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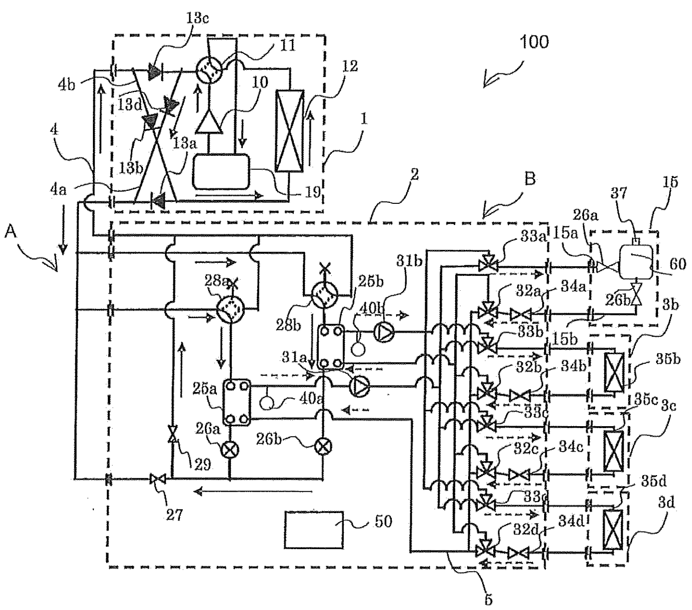
(54) AIR-CONDITIONING APPARATUS

(57) An air-conditioning apparatus includes a refrigerant circuit in which a compressor, a heat source side heat exchanger, an expansion device, and an intermediate heat exchanger exchanging heat between refrigerant and a heat medium are connected by a refrigerant pipe, the refrigerant flowing through the refrigerant circuit, a heat medium circuit in which a pump conveying the heat medium, a use side heat exchanger, and the intermediate heat exchanger are connected by a heat medium pipe, the heat medium flowing through the heat medium circuit, and an air discharge device including a heat medium tank connected to the heat medium circuit and separating air from the heat medium in the heat medium circuit, and an air vent valve provided at the heat medium tank and discharging the air.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus including a refrigerant circuit and a heat medium circuit.

Background Art

[0002] In air-conditioning apparatuses such as multi air-conditioning apparatuses for buildings, a heat source side unit (outdoor unit) is installed outside a building and a use side unit (indoor unit) is installed inside the building, for example. In such air-conditioning apparatuses, refrigerant circulating through a refrigerant circuit provided in the air-conditioning apparatus exchanges heat with air supplied to a use side heat exchanger at the use side heat exchanger of the use side unit, and transfers heat to air or receives heat from air, and thus the air is heated or cooled. Then, the heated or cooled air is sent to an air-conditioning target space, and thus the air-conditioning target space is heated or cooled. As a refrigerant used in such an air-conditioning apparatus, for example, an HFC (hydrofluorocarbon) refrigerant is often used. However, air-conditioning apparatuses using a natural refrigerant such as carbon dioxide (CO_2) have also been suggested.

[0003] Furthermore, various air-conditioning apparatuses called a chiller have been suggested in which cooling energy or heating energy is generated by a heat source side unit installed outside a building (see, for example, Patent Literature 1). Patent Literature 1 discloses an air-conditioning apparatus in which water, antifreeze solution, or other fluid is heated or cooled by a water heat exchanger provided at an outdoor unit, and the water, antifreeze solution, or other fluid is delivered to an indoor unit including a fan coil unit, a panel heater, and other devices, and thus an air-conditioning target space is heated or cooled.

[0004] Furthermore, an air-conditioning apparatus called a waste heat recovery chiller has also been suggested in which four water pipes are connected between a heat source side unit and a use side unit. Patent Literature 2 discloses a multi-room heating and cooling apparatus in which heated or cooled water or other fluid is simultaneously supplied to multiple indoor units and a cooling operation and a heating operation is freely selected for each of the multiple indoor units.

[0005] Furthermore, an air-conditioning apparatus has been suggested in which a refrigerant heat exchanger that exchanges heat between a primary refrigerant flowing through a primary-side refrigerant circuit and a secondary refrigerant flowing through a secondary-side refrigerant circuit is installed in the vicinity of multiple use side units (see, for example, Patent Literature 3).

[0006] An air-conditioning apparatus has also been suggested in which refrigerant heated or cooled by a heat source side unit is supplied to a heat exchanger provided at a relay unit, and heating energy or cooling energy of the supplied refrigerant is transmitted to a heat medium via the heat exchanger (see, for example, Patent Literature 4). Patent Literature 4 discloses a refrigeration cycle apparatus in which a heat source side unit and a branch unit are connected by two pipes.

[0007] Furthermore, an air-conditioning apparatus such as a multi-air-conditioning apparatus for buildings has been suggested in which refrigerant circulates between an outdoor unit and a relay unit and a heat medium such as water circulates between the relay unit and an indoor unit (see, for example, Patent Literature 5). Patent Literature 5 discloses an air-conditioning apparatus in which a distance to which the heat medium is conveyed is shortened by interposing the relay unit between the outdoor unit and the indoor unit to reduce power consumed to convey the heat medium.

Citation List

Patent Literature

[0008]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2005-140444 (Page 4, Fig. 1)
Patent Literature 2: Japanese Unexamined Patent Application Publication No. 5-280818 (Pages 4 to 5, Fig. 1)
Patent Literature 3: Japanese Unexamined Patent Application Publication No. 2001-289465 (Pages 5 to 8, Fig. 1, Fig. 2)
Patent Literature 4: Japanese Unexamined Patent Application Publication No. 2003-343936 (Page 5, Fig. 1)
Patent Literature 5: International Publication No. WO 10/049998 (Page 3, Page 20, Fig. 1)

Summary of Invention

Technical Problem

[0009] For installation of the apparatuses described in Patent Literatures 1 to 5 in buildings, HFC refrigerant or other refrigerant is introduced into a heat source side unit, and water, antifreeze solution, or other fluid that is to exchange heat with the HFC refrigerant or other refrigerant is introduced between the heat source side unit and a use side unit. When the water, antifreeze solution, or other fluid heated or cooled by heat exchange with the HFC refrigerant or other refrigerant is conveyed to the use side unit by a pump or other devices, an air-conditioning target space is heated or cooled. When the heat medium such as water and antifreeze solution is introduced, air remaining in a conveyance passage through which the heat medium flows has to be eliminated. A suggested unit for eliminating air remaining in the conveyance passage includes providing an air vent valve at the conveyance passage, in a test operation or other operations for introduction of an apparatus, eliminating air using the air vent valve while a heat medium is introduced and conveyed to the conveyance passage, or eliminating air and a heat medium at the same time using the air vent valve.

[0010] However, to eliminate air, steps are required such as activating a heat medium conveyance device such as a pump in the apparatus, operating a flow switching valve to convey a heat medium to each use side unit, and heating the heat medium by operating a heat source side unit to discharge air remaining in the heat medium. The steps require a long time, and thus, the workability is not excellent.

[0011] Furthermore, in the case where a unit for eliminating air and a heat medium at the same time using the air vent valve is adopted to eliminate air and antifreeze solution containing a substance that needs environmentally friendly drainage is used as a heat medium, wastewater treatment is required, and the above configuration is not environmentally friendly.

[0012] Furthermore, to eliminate air, in the case where a unit for eliminating air and a heat medium at the same time using the air vent valve is adopted, the heat medium such as water, antifreeze solution, or other fluid continues to be discharged in a test operation or other operations for introduction of the apparatus. Consequently, at the time of apparatus introduction or other times, a large amount of water, antifreeze solution, or other fluid is required, and thus, the workability and economy are not excellent.

[0013] The present invention has been made in light of the above problems, and provides an air-conditioning apparatus with excellent workability, economy, and environmental friendliness.

Solution to Problem

[0014] An air-conditioning apparatus according to an embodiment of the present invention includes a refrigerant circuit in which a compressor, a heat source side heat exchanger, an expansion device, and an intermediate heat exchanger exchanging heat between refrigerant and a heat medium are connected by a refrigerant pipe, the refrigerant flowing through the refrigerant circuit, a heat medium circuit in which a pump conveying the heat medium, a use side heat exchanger, and the intermediate heat exchanger are connected by a heat medium pipe, the heat medium flowing through the heat medium circuit, and an air discharge device including a heat medium tank connected to the heat medium circuit and separating air from the heat medium in the heat medium circuit, and an air vent valve provided at the heat medium tank and discharging the air.

Advantageous Effects of Invention

[0015] The air-conditioning apparatus according to the embodiment of the present invention includes the air discharge device including the heat medium tank and the air vent valve to improve the workability, economy, and environmental friendliness.

Brief Description of Drawings

[0016]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 2] Fig. 2 is a circuit diagram illustrating the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 3] Fig. 3 is a circuit diagram illustrating the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 4] Fig. 4 is a schematic diagram illustrating an air discharge device 15 according to Embodiment 1 of the present invention.
[Fig. 5] Fig. 5 is a circuit diagram illustrating a heat operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 6] Fig. 6 is a circuit diagram illustrating a cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 7] Fig. 7 is a circuit diagram illustrating a heating main operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention.

Description of Embodiments

[0017] Hereinafter, an air-conditioning apparatus according to an embodiment of the present invention will be explained with reference to the drawings. The present invention is not limited to the embodiment described below. In the drawings provided below including Fig. 1, the size relation of individual component members may differ from the actual size relation.

Embodiment 1

[0018] Fig. 1 is a schematic diagram illustrating an air-conditioning apparatus 100 according to Embodiment 1 of the present invention. With reference to Fig. 1, the air-conditioning apparatus 100 will be described below. As illustrated in Fig. 1, the air-conditioning apparatus 100 includes a heat source side unit 1, which is, for example, an outdoor unit, a plurality of use side units 3, which are, for example, indoor units, and a relay unit 2 that is interposed between the heat source side unit 1 and the use side units 3. The relay unit 2 exchanges heat between refrigerant and a heat medium. The heat source side unit 1 and the relay unit 2 are connected by refrigerant pipes 4 through which refrigerant flows, and the relay unit 2 and the use side units 3 are connected by heat medium pipes 5 through which a heat medium flows. Cooling energy or heating energy generated at the heat source side unit 1 is delivered to the use side units 3 via the relay unit 2.

