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

(11) **EP 4 354 031 A1**

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

(43) Date of publication:
17.04.2024 Bulletin 2024/16

(21) Application number: **21945073.1**

(22) Date of filing: **09.06.2021**

(51) International Patent Classification (IPC):
F24F 5/00 (2006.01) ***F24F 11/85*** (2018.01)

(52) Cooperative Patent Classification (CPC):
F24F 5/00; F24F 11/85

(86) International application number:
PCT/JP2021/021843

(87) International publication number:
WO 2022/259396 (15.12.2022 Gazette 2022/50)

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

(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)

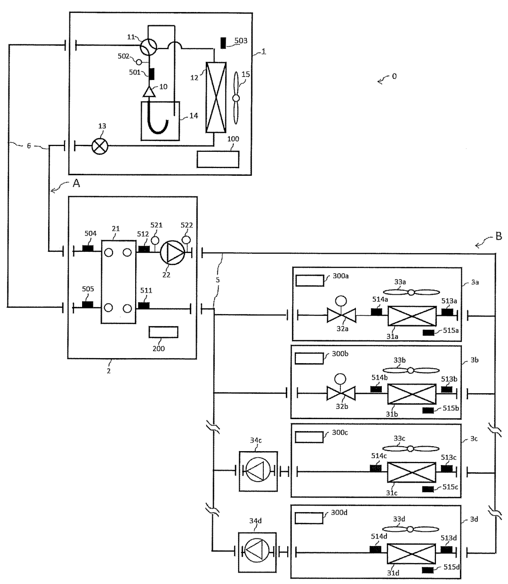
(72) Inventors:
- **FURUYA, Koji**
  Tokyo 100-8310 (JP)
- **WASHIYAMA, Hiroki**
  Tokyo 100-8310 (JP)
- **MOTOMURA, Yuji**
  Tokyo 100-8310 (JP)

(74) Representative: **Witte, Weller & Partner Patentanwälte mbB**
Postfach 10 54 62
70047 Stuttgart (DE)

(54) AIR-CONDITIONING APPARATUS

(57) An air-conditioning apparatus includes a heat-medium cycle circuit that causes a heat medium to circulate in the heat-medium cycle circuit. The heat-medium cycle circuit includes a heat-source-side device, plural indoor heat exchangers, and a main pump, which are connected to each other by a pipe in the heat-medium cycle circuit. The heat-source-side device heats or cools the heat medium, which serves as a heat transfer medium. The plural indoor heat exchangers exchange heat between the heat medium and indoor air to be conditioned. The main pump pressurizes the heat medium and supplies the pressurized heat medium to the plural indoor heat exchangers. The air-conditioning apparatus further includes a pumping-performance-control pump installed in the heat-medium cycle circuit and supporting pumping performance of the main pump.

FIG. 2



EP 4 354 031 A1

Description

Technical Field

[0001] The technology relates to an air-conditioning apparatus, and more particularly, to an air-conditioning apparatus that can support the pumping performance of a pressurizing pump to circulate a heat medium.

Background Art

[0002] An air-conditioning apparatus that performs air-conditioning by use of a heat-medium cycle circuit formed between a heat-source-side device and an indoor unit including an indoor heat exchanger is known. The heat-medium cycle circuit causes a heat medium including brine or water to circulate in the heat-medium cycle circuit. In such an air-conditioning apparatus, the heat-source-side device heats or cools a heat medium and supplies energy to the indoor unit. The indoor unit performs air-conditioning by heating or cooling indoor air with energy supplied from the heat medium (see Patent Literature 1, for example). The air-conditioning apparatus includes a pump that pressurizes a heat medium and causes it to circulate in the heat-medium cycle circuit. The pump pressurizes a heat medium subjected to heat exchange of heating energy or cooling energy with heat-source-side refrigerant in the heat-source-side device and supplies the heat medium to the indoor unit.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2017-053507

Summary of Invention

Technical Problem

[0004] When an air-conditioning apparatus is installed, a pump is selected according to its capability to compensate for a pressure loss caused by scale deposition, for example, and then, the selected pump is installed in a heat-medium cycle circuit. In many cases, the pump is selected according to the pressure loss in a heat medium path leading to the indoor unit installed at the highest place or in the remotest place. For this reason, the pump used in the heat-medium cycle circuit is required to have a high pumping performance. The installation range of indoor units of the air-conditioning apparatus is determined according to the performance of the pump. To increase the installation range of the indoor units, a high pumping performance of a pump is necessary. Nevertheless, using a high-performance pump to achieve the performance required to supply a heat medium to the entire heat-medium cycle circuit increases the overall system cost of the air-conditioning apparatus.

[0005] The present disclosure has been made to solve the above-described problem. It is an object of the present disclosure to provide an air-conditioning apparatus that can support the pumping performance of a pump and increase the installation range of indoor units without cost increase.

