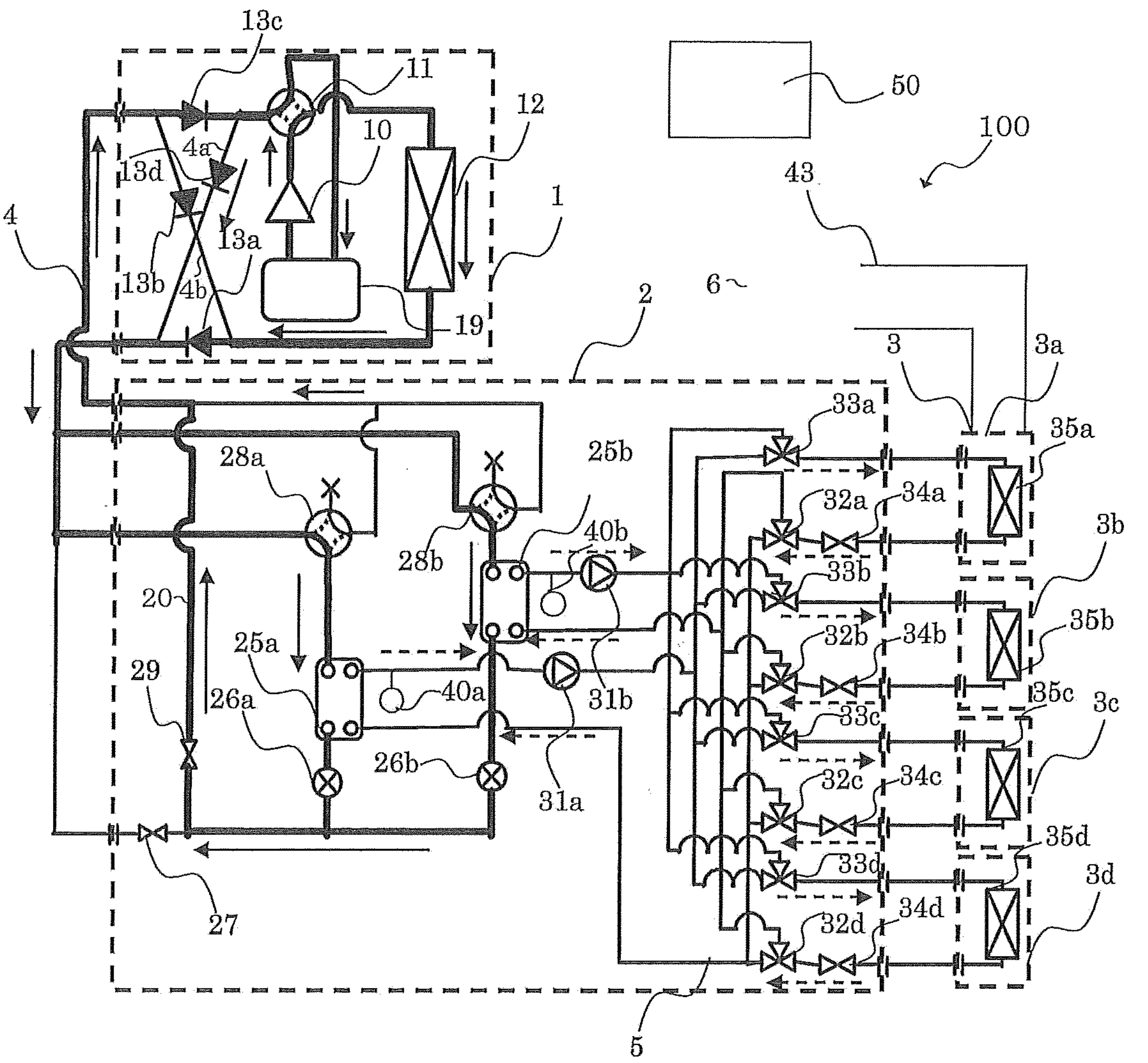
F I G. 7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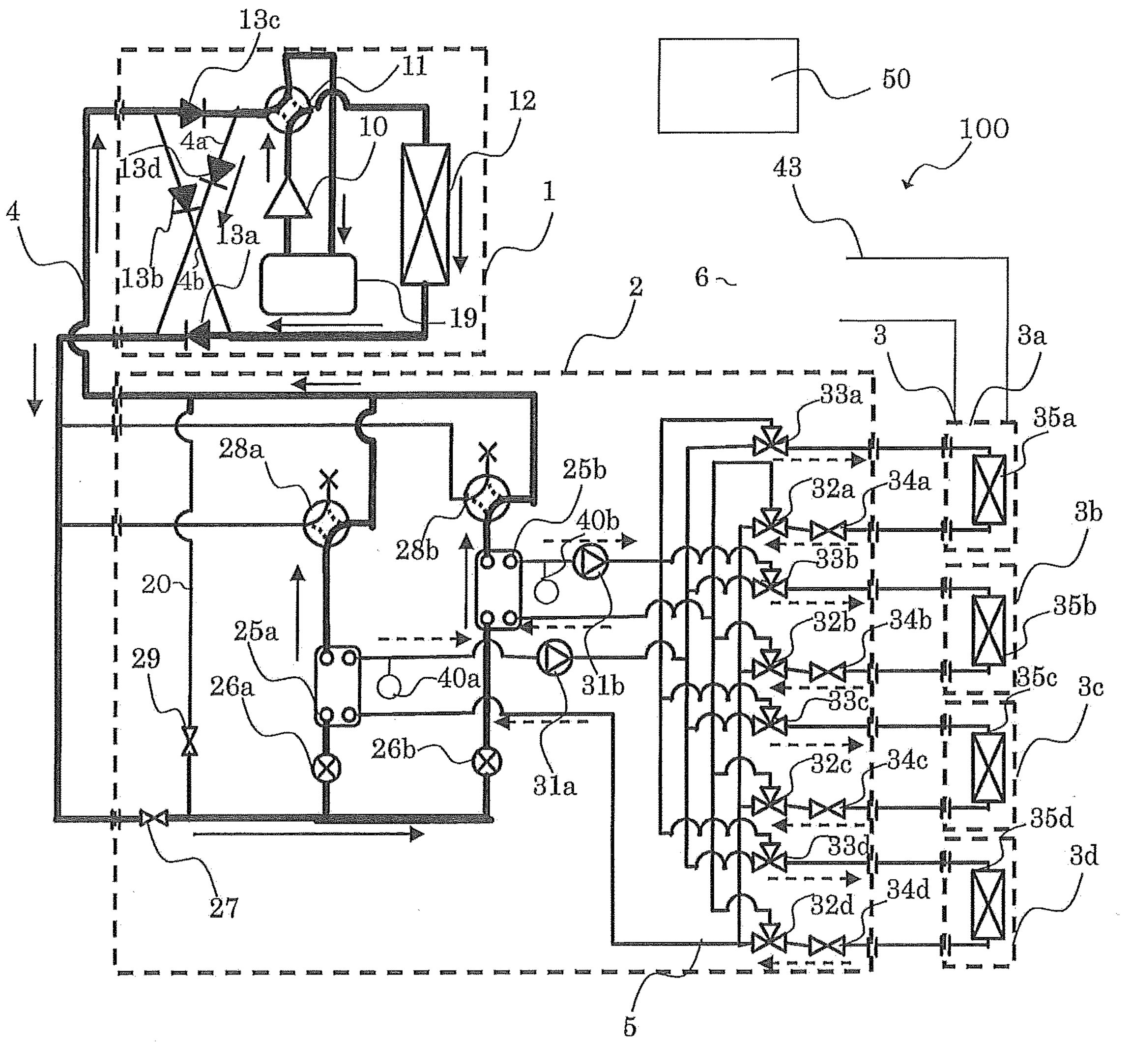
F I G. 8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F I G. 9

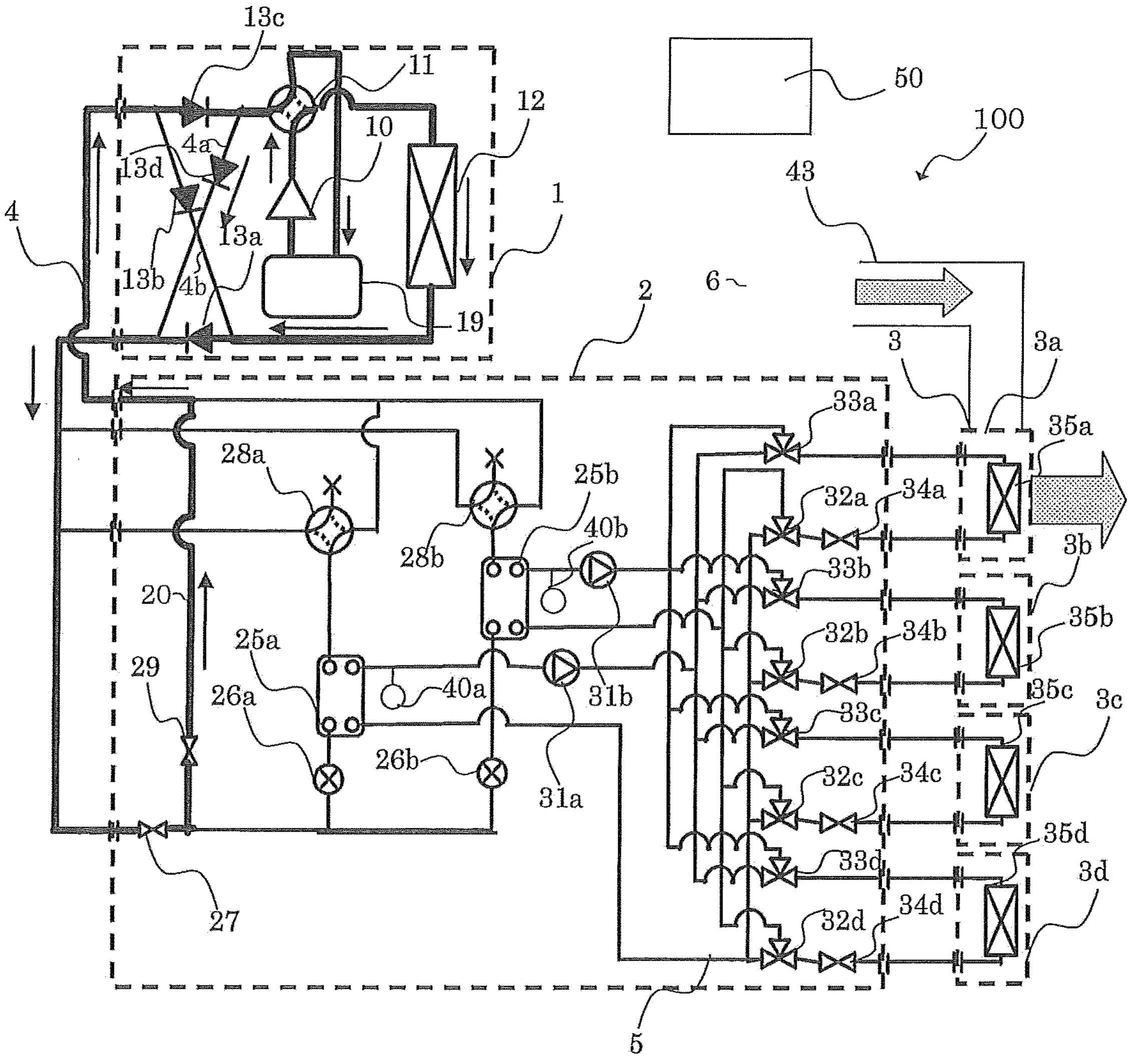
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FIG. 10

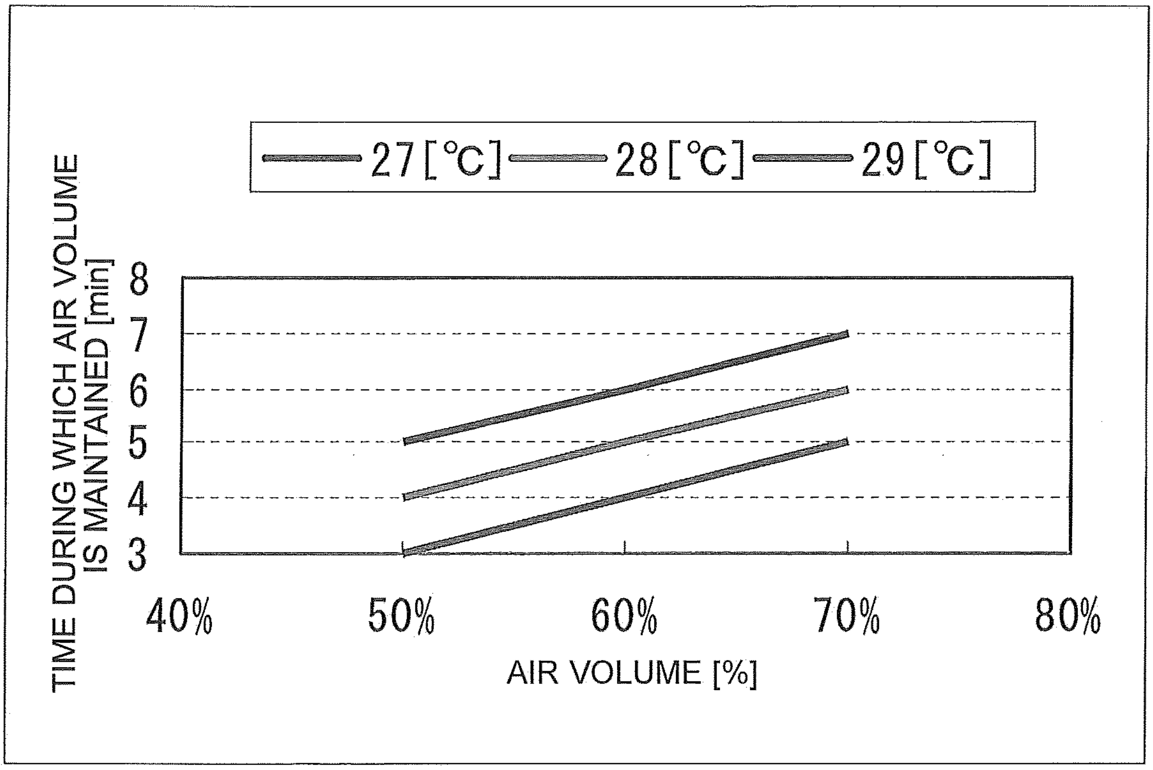
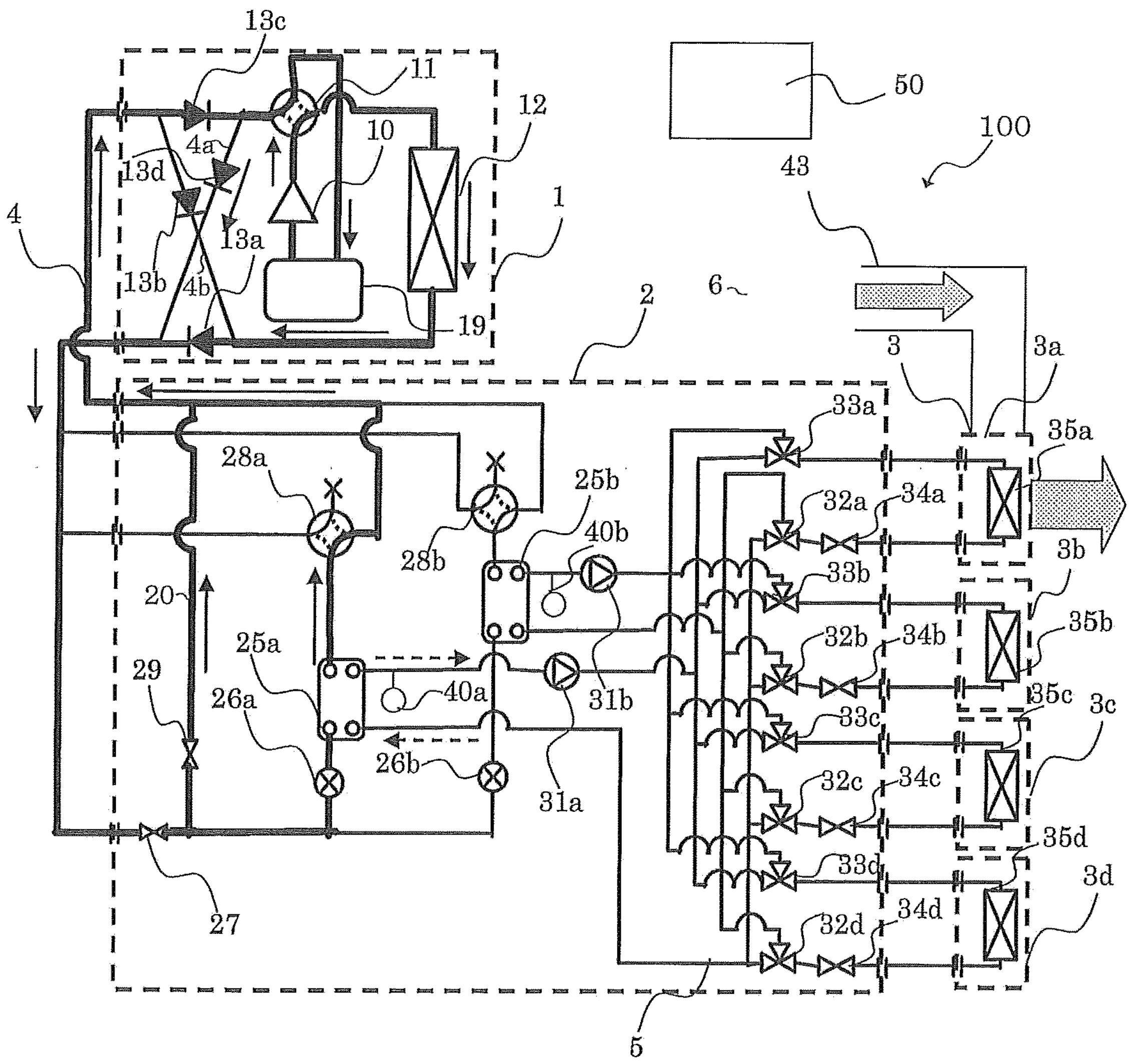