[0019] The heat source side unit 1 is normally arranged in an outdoor space 6, which is a space (for example, a rooftop) outside a structure 9 such as a building, and supplies heating energy or cooling energy to the use side units 3 via the relay unit 2. The relay unit 2 transmits the heating energy or cooling energy generated at the heat source side unit 1 to the use side units 3. The relay unit 2 is a component that is separate from the heat source side unit 1 and the use side units 3, and is installable at a place different from the outdoor space 6 and an indoor space 7. Furthermore, the relay unit 2 is connected to the heat source side unit 1 by the refrigerant pipes 4, and is connected to the use side units 3 by the heat medium pipes 5. The use side units 3 are arranged at positions from which cooling air or heating air can be supplied to the indoor space 7, which is a space (for example, a living room) inside the structure 9, and supply the cooling air or heating air to the indoor space 7, which is an air-conditioning target space.

[0020] Refrigerant is conveyed from the heat source side unit 1 to the relay unit 2 through the refrigerant pipes 4. The conveyed refrigerant exchanges heat with a heat medium at intermediate heat exchangers 25 (see Fig. 2) in the relay unit 2, and heats or cools the heat medium. That is, the heat medium is heated or cooled at the intermediate heat exchangers 25 and turns into hot water or cold water. The hot water heated or cold water cooled at the relay unit 2 is conveyed to the use side units 3 through the heat medium pipes 5 using pumps 31 (see Fig. 2), which are heat medium conveyance devices, and is used by the use side units 3 for a heating operation or cooling operation for the indoor space 7.

[0021] As refrigerant, for example, a single refrigerant such as R-22 and R-134a, a near-azeotropic refrigerant mixture such as R-410A and R-404A, a non-azeotropic refrigerant mixture such as R-407C, a refrigerant having a relatively small global warming potential, such as CF_3 and $CF = CH_2$ having a double bond in the chemical formula or a mixture of such a refrigerant, or a natural refrigerant such as CO_2 and propane, can be used.

[0022] In contrast, as a heat medium, for example, water, antifreeze solution, a liquid mixture of water and antifreeze solution, a liquid mixture of water and an additive having high anti-corrosion effect, or other fluid can be used. The air-conditioning apparatus 100 according to Embodiment 1 will be described in the case where water is adopted as a heat medium.

[0023] As illustrated in Fig. 1, in the air-conditioning apparatus 100 according to Embodiment 1, the heat source side unit 1 and the relay unit 2 are connected by the two refrigerant pipes 4, and the relay unit 2 and each of the use side units 3 are connected by the two heat medium pipes 5. As described above, in the air-conditioning apparatus 100, by connecting the heat source side unit 1, the relay unit 2, and each of the use side units 3 by the two refrigerant pipes 4 and the two heat medium pipes 5, easy construction can be achieved.

[0024] In Fig. 1, a state is illustrated as an example in which the relay unit 2 is installed in a space 8 such as a space above a ceiling, which is a space that is in the structure 9 but is different from the indoor space 7. The relay unit 2 may be installed in any other space such as a common space in which an elevator or other apparatus is installed. Furthermore, in Fig. 1, the case where the use side units 3 are of a ceiling cassette type is illustrated as an example. However, the use side units 3 are not limited to the ceiling cassette type. The use side units 3 may be of any type such as a ceiling embedded type and a ceiling suspended type as long as the use side units 3 are able to blow heating air or cooling air to the indoor space 7 directly or through a duct or other devices.

[0025] Furthermore, in Fig. 1, the case where the heat source side unit 1 is installed in the outdoor space 6 is illustrated as an example. However, the heat source side unit 1 is not limited to be installed as described above. For example, the heat source side unit 1 may be installed in an enclosed space, such as a machine room with a ventilation opening. The heat source side 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. When the heat source side unit 1 is of a water-cooled type, the heat source side unit 1 may be installed inside the structure 9.

[0026] Furthermore, the relay unit 2 may be installed in the vicinity of the heat source side unit 1. In the case where the relay unit 2 is installed in the vicinity of the heat source side unit 1, the length of each of the heat medium pipes 5 that connect the relay unit 2 and the use side units 3 is appropriately adjusted. This is because a longer distance from the relay unit 2 to the use side units 3 accordingly increases power consumed to convey a heat medium, thus reducing energy saving effect. Furthermore, the numbers of connected heat source side units 1, relay units 2, and use side units 3 are not limited to the numbers illustrated in Fig. 1. The numbers of connected heat source side units 1, relay units 2, and use side units 3 may be appropriately determined depending on the structure 9 in which the air-conditioning apparatus 100 is installed.

[0027] In the case where the plurality of relay units 2 are connected to the single heat source side unit 1, the plurality of relay units 2 may be each separately installed in a common space or a space such as a space above a ceiling in the structure 9 such as a building. By installing the plurality of relay units 2 as described above, the intermediate heat exchangers 25 inside each of the relay units 2 is able to bear air-conditioning load. Furthermore, as long as the use side units 3 are installed at a distance or a height within an allowable conveyance range of the heat medium conveyance device in each of the relay units 2, the use side units 3 can be arranged to the entire structure such as a building.

[0028] Fig. 2 is a circuit diagram illustrating the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. As illustrated in Fig. 2, the heat source side unit 1 and the relay unit 2 are connected to each other by the refrigerant pipes 4 via intermediate heat exchangers 25a and 25b provided in the relay unit 2. Furthermore, the relay unit 2 and the use side units 3 are connected to each other by the heat medium pipes 5 via the intermediate heat exchangers 25a and 25b.

[0029] When the indoor space 7 reaches a set temperature, the air-conditioning apparatus 100 according to Embodiment 1 stops supply of a heat medium to use side heat exchangers 35 provided in the use side units 3 (thermo-off). Furthermore, even when the indoor space 7 does not reach the set temperature, when an instruction is issued by a user, the air-conditioning apparatus 100 not only stops supply of a heat medium to the use side heat exchangers 35 provided in the use side units 3 but also stops operation of fans (not illustrated in figures) provided in the vicinity of the use side heat exchangers 35 (stop mode). As described above, the air-conditioning apparatus 100 according to Embodiment 1 performs thermo-off and adjusts the temperature of the indoor space 7 when the indoor space 7 reaches the set temperature, and executes the stop mode when an instruction for stopping operation is received from a user.

[0030] The air-conditioning apparatus 100 includes a refrigerant circuit A, which is a refrigeration cycle in which refrigerant circulates, and a heat medium circuit B through which a heat medium circulates, and a cooling operation or a heating operation can be selected for each of the use side units 3. Hereinafter, a mode in which all of the use side units 3 perform a cooling operation will be referred to as a cooling operation mode, a mode in which all of the use side units 3 perform a heating operation will be referred to as a heating operation mode, and a mode in which some use side units 3 perform a cooling operation and other use side units 3 perform a heating operation will be referred to as a mixed operation mode. The mixed operation mode includes a cooling main mode in which the cooling load is larger than the heating load and a heating main mode in which the heating load is larger than the cooling load.

(Heat Source Side Unit 1)

[0031] In the heat source side 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 installed and are connected by the refrigerant pipes 4. The heat source side unit 1 also includes a first connection pipe 4a, a second connection pipe 4b, and check valves 13a to 13d. By providing the first connection pipe 4a, the second connection pipe 4b, and the check valves 13a to 13d, the air-conditioning apparatus 100 can allow the flow of refrigerant that flows into the relay unit 2 from the heat source side unit 1 into a fixed direction, irrespective of which operation mode is executed among the heating operation mode, the cooling operation mode, the heating main mode, and the cooling main mode.

(Compressor 10)

[0032] The compressor 10 sucks refrigerant, compresses the refrigerant into a high-temperature and high-pressure state, and conveys the refrigerant to the refrigerant circuit A. The discharge side of the compressor 10 is connected to the first refrigerant flow switching device 11, and the suction side of the compressor 10 is connected to the accumulator 19. The compressor 10 is preferred to be an inverter compressor whose capacity can be controlled, for example.

(First Refrigerant Flow Switching Device 11)

[0033] In the heating operation mode and the heating main mode of the mixed operation mode, the first refrigerant flow switching device 11 switches a flow passage to connect the discharge side of the compressor 10 and the check valve 13d and to connect the heat source side heat exchanger 12 and the suction side of the accumulator 19. In the cooling operation mode and the cooling main mode of the mixed operation mode, the first refrigerant flow switching device 11 switches a flow passage to connect the discharge side of the compressor 10 and the heat source side heat exchanger 12 and to connect the check valve 13c and the suction side of the accumulator 19.

(Heat Source Side Heat Exchanger 12)

[0034] The heat source side heat exchanger 12 operates as an evaporator during a heating operation and operates as a condenser or a radiator during a cooling operation. The heat source side heat exchanger 12 exchanges heat between fluid of air supplied from an air-sending device such as a fan (not illustrated in figures) and refrigerant to evaporate and gasify or condense and liquefy the refrigerant. In the heating operation mode, one end of the heat source side heat exchanger 12 is connected to the check valve 13b, and the other end of the heat source side heat exchanger 12 is connected to the suction side of the accumulator 19. In the cooling operation mode, the other end of the heat source side heat exchanger 12 is connected to the discharge side of the compressor 10, and the one end of the heat source side heat exchanger 12 is connected to the check valve 13a. The heat source side heat exchanger 12 is preferred to be a plate fin-and-tube heat exchanger that exchanges heat between refrigerant flowing in the refrigerant pipe 4 and air passing through fins, for example.

(Accumulator 19)

[0035] The accumulator 19 stores excess refrigerant caused by a difference between the heating operation and the cooling operation, excess refrigerant caused by a transient change in the operation (for example, a change in the number of operating use side units 3) or other excess refrigerant. In the heating operation mode, the suction side of the accumulator 19 is connected to the heat source side heat exchanger 12, and the discharge side of the accumulator 19 is connected to the suction side of the compressor 10. In the cooling operation mode, the suction side of the accumulator 19 is connected to the check valve 13c, and the discharge side of the accumulator 19 is connected to the suction side of the compressor 10.