Solution to Problem

[0006] An air-conditioning apparatus of an embodiment of the present disclosure includes a heat-medium cycle circuit that causes a heat medium to circulate in the heat-medium cycle circuit. The heat-medium cycle circuit includes a heat-source-side device, plural indoor heat exchangers, and a main pump, which are connected to each other by a pipe in the heat-medium cycle circuit. The heat-source-side device heats or cools the heat medium, which serves as a heat transfer medium. The plural indoor heat exchangers exchange heat between the heat medium and indoor air to be conditioned. The main pump pressurizes the heat medium and supplies the pressurized heat medium to the plural indoor heat exchangers. The air-conditioning apparatus further includes a pumping-performance-control pump installed in the heat-medium cycle circuit and supporting pumping performance of the main pump. Advantageous Effects of Invention

[0007] In an air-conditioning apparatus of an embodiment of the present disclosure, a pumping-performance-control pump, which supports the pumping performance of a main pump to supply a heat medium to an indoor heat exchanger, is installed in a heat-medium cycle circuit. As a result of driving this pumping-performance-control pump, a heat medium of a required flow rate can be supplied to an indoor heat exchanger installed in a place higher than a heat-source-side device and the main pump or in a place far away from the heat-source-side device and the main pump without necessarily using a main pump, which is a high-performance, expensive pump. It is thus possible to provide an air-conditioning apparatus that can install indoor heat exchangers in a wide range.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 schematically illustrates an installation example of an air-conditioning apparatus 0 according to Embodiment 1.

[Fig. 2] Fig. 2 illustrates an example of the configuration of the air-conditioning apparatus 0 according to Embodiment 1.

[Fig. 3] Fig. 3 is a graph illustrating Q-H lines used for determining the use of a pumping-performance-control pump 34 in Embodiment 1.

[Fig. 4] Fig. 4 is a flowchart illustrating processing for regular time control executed by a controller of the air-conditioning apparatus 0 of Embodiment 1.

[Fig. 5] Fig. 5 is a flowchart illustrating control processing for a main pump 22 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 1.

[Fig. 6] Fig. 6 is a flowchart illustrating control processing for the pumping-performance-control pump 34 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 1.

[Fig. 7] Fig. 7 schematically illustrates an example of the configuration of an air-conditioning apparatus 0 according to Embodiment 2.

[Fig. 8] Fig. 8 is a flowchart illustrating processing for regular time control executed by a controller of the air-conditioning apparatus 0 of Embodiment 2.

[Fig. 9] Fig. 9 is a flowchart illustrating control processing for a pumping-performance-control pump 34 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 2.

Description of Embodiments

[0009] Air-conditioning apparatuses according to embodiments will be described below with reference to the drawings, for example. In the drawings, elements designated by the same reference signs are the same or corresponding elements. This applies to the description throughout the embodiments. The relationship between the sizes of elements shown in the drawings may be different from the relationship between the sizes of actual elements. The modes of the elements in the specification are only examples and the modes are not limited to the modes described in the specification. In particular, regarding combinations of elements, the combinations of elements are not only limited those described in each embodiment but also an element described in one embodiment may be applied to another embodiment. The magnitude of the pressure and the magnitude of the temperature are not those determined as absolute values, but are those determined relatively in relation to the state or the operation of an apparatus, for example. Regarding plural devices of the same type that are distinguished from each other by suffixes, when it is not necessary to specify the individual devices or to distinguish them from each other, the suffixes appended to the devices may be omitted.

Embodiment 1

[0010] Fig. 1 schematically illustrates an installation example of an air-conditioning apparatus 0 according to Embodiment 1. The installation example of the air-conditioning apparatus 0 according to Embodiment 1 will be described below with reference to Fig. 1. The air-conditioning apparatus 0 includes a heat-source-side refrigerant cycle circuit A and a heat-medium cycle circuit B. The heat-source-side refrigerant cycle circuit A forms a path for heat-source-side refrigerant in a circuit form and causes heat-source-side refrigerant to circulate through this path. The heat-medium cycle circuit B forms a path for a heat medium in a circuit form and causes a heat medium to circulate through this path. The heat medium is a medium, such as water, that does not change its state within the operating temperature range, and sends, receives, and transfers heat. The air-conditioning apparatus 0 effects air-conditioning by performing a cooling, heating, and other operation. The heat-source-side refrigerant cycle circuit A serves as a heat-source-side device that heats or cools a heat medium in the heat-medium cycle circuit B and supplies heating energy or cooling energy to the indoor side.

[0011] In Fig. 1, the air-conditioning apparatus 0 according to Embodiment 1 includes one outdoor unit 1, which serves as a heat source unit, plural indoor units 3 (indoor units 3a through 3d), and a relay unit 2. The relay unit 2 is a unit that relays heat transfer between heat-source-side refrigerant circulating in the heat-source-side refrigerant cycle circuit A and a heat medium circulating in the heat-medium cycle circuit B. The outdoor unit 1 and the relay unit 2 are connected to each other by refrigerant pipes 6, which serve as flow paths for heat-source-side refrigerant. Multiple relay units 2 may be connected in parallel with each other and connected to one outdoor unit 1.