27[°C]
28[°C]
29[°C]
TIME DURING WHICH AIR VOLUME IS MAINTAINED [min]
8
7
6
5
4
3
40%
50%
60%
70%
80%
AIR VOLUME [%]

FIG. 11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3
3a
33a
35a
28a
25b
40b
32a
34a
3b
28b
33b
20
35b
25a
32b
34b
40a
29
26a
31b
35c
33c
3c
26b
31a
32c
34c
35d
33d
3d
27
32d
34d
5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/054788

A. CLASSIFICATION OF SUBJECT MATTER
F25B47/02(2006.01)i, *F24F5/00*(2006.01)i, *F25B1/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B47/02, F24F5/00, F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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	WO 2013/008365 A1 (Mitsubishi Electric Corp.), 17 January 2013 (17.01.2013), paragraphs [0098] to [0117]; fig. 8 to 9 (Family: none)	1-13
Y	JP 2011-47607 A (Panasonic Corp.), 10 March 2011 (10.03.2011), paragraphs [0031] to [0033]; fig. 1 to 4 (Family: none)	1-13
Y	JP 2007-232303 A (Toyox Co., Ltd.), 13 September 2007 (13.09.2007), paragraph [0012] (Family: none)	13

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 May, 2013 (07.05.13)	14 May, 2013 (14.05.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/054788

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2010/050002 A1 (Mitsubishi Electric Corp.), 06 May 2010 (06.05.2010), paragraphs [0048] to [0061]; fig. 8 & US 2011/0185756 A1 & EP 2309199 A1 & CN 102112818 A	1-13

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005140444 A **[0008]**
- JP 5280818 A **[0008]**
- JP 2001289465 A **[0008]**
- JP 2003343936 A **[0008]**
- WO 2010050002 A **[0008]**