(Check Valves 13a to 13d)

[0036] The check valve 13c is provided at a portion of the refrigerant pipe 4 between the relay unit 2 and the first refrigerant flow switching device 11 and allows refrigerant to flow only in the direction from the relay unit 2 to the heat source side unit 1. The check valve 13a is provided at a portion of the refrigerant pipe 4 between the heat source side heat exchanger 12 and the relay unit 2 and allows refrigerant to flow only in the direction from the heat source side unit 1 to the relay unit 2. The check valve 13d is provided at the first connection pipe 4a and allows refrigerant discharged from the compressor 10 to flow in the relay unit 2 during a heating operation. The check valve 13b is provided at the second connection pipe 4b and allows refrigerant returned from the relay unit 2 to flow in the suction side of the compressor 10 during a heating operation.

(First Connection Pipe 4a, Second Connection Pipe 4b)

[0037] The first connection pipe 4a allows connection, in the heat source side unit 1, 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. The second connection pipe 4b allows connection, in the heat source side unit 1, 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 the heat source side heat exchanger 12 and the check valve 13a. In Fig. 2, the case where the first connection pipe 4a, the second 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 present invention is not limited to the above configuration. The above components are not necessarily provided.

(Use Side Unit 3)

[0038] The use side units 3 include use side heat exchangers 35a to 35d (may be generically referred to as the use side heat exchangers 35). In Fig. 2, the case where four use side units 3a to 3d are connected to the relay unit 2 via the heat medium pipes 5 is illustrated as an example. However, the number of connected use side units 3 is not limited to four.

(Use Side Heat Exchanger 35)

[0039] The use side heat exchangers 35 are connected to corresponding heat medium flow control devices 34a to 34d (may be generically referred to as heat medium flow control devices 34) via the heat medium pipes 5 and are connected to corresponding second heat medium flow switching devices 33a to 33d (may be generically referred to as second heat medium flow switching devices 33) via the heat medium pipes 5. Furthermore, the use side heat exchangers 35 exchange heat between air supplied from air-sending devices such as fans (not illustrated in figures) and a heat medium to heat or cool the air into heating air or cooling air to be supplied to the indoor space 7. In Fig. 2, the four use side heat exchangers 35a to 35d are provided at the four use side units 3a to 3d, respectively. However, the number of connected use side heat exchangers 35 is not limited to four.

(Relay Unit 2)

[0040] In the relay unit 2, the two intermediate heat exchangers 25a and 25b (may be generically referred to as the intermediate heat exchangers 25), two expansion devices 26a and 26b (may be generically referred to as expansion devices 26), two opening and closing devices 27 and 29, two second refrigerant flow switching devices 28 (may be generically referred to as second refrigerant flow switching devices 28), two pumps 31a and 31b (may be generically referred as pumps 31), four first heat medium flow switching devices 32a to 32d (may be generically referred to as first heat medium flow switching devices 32), the four second heat medium flow switching devices 33a to 33d (may be generically referred to as the second heat medium flow switching devices 33), and the four heat medium flow control devices 34a to 34d (may be generically referred to as the heat medium flow control devices 34) are provided. Furthermore, the relay unit 2 includes a controller 50.

[0041] Functions of the second heat medium flow switching devices 33a to 33d and the heat medium flow control devices 34a to 34d can be integrated, and the second heat medium flow switching devices 33 and the heat medium flow control devices 34 may be integrated as a block by connecting branch ports.

(Intermediate Heat Exchanger 25)

[0042] The intermediate heat exchangers 25 operate as condensers (radiators) or evaporators, exchange heat between refrigerant and a heat medium, and transmit cooling energy or heating energy generated at the heat source side unit 1 and stored in the refrigerant to the heat medium. That is, the intermediate heat exchangers 25 operate as condensers or radiators and transmit heating energy of refrigerant to a heat medium during a heating operation and operate as evaporators and transmit cooling energy of refrigerant to a heat medium during a cooling operation. The intermediate heat exchanger 25a is provided between the expansion device 26a and the second refrigerant flow switching device 28a in the refrigerant circuit A and is used for cooling a heat medium in the 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 circuit A and is used for heating a heat medium in the mixed operation mode.

(Expansion Device 26)

[0043] The expansion devices 26 operate as pressure reducing valves or expansion valves to decompress and expand refrigerant. The expansion device 26a is provided on the upstream side of the intermediate heat exchanger 25a in the flow of refrigerant in a cooling operation. The expansion device 26b is provided on the upstream side of the intermediate heat exchanger 25b in the flow of refrigerant in a cooling operation. The expansion devices 26 may be devices whose opening degrees are variably controllable, such as electronic expansion valves.

(Opening and Closing Devices 27 and 29)

[0044] The opening and closing device 27 and the opening and closing device 29 are, for example, solenoid valves or other devices that can be opened and closed by electrical connection, and open and close flow passages at which the opening and closing device 27 and the opening and closing device 29 are provided. That is, the opening and closing device 27 and the opening and closing device 29 are controlled to be opened and closed depending on an operation mode, and switch the flow passage of refrigerant. The opening and closing device 27 is provided, at a portion of the refrigerant pipe 4 on a refrigerant inlet side, on an upstream side of the expansion devices 26 in a cooling operation. The opening and closing device 29 is provided at a bypass pipe 20 that connects the portion of the refrigerant pipe 4 on the refrigerant inlet side with a portion of the refrigerant pipe 4 on a refrigerant outlet side. The opening and closing device 27 and the opening and closing device 29 may be any device that may open and close the flow passages at which the opening and closing device 27 and the opening and closing device 29 are provided, and may be expansion valves whose opening degree may be controlled, such as electronic expansion valves.

(Second Refrigerant Flow Switching Device 28)

[0045] The second refrigerant flow switching devices 28 are, for example, four-way valves, and switch the flow of refrigerant so that the intermediate heat exchangers 25 operate as condensers or evaporators depending on 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 refrigerant in 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 refrigerant in a cooling operation.

(Pump 31)

[0046] The pumps 31 cause a heat medium that flows through the heat medium pipes 5 to circulate in the heat medium circuit B. The pump 31a is provided at a portion of the heat medium pipe 5 between the intermediate heat exchanger 25a and the second heat medium flow switching devices 33. The pump 31b is provided at a portion of the heat medium pipe 5 between the intermediate heat exchanger 25b and the second heat medium flow switching devices 33. The pumps 31 are, for example, pumps whose capacity is preferably controllable and whose flow rate is preferably adjustable depending on the size of the load in the use side units 3.

(First Heat Medium Flow Switching Device 32)

[0047] The first heat medium flow switching devices 32 switch connection of an outlet side of the flow passage of a heat medium of the use side heat exchangers 35 and an inlet side of the flow passage of a heat medium of the intermediate heat exchangers 25. The number of first heat medium flow switching devices 32 provided corresponds to the number of use side units 3 installed (in Embodiment 1, the number is four). The first heat medium flow switching devices 32 are, for example, three-way valves, and 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. To correspond to the outlet side of the use side units 3a to 3d, the first heat medium flow switching devices 32a to 32d are provided. Furthermore, switching of a heat medium flow passage includes switching from one side to the other side of some heat medium flow passages as well as switching from one side to the other side of all heat medium flow passages.

(Second Heat Medium Flow Switching Device 33)

[0048] The second heat medium flow switching devices 33 switch connection of an outlet side of the flow passage of a heat medium of the intermediate heat exchangers 25 and an inlet side of the flow passage of a heat medium of the use side heat exchangers 35. The number of second heat medium flow switching devices 33 provided corresponds to the number of use side units 3 installed (in Embodiment 1, the number is four). The second heat medium flow switching devices 33 are, for example, three-way valves, and 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 use side heat exchangers 35. To correspond to the use side units 3a to 3d, the second heat medium flow switching devices 33a to 33d are provided. Furthermore, switching of a heat medium flow passage includes switching from one side to the other side of some heat medium flow passages as well as switching from one side to the other side of all heat medium flow passages.

(Heat Medium Flow Control Device 34)

[0049] The heat medium flow control devices 34 are two-way valves or other devices whose opening area can be controlled, and control the flow rate of a heat medium flowing in the heat medium pipes 5. The number of heat medium flow control devices 34 provided corresponds to the number of use side units 3 installed (in Embodiment 1, the number is 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 use side units 3 depending on the temperature of the heat medium flowing into and flowing out of the use side units 3 and supply an amount of heat medium suitable for the indoor load to the use side units 3.

[0050] To correspond to the use side units 3a to 3d, the heat medium flow control devices 34a to 34d are provided. 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 a use side unit 3 requires no load, such as during the stop mode or thermo-off, the supply of a heat medium to the use side unit 3 can be stopped by fully closing the corresponding heat medium flow control device 34.

[0051] When, as the first heat medium flow switching devices 32 or the second heat medium flow switching devices 33, devices having functions of the heat medium flow control devices 34 in addition to functions of the first heat medium flow switching devices 32 and the second heat medium flow switching devices 33 are used, the heat medium flow control devices 34 may be omitted.

[0052] Furthermore, as described above, the first heat medium flow switching devices 32, the second heat medium flow switching devices 33, and the heat medium flow control devices 34 may be integrated (formed as a block) and devices including a flow switching function, a flow control function, and a flow passage closing function may be used in place of the first heat medium flow switching devices 32, the second heat medium flow switching devices 33, and the heat medium flow control devices 34.

[0053] The heat medium pipes 5 through which a heat medium flows include a pipe connected to the intermediate heat exchanger 25a and a pipe connected to the intermediate heat exchanger 25b. Each pipe of the heat medium pipes 5 branches out into branch pipes (in Embodiment 1, four branches) depending on the number of use side units 3 connected to the relay unit 2. The branch pipes of heat medium pipes 5 that are connected to the intermediate heat exchanger 25a and the branch pipes of the heat medium pipes 5 that are connected to the intermediate heat exchanger 25b 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 cause a heat medium from the intermediate heat exchanger 25a or a heat medium from the intermediate heat exchanger 25b to flow into the use side heat exchangers 35.