[0012] Each indoor unit 3 is connected to the relay unit 2 via a heat medium pipe 5, which serves as a flow path for a heat medium. Causing a heat medium having a high flow velocity to flow through the heat medium pipe 5 may remove an oxide film, which serves to protect the pipe, thereby leading to the occurrence of the erosion in the pipe. With the occurrence of erosion, the metal forming the pipe is eroded in a horseshoe-like shape. When, in particular, the temperature of a heat medium is high, erosion is likely to occur. To prevent the occurrence of erosion, it is necessary to regulate the flow velocity of a heat medium flowing through the pipe. Depending on the type of metal forming the pipe, the flow velocity at which erosion occurs varies. When the pipe is made of copper, for example, the flow velocity of a heat medium is regulated to be 1.5 m/s or lower. An explanation will be given of a case in which erosion occurs in the heat medium pipe 5. It may be possible, however, that erosion occur in a flow path in the units and devices of the heat-medium cycle circuit B.

[0013] As heat-source-side refrigerant circulating in the heat-source-side refrigerant cycle circuit A, single refrigerant, such as R-22 and R-134a, a near-azeotropic refrigerant mixture, such as R-410A and R-404A, and a zeotropic refrigerant mixture, such as R-407C, may be used. Additionally, refrigerant having a double bond in its chemical formula and having a relatively small global warming potential, such as $CF_3CF=CH_2$, and a mixture of such refrigerant, and natural refrigerant, such as CO_2 and propane, may also be used. As a heat medium circulating in the heat-medium cycle circuit B, brine (antifreeze), water, a mixed solution of brine and water, a mixed solution of water and an additive having a high anticorrosive effect, for example, may be used. In this manner, in the air-conditioning apparatus 0 of Embodiment 1, a highly safe medium can be used as a heat medium.

[0014] Fig. 2 illustrates an example of the configuration of the air-conditioning apparatus 0 according to Embodiment 1. The configurations of units and devices forming the air-conditioning apparatus 0 will be discussed below with reference to Fig. 2. As described above, the outdoor unit 1 and the relay unit 2 are connected to each other by the refrigerant pipes 6, and the relay unit 2 and each indoor unit 3 are connected to each other by the heat medium pipe 5. In Fig. 2, four indoor units 3 are connected to the relay unit 2 via the heat medium pipes 5. However, the number of indoor units 3 connected to the relay unit 2 is not limited to four.

<Outdoor Unit 1>

[0015] The outdoor unit 1 is a unit that transfers heat by causing heat-source-side refrigerant to circulate in the heat-source-side refrigerant cycle circuit A and that causes a heat-medium heat exchanger 21 of the relay unit 2 to exchange heat between the heat-source-side refrigerant and a heat medium. The outdoor unit 1 includes a compressor 10, a heat-source-side heat exchanger 12, an expansion device 13, and an accumulator 14 inside a housing. The compressor 10, a refrigerant flow switching device 11, the heat-source-side heat exchanger 12, and the accumulator 14 are installed in a state in which they are connected to each other by the refrigerant pipes 6. The compressor 10 sucks heat-source-side refrigerant, compresses it, changes its state to a high-temperature and high-pressure state, and discharges it. The compressor 10 is desirably a capacity-controllable compressor, for example. The refrigerant flow switching device 11 is a device that switches the flow paths of heat-source-side refrigerant according to whether the air-conditioning apparatus 0 is in a cooling operation mode or in a heating operation mode. The refrigerant flow switching device 11 includes a four-way valve. When only one of a cooling operation and a heating operation is performed, the provision of the refrigerant flow switching device 11 is not necessary.

[0016] The heat-source-side heat exchanger 12 exchanges heat between outside air supplied from a heat-source-side fan 15 and heat-source-side refrigerant. In the heating operation mode, the heat-source-side heat exchanger 12 serves as an evaporator to cause heat-source-side refrigerant to receive heat. In the cooling operation mode, the heat-source-side heat exchanger 12 serves as a condenser or a radiator to cause heat-source-side refrigerant to reject heat. The expansion device 13 is a device that serves as a pressure reducing valve to reduce the pressure of heat-source-side refrigerant and also as an expansion valve to expand the heat-source-side refrigerant. The expansion device 13 may desirably be a device, such as an electronic expansion valve, that can control the opening degree to a desirable angle and adjust the flow rate of heat-source-side refrigerant to a desirable value. There may be a case in which the expansion device 13 is installed in the relay unit 2. The accumulator 14 is a tank installed on the suction side of the compressor 10. The accumulator 14 stores a surplus amount of refrigerant, which may be generated because of a difference between the amount of refrigerant used in the heating operation mode and that in the cooling operation mode or may be generated during the operation transition period. There may be a case in which the accumulator 14 is not installed in the heat-source-side refrigerant cycle circuit A.