(Temperature Sensor 40)

[0054] Furthermore, in the relay unit 2, two temperature sensors 40a and 40b (may be generically referred to as temperature sensors 40) for measuring the temperature of a heat medium on the outlet side of the intermediate heat exchangers 25 are provided. Information of temperature measured by the temperature sensors 40 is sent to the controller 50 that integrally controls 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 air-sending devices (not illustrated in figures), 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 use side units 3, and other operations.

[0055] The temperature sensors 40 measure the temperature of a heat medium flowing out of the intermediate heat exchangers 25, that is, a heat medium on the outlet side of the intermediate heat exchangers 25. The temperature sensor 40a is provided at the heat medium pipe 5 on the suction side of the pump 31a. The temperature sensor 40b is provided at the heat medium pipe 5 on the suction side of the pump 31b. The temperature sensors 40 may be, for example, thermistors.

(Controller 50)

[0056] The controller 50 is a microcomputer or other devices. The controller 50 controls the driving frequency of the compressor 10, the rotation speed (and turning on and off) of air-sending devices (not illustrated in figures), switching of the first refrigerant flow switching device 11, driving of the pumps 31, the opening degree of the expansion devices 26, 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, driving of the heat medium flow control devices 34, opening and closing of the opening and closing devices 27 and 29, and other operations, on the basis of detection results from the various detection units and instructions from a remote controller or other devices. That is, the controller 50 controls actuators or other devices included in these components and executes operation modes. The case where the controller 50 is provided in the relay unit 2 is illustrated as an example. However, the controller 50 is not limited to be provided in the relay unit 2. The controller 50 may be provided in the heat source side unit 1 or the use side unit 3. The controller 50 may also communicate with each component.

(Air Discharge Device 15)

[0057] Next, the air discharge device 15 will be described. Fig. 3 is a circuit diagram illustrating the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. As illustrated in Fig. 3, the air discharge device 15 is connected to the heat medium circuit B. A heat medium conveyed by the pumps 31 flows into the air discharge device 15, and then flows out of the air discharge device 15. The position in which the air discharge device 15 is connected to the heat medium circuit B is not limited. For example, the air discharge device 15 may be installed via a connection port allowing connection between the relay unit 2 and a use side unit 3. In Fig. 3, the use side unit 3a illustrated in Fig. 2 is removed, and the air discharge device 15 is connected to the connection port for the removed use side unit 3a. As described above, the air discharge device 15 is detachably connected to the heat medium circuit B.

[0058] Fig. 4 is a schematic diagram illustrating the air discharge device 15 according to Embodiment 1 of the present invention. As illustrated in Fig. 4, the air discharge device 15 includes a heat medium tank 17, an upstream side stop valve 16a, a downstream side stop valve 16b, and an air vent valve 18.

(Heat Medium Tank 17)

[0059] A heat medium flows into the heat medium tank 17. In the heat medium tank 17, air contained in the heat medium flowing into the heat medium circuit B is lifted up to an upper part of the tank using a difference in the density between the heat medium and air. Thus, in the heat medium tank 17, air stays in the upper part of the tank, and the heat medium stays in a lower part of the tank. As described above, in the heat medium tank 17, air and a heat medium in the heat medium circuit B is separated from each other.

(Upstream Side Stop Valve 16a, Downstream Side Stop Valve 16b)

[0060] The upstream side stop valve 16a is provided at an upstream side pipe 15a that is connected on the inflow side of a heat medium of the heat medium tank 17, and opens and closes the flow passage of a heat medium. The upstream side pipe 15a is connected to an upper side part of the heat medium tank 17. The downstream side stop valve 16b is provided at a downstream side pipe 15b that is connected to an outflow side of a heat medium of the heat medium tank 17, and opens and closes the flow passage of a heat medium. The downstream side pipe 15b is connected to a lower part of the heat medium tank 17. The downstream side stop valve 16b is provided at a portion lower than that of the upstream side stop valve 16a. The upstream side stop valve 16a and the downstream side stop valve 16b are used when the air discharge device 15 is attached to or detached from the heat medium circuit B. The upstream side stop valve 16a and the downstream side stop valve 16b are to open and close the flow passage and may be electrically or manually operated as long as the flow passage can be opened and closed.

(Air Vent Valve 18)

[0061] The air vent valve 18 is provided at the heat medium tank 17 and discharges air. The air vent valve 18 is provided above, in particular, at the top part, of the heat medium tank 17. The air vent valve 18 is, for example, an automatic air vent valve, and discharges only air staying in the upper part of the heat medium tank 17 to the outside of the air discharge device 15. Thus, air staining in the upper part of the heat medium tank 17 is discharged through the air vent valve 18 to the outside of the air discharge device 15, and a heat medium staying in the lower part of the heat medium tank 17 passes through the downstream side stop valve 16b and flows in the heat medium circuit B. The air vent valve 18 may have a configuration of any air vent valve as long as no heat medium is discharged.

[0062] In the air-conditioning apparatus 100, the refrigerant 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, in the air-conditioning apparatus 100, the heat medium 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 heat medium pipes 5. The plurality of use side heat exchangers 35 are connected in parallel to each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b to form the heat medium circuit B as multiple systems.

[0063] Consequently, in the air-conditioning apparatus 100, the heat source side unit 1 and the relay unit 2 are connected via the intermediate heat exchanger 25a and the intermediate heat exchanger 25b that are provided in the relay unit 2, and the relay unit 2 and the use side 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 refrigerant that circulates through the refrigerant circuit A and a heat medium that circulates through the heat medium circuit B. With the use of the above configuration, the air-conditioning apparatus 100 achieves a cooling operation or a heating operation suitable for the indoor load.

[0064] Next, individual operation modes executed by the air-conditioning apparatus 100 will be explained. Operation modes executed by the air-conditioning apparatus 100 include a heating operation mode (heating only mode) in which all of the driving use side units 3 perform a heating operation, a cooling operation mode (cooling only mode) in which all of the driving use side units 3 perform a cooling operation, a cooling main mode, which is a mixed operation mode, in which the cooling load is larger than the heating load, and a heating main mode, which is another mixed operation mode, in which the heating load is larger than the cooling load. The above operation modes are each executed by combining switching of the first refrigerant flow switching device 11, the second refrigerant flow switching devices 28, the first heat medium flow switching devices 32, and the second heat medium flow switching devices 33 and opening and closing of the opening and closing device 27 and the opening and closing device 29.

(Heating Operation Mode (Heating Only Mode))

[0065] Fig. 5 is a circuit diagram illustrating a heating operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In Fig. 5, an example in which all of the four use side units 3a to 3d are in the heating operation mode is illustrated. In Fig. 5, pipes through which refrigerant flows are represented by thick lines, and the flow direction of refrigerant is represented by solid arrows. Furthermore, the flow direction of a heat medium is represented by broken arrows.

[0066] In the heating operation mode (heating only mode), in the heat source side unit 1, the first refrigerant flow switching device 11 switches a flow passage to cause refrigerant discharged from the compressor 10 to flow into the relay unit 2 without passing through the heat source side heat exchanger 12.

[0067] In the relay unit 2, the four first heat medium flow switching devices 32a to 32d and the four second heat medium flow switching devices 33a to 33d are opened with heating side opening angles or intermediate opening angles, and the four heat medium flow control devices 34a to 34d are opened at predetermined opening degrees. Furthermore, the opening and closing device 27 is closed, the opening and closing device 29 is opened, and the expansion device 26a and the expansion device 26b are opened at predetermined opening degrees. The pumps 31 are set to a flow rate instruction value corresponding to the load of the use side units 3. The second refrigerant flow switching device 28a switches a flow passage to connect the inflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25a, and the second refrigerant flow switching device 28b switches a flow passage to connect the inflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25b. Thus, all of the four use side units 3a to 3d are in the heating operation mode.

[0068] First, the flow of refrigerant in the refrigerant circuit A will be explained. High-temperature and low-pressure refrigerant is compressed by the compressor 10 into high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 passes through the first refrigerant flow switching device 11 and first connection pipe 4a, and flows out of the heat source side unit 1. The high-temperature and high-pressure gas refrigerant flowing out of the heat source side unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2. The high-temperature and high-pressure gas refrigerant flowing into the relay unit 2 passes through the second refrigerant flow switching devices 28a and 28b, and then flows into the intermediate heat exchangers 25a and 25b. Then, the refrigerant exchanges heat with a heat medium and is condensed at the intermediate heat exchangers 25a and 25b, and turns into low-temperature and high-pressure refrigerant. The low-temperature and high-pressure refrigerant is expanded at the expansion devices 26a and 26b, and turns into low-temperature and low-pressure refrigerant. Subsequently, the refrigerant passes through the opening and closing device 29, and is conveyed to the heat source side unit 1. Then, the refrigerant exchanges heat with outside air at the heat source side heat exchanger 12, and turns into high-temperature and low-pressure gas refrigerant. Then, the high-temperature and low-pressure gas refrigerant is sucked again into the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0069] At this time, the opening degrees of the expansion devices 26a and 26b are controlled to make the subcooling (degree of subcooling) constant. The subcooling (degree of subcooling) is obtained as a difference between a value obtained by converting the pressure of refrigerant flowing between the intermediate heat exchangers 25a and 25b and the expansion devices 26a and 26b into saturation temperature and the temperature on the outlet side of the intermediate heat exchangers 25a and 25b.

[0070] Next, the flow of a heat medium in the heat medium circuit B will be explained. In the relay unit 2, the pumps 31a and 31b are driven, the heat medium flow control devices 34a to 34d are opened, and a heat medium circulates between each of intermediate heat exchangers 25a and 25b and the use side heat exchangers 35a to 35d. Furthermore, all of the three ways of the second heat medium flow switching devices 33a to 33d are opened to cause a heat medium supplied through the pump 31a and the pump 31b to flow into the use side heat exchangers 35a to 35d.

[0071] 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, by the heat medium flow control devices 34a to 34d, the flow rate of a heat medium is controlled to be a flow rate necessary for an air-conditioning load required for an indoor space, and the heat medium is caused to flow into the use side heat exchangers 35a to 35d. The heat medium flowing out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d, and flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. Then, the heat medium exchanges heat with refrigerant at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and is thus heated. Subsequently, the heat medium is sucked again into the pump 31a and the pump 31 b.