<Indoor Unit 3>

[0017] The indoor unit 3 is a unit that sends conditioned air to the indoor space. The respective indoor units 3 of Embodiment 1 include indoor heat exchangers 31 (indoor heat exchangers 31a through 31d) and indoor fans 33 (indoor fans 33a through 33d). Among the individual indoor units 3, the respective indoor units 3a and 3b include indoor flow rate adjusting devices 32 (indoor flow rate adjusting devices 32a and 32b). The respective indoor units 3c and 3d include pumping-performance-control pumps 34 (pumping-performance-control pumps 34c and 34d). The indoor heat exchangers 31, indoor flow rate adjusting devices 32, and pumping-performance-control pumps 34 are devices included in the heat-medium cycle circuit B. Depending on the system, there may be a case in which the indoor flow rate adjusting device 32 and the pumping-performance-control pump 34 are not installed in the heat-medium cycle circuit B.

[0018] The indoor heat exchanger 31 includes a heat transfer tube and fins, for example. A heat medium passes through the heat transfer tube of the indoor heat exchanger 31. The indoor heat exchanger 31 exchanges heat between a heat medium and indoor space air supplied from the indoor fan 33. When a heat medium cooler than air passes through the heat transfer tube, the air is cooled and the indoor space is cooled. The indoor fan 33 produces a flow of indoor space air that passes through the indoor heat exchanger 31 and that returns to the indoor space.

[0019] The indoor flow rate adjusting device 32 includes a two-way valve, for example, that can control the opening degree (aperture area) of the valve. The indoor flow rate adjusting device 32 controls the flow rate of a heat medium (amount of heat medium flowing per unit time) flowing into and out of the indoor heat exchanger 31 by adjusting the opening degree. According to the temperature of a heat medium flowing into the indoor unit 3 and the temperature of the heat medium flowing out of the indoor unit 3, the indoor flow rate adjusting device 32 adjusts the amount of heat medium to pass through the indoor heat exchanger 31 so that the indoor heat exchanger 31 can exchange heat by use of the amount of heat corresponding to the indoor thermal load. When the indoor heat exchanger 31 is not required to exchange heat with a thermal load, such as when the air-conditioning apparatus 0 is in a stopped state or in a thermo-off state, the indoor flow rate adjusting device 32 can fully close the valve and stop supplying a heat medium so that the heat medium does not flow into and out of the indoor heat exchanger 31. In Fig. 2, the indoor flow rate adjusting device 32 is disposed in a pipe on the outflow side of the indoor heat exchanger 31 out of which a heat medium flows. However, the position of the indoor flow rate adjusting device 32 is not restricted to this position. For example, the indoor flow rate adjusting device 32 may be disposed on the inflow side of the indoor heat exchanger 31 into which a heat medium flows.

[0020] Fig. 3 is a graph illustrating Q-H lines used for determining the use of the pumping-performance-control pump 34 in Embodiment 1. The pumping-performance-control pump 34 assists a main pump 22 in supplying a heat medium. For example, for an indoor unit 3 placed in a heat medium path through which it is difficult to sufficiently supply a heat medium with the pumping performance of the main pump 22, such as for an indoor unit 3 placed at a higher level than the relay unit 2 or in a remote place from the relay unit 2, the pumping-performance-control pump 34 is installed instead of the indoor flow rate adjusting device 32. In the heat-medium cycle circuit B, each pumping-performance-control pump 34 is connected directly to the main pump 22 and is connected in parallel with another pumping-performance-control pump 34. Hereinafter, the pumping-performance-control pump 34 will be explained in a case in which it is included in the indoor unit 3 and is placed in a heat medium path while being connected to the indoor unit 3. However, this configuration is only an example. The pumping-performance-control pump 34 may be an independent device separately provided from the indoor unit 3.

[0021] The path pressure loss in a heat medium path from the relay unit 2 to the indoor unit 3 at the time when a heat medium flows at a rated flow rate Q1, which is set according to the capacity of the indoor unit 3, is represented by ΔPr. The total pumping performance produced by the main pump 22 of the relay unit 2 and the pumping-performance-control pump 34 connected to the indoor unit 3 is represented by P. In this case, the use of the pumping-performance-control pump 34 is determined to satisfy the expression: total pumping performance P > path pressure loss ΔPr.

[0022] According to the temperature of a heat medium flowing into the indoor unit 3 and the temperature of the heat medium flowing out of the indoor unit 3, the pumping-performance-control pump 34 adjusts the amount of heat medium to pass through the indoor heat exchanger 31 so that the indoor heat exchanger 31 can exchange heat by use of the amount of heat corresponding to the indoor thermal load.

[0023] An indoor unit control device 300, which will be discussed later, has map data indicating the relationship between the applied voltage and the flow rate of the pumping-performance-control pump 34 and the applied voltage and the flow rate of the main pump 22, which is recorded during a test operation discussed later. The indoor unit control device 300 adjusts the voltage to be applied to the pumping-performance-control pump 34 at the start of the operation of the indoor unit 3 such that the flow rate of a heat medium passing through the indoor unit 3 becomes equal to the rated flow rate Q1. In Fig. 2, the pumping-performance-control pump 34 is disposed in a pipe on the outflow side of the indoor heat exchanger 31 out of which a heat medium flows. However, the position of the pumping-performance-control pump 34 is not restricted to this position. For example, the pumping-performance-control pump 34 may be disposed on the inflow side of the indoor heat exchanger 31 into which a heat medium flows. When the indoor unit 3 stops operating, for example, the pumping-performance-control pump 34 in Embodiment 1 can prevent a heat medium from passing through to stop a flow of the heat medium. The pumping-performance-control pump 34 can thus serve, not only as a pressurizing device, but also as a flow rate adjusting device.