(Cooling Operation Mode (Cooling Only Mode))

[0072] Fig. 6 is a circuit diagram illustrating a cooling operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In Fig. 6, an example in which all of the four use side units 3a to 3d are in the cooling operation mode is illustrated. In Fig. 6, pipes through which refrigerant flows are represented by thick lines, and the flow direction of refrigerant is represented by solid arrows. Furthermore, the flow direction of a heat medium is represented by broken arrows.

[0073] In the cooling operation mode (cooling only mode), in the heat source side unit 1, the first refrigerant flow switching device 11 switches a flow passage to cause refrigerant discharged from the compressor 10 to flow into the heat source side heat exchanger 12.

[0074] In the relay unit 2, the four first heat medium flow switching devices 32a to 32d and the four second heat medium flow switching devices 33a to 33d are opened with cooling side opening angles or intermediate opening angles, and the four heat medium flow control devices 34a to 34d are opened at predetermined opening degrees. Furthermore, the opening and closing device 27 is opened, the opening and closing device 29 is closed, and the expansion devices 26a and 26b are opened at predetermined opening degrees. The pumps 31 are set to a flow rate instruction value corresponding to the load of the use side units 3. The second refrigerant flow switching device 28a switches a flow passage to connect the outflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25a, and the second refrigerant flow switching device 28b switches a flow passage to connect the outflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25b. Thus, all of the four use side units 3a to 3d are in the cooling operation mode.

[0075] First, the flow of refrigerant in the refrigerant circuit A will be explained. High-temperature and low-pressure refrigerant is compressed by the compressor 10 into high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 passes through the first refrigerant flow switching device 11, and flows into the heat source side heat exchanger 12. The refrigerant exchanges heat with outside air, and turns into low-temperature and high-pressure liquid refrigerant or two-phase refrigerant. Then, the refrigerant passes through the check valve 13a, and flows out of the heat source side unit 1. The low-temperature and high-pressure liquid refrigerant or two-phase refrigerant flowing out of the heat source side unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2. The low-temperature and high-pressure liquid refrigerant or two-phase refrigerant flowing into the relay unit 2 passes through the opening and closing device 27, is expanded at the expansion device 26a and the expansion device 26b into low-temperature and low-pressure two-phase refrigerant. Then, the refrigerant exchanges heat with a heat medium at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and turns into high-temperature and low-pressure refrigerant. Then, the refrigerant flows into the heat source side unit 1 from the relay unit 2, and is sucked again to the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0076] At this time, the opening degree of the expansion devices 26a and 26b is controlled to make the superheat (degree of superheat) constant. The superheat (degree of superheat) is obtained as a difference between a value obtained by converting the pressure of refrigerant flowing between the intermediate heat exchangers 25a and 25b and the expansion devices 26a and 26b into saturation temperature and the temperature on the outlet side of the intermediate heat exchangers 25a and 25b.

[0077] Next, the flow of a heat medium in the heat medium circuit B will be explained. In the relay unit 2, the pumps 31a and 31b are driven, the heat medium flow control devices 34a to 34d are opened, and a heat medium circulates between each of intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use side heat exchangers 35a to 35d. Furthermore, all of the three ways of the second heat medium flow switching devices 33a to 33d are opened to cause a heat medium supplied through the pump 31a and the pump 31b to flow into the use side heat exchangers 35a to 35d.

[0078] 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, by the heat medium flow control devices 34a to 34d, the flow rate of a heat medium is controlled to be a flow rate necessary for an air-conditioning load required for an indoor space, and the heat medium is caused to flow into the use side heat exchangers 35a to 35d. The heat medium flowing out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d, and flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. Then, the heat medium exchanges heat with refrigerant at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and is thus cooled. Subsequently, the heat medium is sucked again into the pump 31a and the pump 31 b.

(Mixed Operation Mode (Heating Main Mode))

[0079] Fig. 7 is a circuit diagram illustrating a heating main operation of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. In Fig. 7, some of the four use side units 3a to 3d perform a heating operation, and the other use side units 3 perform a cooling operation. In Fig. 7, a heating main mode in which the proportion of the heating operation is larger than the proportion of the cooling operation will be explained.

[0080] In Fig. 7, pipes through which refrigerant flows are represented by thick lines, and the flow direction of refrigerant is represented by solid arrows. Furthermore, the flow direction of a heat medium is represented by broken arrows.

[0081] In the mixed operation mode (heating main mode), in the heat source side unit 1, the first refrigerant flow switching device 11 switches a flow passage to cause refrigerant discharged from the compressor 10 to flow into the relay unit 2 without passing through the heat source side heat exchanger 12.

[0082] In the relay unit 2, among the four first heat medium flow switching devices 32a to 32d and the four second heat medium flow switching devices 33a to 33d, a second heat medium flow switching device 33 that is contributed to connection of a use side unit 3 in the heating operation mode is set to a heating side opening angle, and a second heat medium flow switching device 33 that is contributed to connection of a use side unit 3 in the cooling operation mode is set to a cooling side opening angle. The four heat medium flow control devices 34a to 34d are opened at predetermined opening degrees. Furthermore, the opening and closing device 27 is closed, the opening and closing device 29 is closed, and the expansion device 26a and the expansion device 26b are opened at predetermined opening degrees. The pumps 31 are set to a flow rate instruction value corresponding to the load of the use side units 3. The second refrigerant flow switching device 28a switches a flow passage to connect the outflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25a, and the second refrigerant flow switching device 28b switches a flow passage to connect the inflow side of the refrigerant pipe 4 and the intermediate heat exchanger 25b. Thus, some of the four driving use side units 3a to 3d are in the heating operation mode, and the other driving use side units 3 are in the cooling operation mode.

[0083] First, the flow of refrigerant in the refrigerant circuit A will be explained. High-temperature and low-pressure refrigerant is compressed by the compressor 10 into high-temperature and high-pressure gas refrigerant, and is discharged. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 passes through the first refrigerant flow switching device 11 and the first connection pipe 4a, and flows out of the heat source side unit 1. The high-temperature and high-pressure gas refrigerant flowing out of the heat source side unit 1 passes through the refrigerant pipe 4, and flows into the relay unit 2. The high-temperature and high-pressure gas refrigerant flowing into the relay unit 2 passes through the second refrigerant flow switching device 28b, and flows into the intermediate heat exchanger 25b. Then, the refrigerant exchanges heat with a heat medium and is condensed at the intermediate heat exchanger 25b, and turns into low-temperature and high-pressure refrigerant. The low-temperature and high-pressure refrigerant is expanded at the expansion device 26b and the expansion device 26a, and turns into low-temperature and low-pressure refrigerant. Subsequently, the refrigerant flows into the intermediate heat exchanger 25a. Then, the refrigerant exchanges heat with a heat medium and evaporated at the intermediate heat exchanger 25a, and turns into high-temperature and low-pressure refrigerant. The high-temperature and low-pressure refrigerant passes through the second refrigerant flow switching device 28a, and is then conveyed to the heat source side unit 1. Then, the refrigerant exchanges heat with outside air at the heat source side heat exchanger 12, and turns into high-temperature and low-pressure gas refrigerant. Then, the high-temperature and low-pressure gas refrigerant is sucked again into the compressor 10 via the first refrigerant flow switching device 11 and the accumulator 19.

[0084] At this time, the opening degree of the expansion device 26b is controlled to make the subcooling (degree of subcooling) constant. The subcooling (degree of subcooling) is obtained as a difference between a value obtained by converting the pressure of refrigerant flowing between the intermediate heat exchanger 25b and the expansion device 26b into saturation temperature and the temperature on the outlet side of the intermediate heat exchanger 25b.

[0085] Furthermore, the opening degree of the expansion device 26a is controlled to make the superheat (degree of superheat) constant. The superheat (degree of superheat) is obtained as a difference between a value obtained by converting the pressure of refrigerant flowing between the intermediate heat exchanger 25a and the expansion device 26a into saturation temperature and the temperature on the outlet side of the intermediate heat exchanger 25a.

[0086] In the cooling main mode of the mixed operation mode, in the heat source side unit 1, the first refrigerant flow switching device 11 switches a flow passage to cause refrigerant discharged from the compressor 10 to flow into the heat source side heat exchanger 12.

[0087] Next, the flow of a heat medium in the heat medium circuit B will be explained. In the relay unit 2, the pumps 31a and 31b are driven, and the heat medium flow control devices 34a to 34d are opened. Furthermore, three ways of the second heat medium flow switching devices 33a to 33d are set to predetermined opening degrees so that, among heat media supplied from the pump 31a and the pump 31b, a heat medium conveyed through the pump 31b flows into a use side heat exchanger 35 in a use side unit 3 in the heating operation mode and a heat medium conveyed through the pump 31a flows into a use side heat exchanger 35 in a use side unit 3 in the cooling operation mode. The heat medium circulates between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and the use side heat exchangers 35a to 35d.

[0088] 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, by the heat medium flow control devices 34a to 34d, the flow rate of a heat medium is controlled to be a flow rate necessary for an air-conditioning load required for an indoor space, and the heat medium is caused to flow into the use side heat exchangers 35a to 35d. The heat medium flowing out of the heat medium flow control devices 34a to 34d passes through the first heat medium flow switching devices 32a to 32d, and flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. Then, the heat medium exchanges heat with refrigerant, and is thus cooled at the intermediate heat exchanger 25a. Subsequently, the heat medium exchanges heat with refrigerant, and is thus heated at the intermediate heat exchanger 25b. Subsequently, the heat medium is sucked again into the pump 31a and the pump 31b.

(Air Vent Mode)

[0089] Next, an air vent mode will be explained. The air vent mode is an operation mode in which, for example, after the air-conditioning apparatus 100 is installed, when the air-conditioning apparatus 100 is used for the first time, air in the heat medium circuit B of the relay unit 2 and the use side units 3 is discharged out of the air-conditioning apparatus 100.