<Relay Unit 2>

[0024] The configuration of the relay unit 2 will be described below. The relay unit 2 is a unit including a device that transfers heat between heat-source-side refrigerant circulating in the heat-source-side refrigerant cycle circuit A and a heat medium circulating in the heat-medium cycle circuit B. The relay unit 2 includes the heat-medium heat exchanger 21 and the main pump 22. The heat-medium heat exchanger 21 exchanges heat between heat-source-side refrigerant and a heat medium to transfer heat from the heat-source-side refrigerant to the heat medium. When the heat medium is heated, the heat-medium heat exchanger 21 serves as a condenser or a radiator to cause the heat-source-side refrigerant to reject heat. When the heat medium is cooled, the heat-medium heat exchanger 21 serves as an evaporator to cause the heat-source-side refrigerant to receive heat. The main pump 22 is a device that sucks a heat medium and pressurizes it and thus causes the heat medium to circulate in the heat-medium cycle circuit B.

[0025] Operations of the devices of the heat-source-side refrigerant cycle circuit A of the air-conditioning apparatus 0 will be discussed below with reference to a flow of heat-source-side refrigerant circulating in the heat-source-side refrigerant cycle circuit A. A description will first be given of a case in which a heat medium is cooled. The compressor 10 sucks heat-source-side refrigerant, compresses it, changes its state to a high-temperature and high-pressure state, and discharges it. The discharged heat-source-side refrigerant flows into the heat-source-side heat exchanger 12 via the refrigerant flow switching device 11. The heat-source-side heat exchanger 12 exchanges heat between air supplied by the heat-source-side fan 15 and the heat-source-side refrigerant and thus condenses and liquefies the heat-source-side refrigerant. The condensed and liquefied heat-source-side refrigerant passes through the expansion device 13. When the condensed and liquefied heat-source-side refrigerant passes through the expansion device 13, the expansion device 13 reduces the pressure of the heat-source-side refrigerant. The heat-source-side refrigerant reduced in pressure then flows out of the outdoor unit 1, passes through the refrigerant pipe 6, and flows into the heat-medium heat exchanger 21 of the relay unit 2. When the heat-source-side refrigerant passes through the heat-medium heat exchanger 21, the heat-medium heat exchanger 21 exchanges heat between the heat-source-side refrigerant and a heat medium and thus evaporates and gasifies the heat-source-side refrigerant. At this time, the heat medium is cooled. After the heat-source-side refrigerant flows out of the heat-medium heat exchanger 21, the heat-source-side refrigerant flows out of the relay unit 2, passes through the refrigerant pipe 6, and flows into the outdoor unit 1. The evaporated and gasified heat-source-side refrigerant passes through the refrigerant flow switching device 11 again, and the compressor 10 sucks the heat-source-side refrigerant.

[0026] A description will be given below of a case in which a heat medium is heated. The compressor 10 sucks heat-source-side refrigerant, compresses it, changes its state to a high-temperature and high-pressure state, and discharges it. The discharged heat-source-side refrigerant flows out of the outdoor unit 1 via the refrigerant flow switching device 11, passes through the refrigerant pipe 6, and flows into the heat-medium heat exchanger 21 of the relay unit 2 . When the heat-source-side refrigerant passes through the heat-medium heat exchanger 21, the heat-medium heat exchanger 21 exchanges heat between the heat-source-side refrigerant and a heat medium and thus condenses and liquefies the heat-source-side refrigerant. At this time, the heat medium is heated. After the condensed and liquefied heat-source-side refrigerant flows out of the heat-medium heat exchanger 21, the heat-source-side refrigerant flows out of the relay unit 2, passes through the refrigerant pipe 6, and passes through the expansion device 13 of the outdoor unit 1. When the condensed and liquefied heat-source-side refrigerant passes through the expansion device 13, the expansion device 13 reduces the pressure of the heat-source-side refrigerant. The heat-source-side refrigerant reduced in pressure flows into the heat-source-side heat exchanger 12. The heat-source-side heat exchanger 12 exchanges heat between air supplied by the heat-source-side fan 15 and the heat-source-side refrigerant and thus evaporates and gasifies the heat-source-side refrigerant. The evaporated and gasified heat-source-side refrigerant passes through the refrigerant flow switching device 11 again, and the compressor 10 sucks the heat-source-side refrigerant.

[0027] The air-conditioning apparatus 0 includes various sensors, which serve as detection devices that detect physical quantities. In the heat-source-side refrigerant cycle circuit A, a discharge temperature sensor 501, a discharge pressure sensor 502, and an outdoor temperature sensor 503 are installed in the outdoor unit 1. The discharge temperature sensor 501 detects the temperature of refrigerant discharged by the compressor 10 and outputs a discharge temperature detection signal. An outdoor unit control device 100, which will be discussed later, obtains the discharge temperature detection signal output from the discharge temperature sensor 501. The discharge temperature sensor 501 includes a thermistor, for example. Other temperature sensors, which are described below, also each include a thermistor. The discharge pressure sensor 502 detects the pressure of refrigerant discharged by the compressor 10 and outputs a discharge pressure detection signal. The outdoor unit control device 100, which will be discussed later, obtains the discharge pressure detection signal output from the discharge pressure sensor 502. The outdoor temperature sensor 503 is disposed in the outdoor unit 1 and at a portion of the heat-source-side heat exchanger 12 from which air flows in. The outdoor temperature sensor 503 detects the outdoor temperature, which is an ambient temperature of the outdoor unit 1, for example, and outputs an outdoor temperature detection signal. The outdoor unit control device 100, which will be discussed later, obtains the outdoor temperature detection signal output from the outdoor temperature sensor 503.

[0028] In the heat-source-side refrigerant cycle circuit A, a first refrigerant temperature sensor 504 and a second refrigerant temperature sensor 505 are installed in the relay unit 2. In a flow of refrigerant in the heat-source-side refrigerant cycle circuit A, the first refrigerant temperature sensor 504 is installed in a pipe on the inflow side of the heat-medium heat exchanger 21 into which refrigerant flows during the cooling of a heat medium. The first refrigerant temperature sensor 504 detects the temperature of refrigerant flowing into the heat-medium heat exchanger 21 and outputs a refrigerant detection signal, while the second refrigerant temperature sensor 505 detects the temperature of refrigerant flowing out of the heat-medium heat exchanger 21 and outputs a refrigerant detection signal. A relay unit control device 200, which will be discussed later, obtains the refrigerant detection signal output from the first refrigerant temperature sensor 504 and the refrigerant detection signal output from the second refrigerant temperature sensor 505.

[0029] In the heat-medium cycle circuit B, a heat-medium inlet temperature sensor 511 and a heat-medium outlet temperature sensor 512 are installed in the relay unit 2. In a flow of a heat medium in the heat-medium cycle circuit B, the heat-medium inlet temperature sensor 511 is installed in a pipe on the inflow side of the heat-medium heat exchanger 21 into which a heat medium flows. The heat-medium inlet temperature sensor 511 detects the temperature of a heat medium flowing into the heat-medium heat exchanger 21 and outputs a heat-medium inflow detection signal. The relay unit control device 200, which will be discussed later, obtains the heat-medium inflow detection signal output from the heat-medium inlet temperature sensor 511. In a flow of a heat medium in the heat-medium cycle circuit B, the heat-medium outlet temperature sensor 512 is installed in a pipe on the outflow side of the heat-medium heat exchanger 21 out of which a heat medium flows. The heat-medium outlet temperature sensor 512 detects the temperature of a heat medium flowing out of the heat-medium heat exchanger 21 and outputs a heat-medium outflow detection signal. The relay unit control device 200, which will be discussed later, obtains the heat-medium outflow detection signal output from the heat-medium outlet temperature sensor 512. In the heat-medium cycle circuit B, detection devices, such as a pressure sensor and a flow rate sensor, may be installed in the relay unit 2, although they are not installed in the relay unit 2 of the air-conditioning apparatus 0 of Embodiment 1.

[0030] In the heat-medium cycle circuit B, indoor inlet temperature sensors 513 (indoor inlet temperature sensors 513a through 513d) are installed in the respective indoor units 3, and indoor outlet temperature sensors 514 (indoor outlet temperature sensors 514a through 514d) are also installed in the respective indoor units 3. Each indoor inlet temperature sensor 513 detects the temperature of a heat medium flowing into the corresponding one of the indoor heat exchangers 31 and outputs an inflow detection signal. The indoor unit control device 300, which will be discussed later, included in each indoor unit 3 obtains the inflow detection signal output from the corresponding indoor outlet temperature sensor 514. Each indoor outlet temperature sensor 514 detects the temperature of a heat medium flowing out of the corresponding one of the indoor heat exchangers 31 and outputs an outflow detection signal. The indoor unit control device 300, which will be discussed later, obtains the inflow detection signal output from the corresponding indoor outlet temperature sensor 514.

[0031] In the heat-medium cycle circuit B, indoor inflow pressure sensors 521 (indoor inflow pressure sensors 521a and 521b) are installed in the respective indoor units 3, and indoor outflow pressure sensors 522 (indoor outflow pressure sensors 522a and 522b) are also installed in the respective indoor units 3. The indoor inflow pressure sensor 521 is disposed on the inflow side of the indoor flow rate adjusting device 32 of each indoor unit 3 into which a heat medium flows, and outputs a signal indicating the detected pressure, while the indoor outflow pressure sensor 522 is disposed on the outflow side of the indoor flow rate adjusting device 32 of each indoor unit 3 out of which a heat medium flows, and outputs a signal indicating the detected pressure. The indoor unit control device 300, which will be discussed later, included in each indoor unit 3 obtains a signal indicating the detected pressure output from the indoor inflow pressure sensor 521 and a signal indicating the detected pressure output from the indoor outflow pressure sensor 522.