[0090] In Fig. 3, an example in which one air discharge device 15 is interposed between the second heat medium flow switching device 33a and the heat medium flow control device 34a and the three use side units 3b to 3d are interposed between the first heat medium flow switching devices 33b to 33d and the heat medium flow control devices 34b to 34d will be explained. In Fig. 3, the flow direction of refrigerant is represented by solid arrows, and the flow direction of a heat medium is represented by broken arrows.

[0091] In the relay unit 2, the pump 31a and the pump 31b are driven, all of the heat medium flow control devices 34a to 34d connected to the use side units 3b to 3d and the air discharge device 15 are opened, and a heat medium circulates between each of the intermediate heat exchanger 25a and the intermediate heat exchanger 25b and each of the air discharge device 15 and the use side heat exchangers 35b to 35d. Furthermore, the opening degrees of the three ways of the second heat medium flow switching devices 33a to 33d are set to intermediate opening angles to cause a heat medium supplied through the pump 31a and the pump 31b to flow into the air discharge device 15 and the use side heat exchangers 35b to 35d. Furthermore, the upstream side stop valve 16a and the downstream side stop valve 16b in the air discharge device 15 are connected to the heat medium circuit B and are then opened. Thus, the heat medium is allowed to flow into the air discharge device 15 from the heat medium circuit B.

[0092] The heat medium flows out of the air discharge device 15 and the use side heat exchangers 35b to 35d, and flows into the heat medium flow control devices 34a to 35d. At this time, the heat medium flow control devices 34a to 34d are opened as described above. The heat medium conveyed through the pumps 31a and 31b flows into the use side units 3b to 3d, and at the same time, air contained in the heat medium circuit B is conveyed and stirred inside the heat medium circuit B. Subsequently, while the air discharge device 15 and one heat medium flow control device 34 are opened, the other heat medium flow control devices 34 are closed. Thus, the conveyed heat medium and a part of remaining air flow into the upstream side stop valve 16a of the air discharge device 15, and air in the heat medium tank 17 is discharged out of the air discharge device 15 by the air vent valve 18.

[0093] Subsequently, the opened heat medium flow control device 34 is closed, and one of the remaining heat medium flow control devices 34 is opened, and the above operation is performed. Then, the above operation is repeated, and the heat medium and a part of remaining air sequentially flows into the air discharge device 15, and thus air in the heat medium circuit B can be discharged out of the air-conditioning apparatus 100. After air is discharged out of the air-conditioning apparatus 100 by the air discharge device 15, only the heat medium passes through the downstream side stop valve 16b and reaches the heat medium flow control device 34a. Subsequently, the heat medium passes through the first heat medium flow switching device 32a, and flows into the intermediate heat exchanger 25a and the intermediate heat exchanger 25b. Then, the heat medium exchanges heat with refrigerant at the intermediate heat exchanger 25a and the intermediate heat exchanger 25b, and is sucked again into the pump 31a and the pump 31b.

[0094] In operation modes other than the air vent mode, both the upstream side stop valve 16a and the downstream side stop valve 16b are closed. Thus, a heat medium does not flow into the air discharge device 15.

[0095] Next, an action of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention will be explained. A heat medium containing air flows into the heat medium tank 17. Then, due to a difference in the density between the heat medium and air, air is lifted up to an upper part of the tank, and the heat medium stays in a lower part of the tank. Air lifted up to the upper part of the heat medium tank 17 is discharged out of the air discharge device 15 by the air vent valve 18. The heat medium from which air has been eliminated flows again into the heat medium circuit B from the heat medium tank 17. As described above, the air-conditioning apparatus 100 may efficiently discharge air contained in the heat medium circuit B, and time for eliminating air can be shortened. Consequently, the workability of the air-conditioning apparatus 100 is excellent. Furthermore, a heat medium is not discharged out of the air-conditioning apparatus 100. Consequently, even if antifreeze solution is used as a heat medium, wastewater treatment is not required. Thus, the air-conditioning apparatus 100 has an excellent environmental friendliness. Furthermore, a heat medium is not discharged out of the air-conditioning apparatus 100, and consequently, excess water is not required for introduction of the air-conditioning apparatus 100. Thus, the workability and economy of the air-conditioning apparatus 100 is excellent. Furthermore, the air discharge device 15 includes the heat medium tank 17, and consequently, separation between a heat medium and air can be achieved due to a difference in the density between the heat medium and air. Installation position of the heat medium tank 17 is not limited, and consequently, the installation position of the air discharge device 15 is set highly flexibly. Furthermore, the air discharge device 15 is detachably connected to the heat medium circuit B. Thus, the air-conditioning apparatus 100 is highly versatile.

[0096] In the case where antifreeze solution is used as a heat medium, at the time when the pumps 31 start, undiluted solution of antifreeze solution is stored in advance in the heat medium tank 17. Water for dilution is filled in the heat medium circuit B to dilute the antifreeze solution. After the heat medium circuit B starts, the air vent mode is executed. As described above, in the case where antifreeze solution is used as a heat medium, by storing antifreeze solution before dilution into the heat medium tank 17, an operation for filling the antifreeze solution in the heat medium circuit B as in a known technique may be omitted.

[0097] Furthermore, after an air vent operation is performed, the air discharge device 15 may be kept connected to the heat medium circuit B. In this case, the upstream side stop valve 16a and the downstream side stop valve 16b are closed during a normal operation in which an air vent operation is not being performed, and the upstream side stop valve 16a and the downstream side stop valve 16b are periodically opened while a heating operation, a cooling operation, or a mixed operation is being performed. Thus, air remaining in the heat medium circuit B or air dissolved into a heat medium and the heat medium flow into the air discharge device 15, and air may thus be discharged. In the case where the air discharge device 15 is always connected to the heat medium circuit B, the upstream side stop valve 16a and the downstream side stop valve 16b may be omitted. In this case, during a normal operation, air is kept vented during an operation. Consequently, the safety in a running operation of the air-conditioning apparatus 100 increases. Furthermore, a configuration in which the air discharge device 15 is attached in place of the use side unit 3a is illustrated as an example. However, a connection port for the air discharge device 15 may be separately provided at the heat medium circuit B. In the case where the air discharge device 15 is not used, a valve provided in the vicinity of the connection port is closed. In the case where the air discharge device 15 is used, the valve is opened, and a heat medium flows in the air discharge device 15. Thus, the air discharge device 15 can be used while the use side unit 3a is being used.

[0098] The case where the second refrigerant flow switching devices 28 are four-way valves is illustrated as an example. However, the present invention is not limited to this example. A plurality of two-way flow switching valves or three-way flow switching valves may be used to cause refrigerant to flow through a similar flow passage. Furthermore, the case where two intermediate heat exchangers 25 and two expansion devices 26 are provided is illustrated as an example. However, one or three or more intermediate heat exchangers 25 and one or three or more expansion devices 26 may be provided. Furthermore, the case where the heat medium flow control devices 34 are provided at the relay unit 2 is illustrated as an example. However, the heat medium flow control devices 34 are not limited to be provided at the relay unit 2. The heat medium flow control devices 34 may be provided at the use side units 3 or may be provided at a component different from the relay unit 2 and the use side units 3.

[0099] The case where the accumulator 19 is provided at the heat source side unit 1 of the air-conditioning apparatus 100 is illustrated as an example. However, the accumulator 19 may be omitted. Furthermore, the case where air-sending devices are attached to the heat source side heat exchanger 12 and the use side heat exchangers 35 to prompt condensation or evaporation by sending air is illustrated as an example. However, air-sending devices are not necessarily attached to the heat source side heat exchanger 12 and the use side heat exchangers 35. For example, panel heaters or other devices using radiation may be used as the use side heat exchangers 35, and water-cooled-type heat exchangers or other devices in which heat is transmitted by water or antifreeze solution may be used as the heat source side heat exchanger 12. That is, heat exchangers of any type may be used for the heat source side heat exchanger 12 and the use side heat exchangers 35 as long as the heat exchangers can transfer heat or receive heat.

[0100] Furthermore, the case where four use side heat exchangers 35 and four heat medium flow control devices 34 (four pairs in total) are provided is illustrated as an example. However, at least one pair of a use side heat exchanger 35 and a heat medium flow control device 34 is only required, and the number of pairs is not limited to four. Furthermore, the case where two intermediate heat exchangers 25 are provided is illustrated as an example. However, the number of intermediate heat exchangers 25 is not limited to two. Three or more intermediate heat exchangers 25 may be installed as long as the intermediate heat exchangers 25 is each configured to cool or heat a heat medium. Furthermore, each of the pump 31a and the pump 31b may not be configured as a single component. A plurality of small-volume pumps may be connected in parallel.

[0101] Furthermore, the case where the air vent valve 18 provided at the air discharge device 15 is an automatic air vent valve that extracts only air from among a heat medium and the air and discharges the air outside the air discharge device 15 is illustrated as an example. However, the air vent valve 18 is not limited to be an automatic air vent valve. The air vent valve 18 may be a manual air vent valve. In this case, air is removed from the air discharge device 15 by periodical valve opening operations.

[0102] Furthermore, for example, antifreeze solution (brine), water, a liquid mixture of antifreeze solution and water, a liquid mixture of water and an additive having high anti-corrosion effect, or other fluid may be used as a heat medium flowing through the heat medium circuit B. Thus, no refrigerant flows through the heat medium circuit B, and consequently, safety may be ensured even if a heat medium leaks in the indoor space 7.

Reference Signs List

[0103] 1: heat source side unit, 2: relay unit, 3, 3a, 3b, 3c, 3d: use side unit, 4: refrigerant pipe, 4a: first connection pipe, 4b: second 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, 13b, 13c, 13d: check valve, 15: air discharge device, 15a: upstream side pipe, 15b: downstream side pipe, 16a: upstream side stop valve, 16b: downstream side stop valve, 17: heat medium tank, 18: air vent valve, 19: accumulator, 20: bypass pipe, 25, 25a, 25b: intermediate heat exchanger, 26a, 26b: expansion device, 27, 29: opening and closing device, 31, 31a, 31b: pump, 32, 32a, 32b, 32c, 32d: first heat medium flow switching device, 33, 33a, 33b, 33c, 33d: second heat medium flow switching device, 34, 34a, 34b, 34c, 34d: heat medium flow control device, 35, 35a, 35b, 35c, 35d: use side heat exchanger, 40, 40a, 40b: temperature sensor, 50: controller, 100: air-conditioning apparatus, A: refrigerant circuit, B: heat medium circuit

The subject-matter of the present invention relates, inter alia, to the following aspects:

1. An air-conditioning apparatus comprising:

a refrigerant circuit in which a compressor, a heat source side heat exchanger, an expansion device, and an intermediate heat exchanger configured to exchange heat between refrigerant and a heat medium are connected by a refrigerant pipe, the refrigerant flowing through the refrigerant circuit;

a heat medium circuit in which a pump configured to convey the heat medium, a use side heat exchanger, and the intermediate heat exchanger are connected by a heat medium pipe, the heat medium flowing through the heat medium circuit; and

an air discharge device including a heat medium tank connected to the heat medium circuit and configured to separate air from the heat medium in the heat medium circuit, and an air vent valve provided at the heat medium tank and configured to discharge the air.

2. The air-conditioning apparatus of aspect 1, wherein the air vent valve is provided in an upper part of the heat medium tank.

3. The air-conditioning apparatus of aspect 1 or 2, wherein the air discharge device further includes

an upstream side stop valve provided at an upstream side pipe connected to an inflow side of the heat medium of the heat medium tank, the upstream side stop valve being configured to open and close a flow passage of the heat medium, and

a downstream side stop valve provided at a downstream side pipe connected to an outflow side of the heat medium of the heat medium tank, the downstream side stop valve being configured to open and close a flow passage of the heat medium.

4. The air-conditioning apparatus of aspect 3, wherein the upstream side stop valve is provided at the upstream side pipe connected to a side part of the heat medium tank, and wherein the downstream side stop valve is provided at the downstream side pipe connected to a lower part of the heat medium tank.

5. The air-conditioning apparatus of any one of aspects 1 to 4, wherein the air discharge device is detachably connected to the heat medium circuit.

6. The air-conditioning apparatus of any one of aspects 1 to 5, wherein the heat medium comprises antifreeze solution, and wherein the antifreeze solution is stored in the heat medium tank at a time when the pump starts.

7. The air-conditioning apparatus of any one of aspects 1 to 6, further comprising:

a heat source side unit including the compressor and the heat source side heat exchanger;
a relay unit connected to the heat source side unit and including the expansion device, the intermediate heat exchanger, and the pump; and
a use side unit connected to the relay unit and including the use side heat exchanger.

8. The air-conditioning apparatus of aspect 7, wherein the air discharge device is connected to the relay unit via a connection port configured to allow connection between the relay unit and the use side unit.

Claims

1. An air-conditioning apparatus comprising:

a refrigerant circuit (A) in which a compressor (10), a heat source side heat exchanger (12), an expansion device (26a, 26b), and an intermediate heat exchanger (25a, 25b) configured to exchange heat between refrigerant and a heat medium are connected by a refrigerant pipe (4), the refrigerant flowing through the refrigerant circuit (A);
a heat medium circuit (B) in which a pump (31a, 31b) configured to convey the heat medium, a plurality of use side heat exchangers (35a, 35b, 35c, 35d), a plurality of heat medium flow control devices (34a, 34b, 34c, 34d), and the intermediate heat exchanger (25a, 25b) are connected by a heat medium pipe (5), the heat medium flowing through the heat medium circuit (B), the plurality of heat medium flow control devices (34a, 34b, 34c, 34d) each being configured to control a flow rate of the heat medium flowing through a corresponding one of the plurality of use side heat exchangers (35a, 35b, 35c, 35d); and
an air discharge device (15) including a heat medium tank (17) connected to the heat medium circuit (B) and configured to separate air from the heat medium in the heat medium circuit (B), and an air vent valve (18) provided at the heat medium tank (17) and configured to discharge the air,
in an air vent mode in which the air is discharged, one of the plurality of heat medium flow control devices (34a, 34b, 34c, 34d) being opened while remaining one or more of the plurality of heat medium flow control devices (34a, 34b, 34c, 34d) are closed to discharge the air and then opened one of the plurality of heat medium flow control devices (34a, 34b, 34c, 34d) being sequentially switched to repeatedly discharge the air.

2. The air-conditioning apparatus of claim 1, wherein the air discharge device (15) is detachably connected to the heat medium circuit (B).

3. The air-conditioning apparatus of any one of claims 1 or 2, wherein the heat medium comprises antifreeze solution, and wherein the antifreeze solution is stored in the heat medium tank (17) at a time when the pump (31a, 31b) starts.

4. The air-conditioning apparatus of any one of claims 1 to 3, further comprising:

a heat source side unit (1) including the compressor (10) and the heat source side heat exchanger (12);
a relay unit (2) connected to the heat source side unit (1) and including the expansion device (26a, 26b), the intermediate heat exchanger (25a, 25b), and the pump (31a, 31b) ; and
a use side unit (3a, 3b, 3c, 3d) connected to the relay unit (2) and including the use side heat exchanger (35a, 35b, 35c, 35d).

5. The air-conditioning apparatus of claim 4, wherein the air discharge device (15) is connected to the relay unit (2) via a connection port configured to allow connection between the relay unit (2) and the use side unit (3a, 3b, 3c, 3d).

FIG. 1

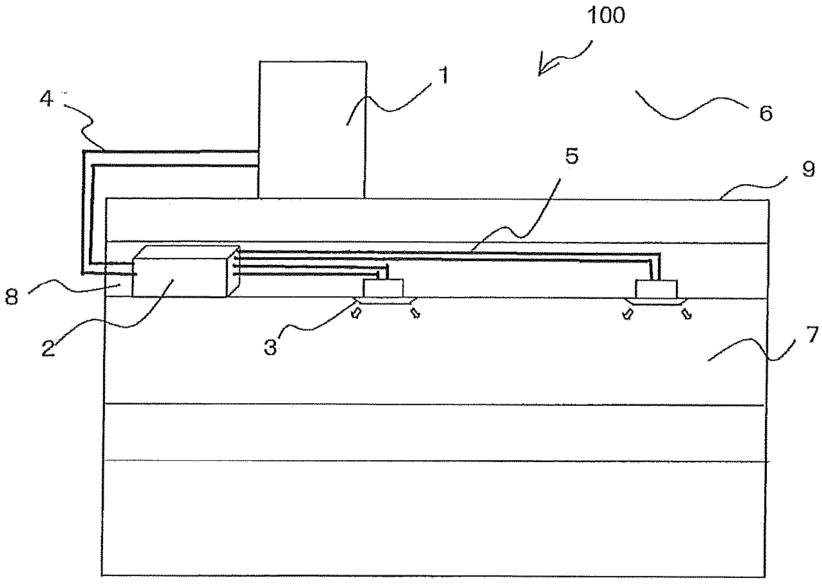
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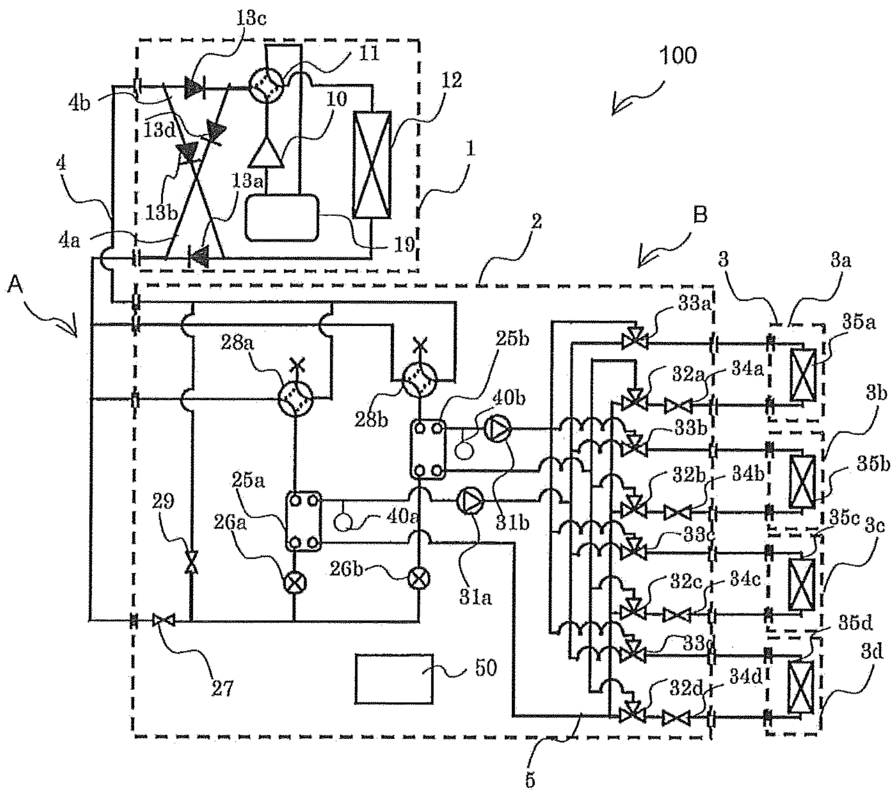
FIG. 2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35c
3c
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27
50
33d
32d
34d
5