[0032] When, for example, a pressure sensor that detects the pressure of the entirety of a heat medium circulating in the heat-medium cycle circuit B is installed in the relay unit 2, the indoor inflow pressure sensor 521 may be omitted. Alternatively, a flow rate detection device may be provided to detect the flow rate, instead of a pressure sensor. When the pumping-performance-control pump 34 installed in the indoor unit 3 has a map representing the relationships between the applied voltage, rotation frequency, and flow rate, the flow rate can be detected from the relationship between the applied voltage and the rotation frequency. In this case, the provision of a pressure sensor can be omitted. A heat-amount detection device may be provided to detect the amount of heat used for heat exchange between a heat medium and air in the indoor space, which is a thermal load. Each indoor unit control device 300 determines the amount of heat used for heat exchange in the corresponding one of the indoor heat exchangers 31 by calculations, for example. Each indoor unit control device 300 then sends a signal indicating data on the determined amount of heat, for example, to the relay unit control device 200.

[0033] In the respective indoor units 3, indoor temperature sensors 515 (indoor temperature sensors 515a through 515d) are installed. Each indoor temperature sensor 515 detects the suction temperature, which is the temperature of air generated by the driving of the corresponding one of the indoor fans 33 and flowing into the corresponding one of the indoor heat exchangers 31, and outputs a suction temperature detection signal. The suction temperature may be determined as the temperature of indoor air to be subjected to air-conditioning in the indoor space, which is a thermal load.

[0034] The configurations of control system devices in the air-conditioning apparatus 0 of Embodiment 1 will be described below. As illustrated in Fig. 2, each unit includes a controller that controls the devices included in the corresponding unit. Each controller executes processing according to data on physical quantities indicated by signals sent from various sensors and according to signals indicating instructions and settings output from input devices (not shown), for example. Each controller is connected to the other controllers by a wired or wireless communication medium so that it can send and receive signals indicating various types of data to and from the other controllers. The outdoor unit 1 includes the outdoor unit control device 100. The relay unit 2 includes the relay unit control device 200. The respective indoor units 3 include the indoor unit control devices 300 (indoor unit control devices 300a through 300d).

[0035] Each controller includes a microcomputer. The microcomputer includes a control arithmetic processing unit, such as a central processing unit (CPU). Each controller also includes an input-output port that manages input and output of various signals. The microcomputer includes, as storage devices, a volatile storage device (not shown), such as a random access memory (RAM), that can temporarily store data, and a non-volatile auxiliary storage device (not shown), such as a hard disk and a flash memory. Each controller can store in storage devices various types of data indicated by signals sent from other controllers and various sensors and data obtained by executing control arithmetic processing. Data formed into a program describing a processing procedure to be executed by the control arithmetic processing unit is also stored in a storage device. The control arithmetic processing unit then executes processing according to the program data and processing of each device is thus taken place. However, this is only an example. For instance, each device may be a dedicated device (hardware). The controller has a timing device, such as a timer.

[0036] Regarding communication between the individual controllers in Embodiment 1, each indoor unit control device 300 can input data on the pressure and the temperature, for example, detected by the sensors in the corresponding indoor unit 3 into a signal and send the signal to the relay unit control device 200 of the relay unit 2. Each indoor unit control device 300 can also send data on the set indoor temperature input from a remote controller (not shown) and data on the calculated amount of heat to the relay unit control device 200 of the relay unit 2. Each indoor unit control device 300 can also send data on the characteristics of a device included in the corresponding indoor unit 3, such as data on the heat exchange capacity of the corresponding indoor heat exchanger 31, to the relay unit control device 200.

[0037] An explanation will be given of a case in which flow rate control processing for the pumping-performance-control pump 34, which will be discussed later, is executed by the relay unit control device 200 or the indoor unit control device 300. However, the disclosure is not restricted to this configuration. For example, the pumping-performance-control pump 34 may include a controller and independently execute flow rate control processing according to map data, which will be discussed later.

[0038] A test operation of the heat-medium cycle circuit B in the air-conditioning apparatus 0 of Embodiment 1 will be discussed below. An explanation will be given of a case in which the relay unit control device 200 controls the devices related to the test operation by controlling the devices of the relay unit control device 200 or sending instructions to the indoor unit control device 300. However, this is only an example, and another controller may execute processing.

[0039] When the test operation is conducted, the air-conditioning apparatus 0 first fully opens the indoor flow rate adjusting devices 32 of all the indoor units 3 to the maximum possible opening degree and starts operating. At this time, the air-conditioning apparatus 0 drives the main pump 22 of the relay unit 2 and all the pumping-performance-control pumps 34 with the maximum possible applied voltage. Then, according to the output value from the indoor inflow pressure sensor 521, the output value from the indoor outflow pressure sensor 522, and map data representing the relationships between the applied voltage, rotation frequency, and flow rate stored in the pumping-performance-control pump 34, it is checked that the air-conditioning apparatus 0 is operating by causing a heat medium to circulate in all the indoor units 3.