FIG. 3

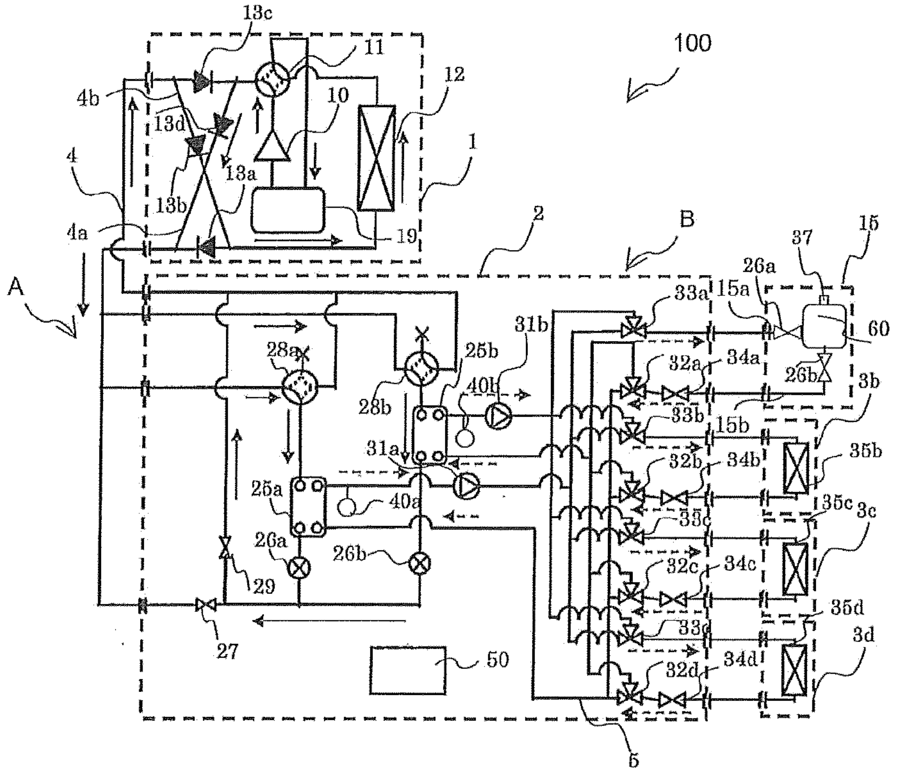
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FIG. 4

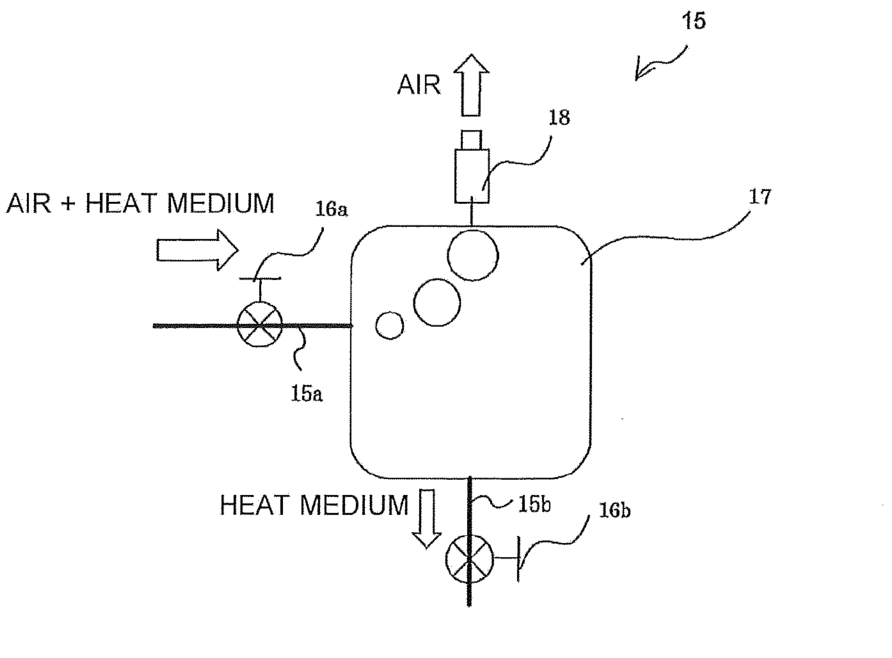
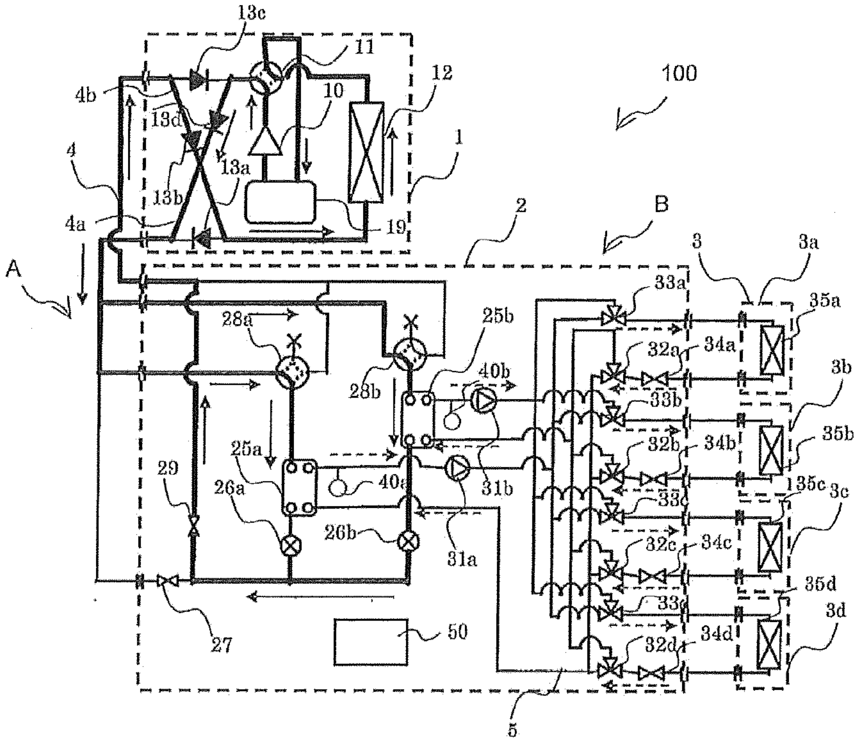

15
AIR
18
17
AIR + HEAT MEDIUM
16a
15a
HEAT MEDIUM
15b
16b

FIG. 5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29
35c
3c
26a
31b
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35d
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27
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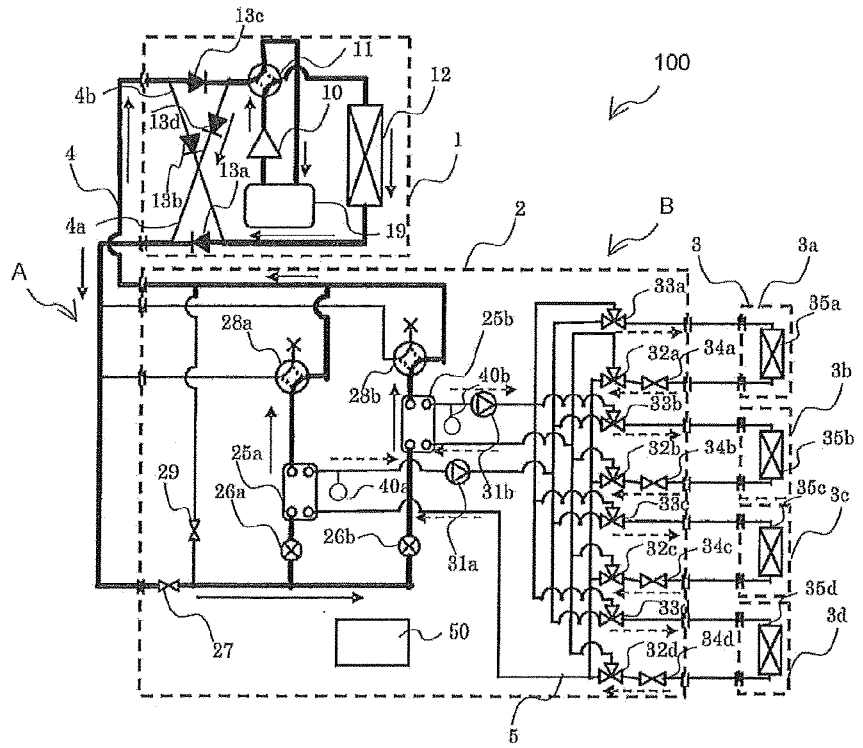
34d
5

FIG. 6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35c
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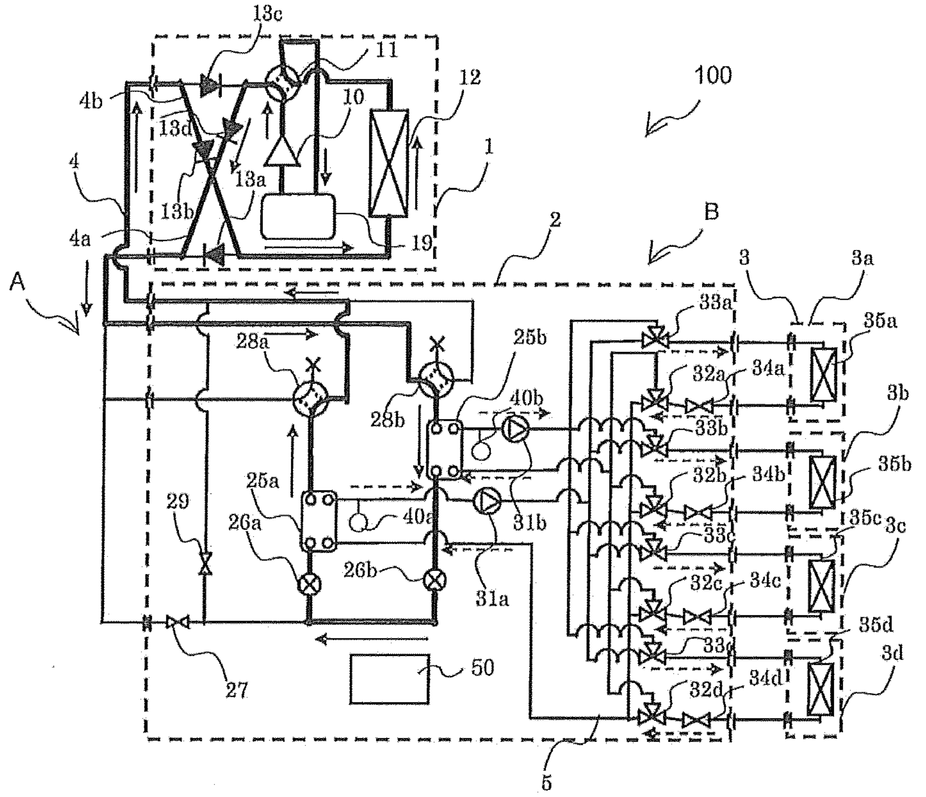
34d
5

FIG. 7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3c
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26b
32c
34c
31a
35d
33d
3d
27
32d
34d
50
5

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 7914

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			F24D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	7 November 2018	Ast, Gabor

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