[0040] Then, the air-conditioning apparatus 0 closes the indoor flow rate adjusting devices 32 of the indoor units 3 other than the indoor flow rate adjusting device 32a of the indoor unit 3a and starts operating. At this time, the air-conditioning apparatus 0 stops all the pumping-performance-control pumps 34 and drives the main pump 22 of the relay unit 2 with the maximum possible applied voltage. In a state in which the indoor flow rate adjusting device 32a of the indoor unit 3a is fully open to the maximum possible opening degree as described above, the relay unit control device 200 calculates the pressure difference ΔP between the pressure detected by the indoor outflow pressure sensor 522 and the pressure by the indoor inflow pressure sensor 521 included in the relay unit 2. Then, the relay unit control device 200 calculates the path pressure loss ΔPr from the pressure difference ΔP and records data on the path pressure loss ΔPr.

[0041] The relay unit control device 200 also records data on the flow rate Qa of the heat medium flowing through the indoor unit 3a. The relay unit control device 200 calculates the pressure difference ΔP between the pressure detected by the indoor inflow pressure sensor 521 and the pressure by the indoor outflow pressure sensor 522 at the time when the heat medium has passed through the indoor unit 3a. The relay unit control device 200 also determines the flow rate Qa of the heat medium according to the pressure difference ΔPa. The flow rate Qa of the heat medium may be determined from the pressure difference ΔP between the pressures detected by the pressure sensors installed in the corresponding indoor unit 3 or the relay unit 2, as discussed above, and from a Cv value in a flow path through which the heat medium flows. Alternatively, a detector, such as a flow rate detection device, may be installed to detect the flow rate Qa. When the flow rate Q of a heat medium is calculated from the pressure difference ΔP between the pressures detected by the pressure sensors, Q may be expressed by $Q = 45.58 \times Cv \times (\Delta P/G)^{1/2}$, where Cv is the Cv value in a flow path of the heat medium in a liquid state and G is the specific gravity of the heat medium.

[0042] Then, the relay unit control device 200 calculates the path pressure loss ΔPra_t at the time when the heat medium flows at a rated flow rate Q1a corresponding to the capacity of the indoor unit 3a. The path pressure loss ΔPra_t can be calculated by $\Delta Pra\_t = \Delta Pra \times (Q1a/Qa)^2$ from the flow rate Qa of the heat medium and the path pressure loss ΔPra calculated by the relay unit control device 200 as described above. The relay unit control device 200 then records data on the calculated path pressure loss ΔPra_t.

[0043] Then, the air-conditioning apparatus 0 closes the indoor flow rate adjusting device 32a of the indoor unit 3a and opens the indoor flow rate adjusting device 32b to the maximum possible opening degree. The air-conditioning apparatus 0 then starts operating. The relay unit control device 200 records data obtained by the operation of the air-conditioning apparatus 0. The air-conditioning apparatus 0 repeats the above-described operation until the relay unit control device 200 records data for all the indoor units 3. In this manner, data on the path pressure loss ΔPr_t at the time when a heat medium flows at the rated flow rate Q1 in each indoor unit 3 is recorded in the relay unit control device 200.

[0044] The air-conditioning apparatus 0 then closes the indoor flow rate adjusting devices 32 of all the indoor units 3 and starts operating. At this time, in the air-conditioning apparatus 0, the main pump 22 of the relay unit 2 and the pumping-performance-control pump 34c of the indoor unit 3c are driven. The main pump 22 is driven with the maximum possible applied voltage. The pumping-performance-control pump 34c is driven with the application of a voltage that can make a heat medium flow at a rated flow rate Q1c corresponding to the capacity of the indoor unit 3c. The voltage applied to the pumping-performance-control pump 34c is represented by Vc_t_max%. The relay unit control device 200 records data on Vc t_max%. Then, the main pump 22 of the relay unit 2 is driven with an applied voltage that is reduced to x% of the maximum possible applied voltage. The pumping-performance-control pump 34c is driven with the application of a voltage that can make a heat medium flow at the rated flow rate Q1c corresponding to the capacity of the indoor unit 3c. The voltage applied to the pumping-performance-control pump 34c is represented by Vc_t_x%. The relay unit control device 200 records data on Vc_t_x %.

[0045] The air-conditioning apparatus 0 repeats the above-described operation by changing the voltage to be applied to the main pump 22 of the relay unit 2. The relay unit control device 200 then records, as map data, data indicating the relationship between the applied voltage of the main pump 22 of the relay unit 2 and the applied voltage of the pumping-performance-control pump 34c that can make a heat medium flow at the rated flow rate Q1c corresponding to the capacity of the indoor unit 3c.

[0046] Then, the air-conditioning apparatus 0 stops the pumping-performance-control pump 34c of the indoor unit 3c and drives the pumping-performance-control pump 34d of the indoor unit 3d. The air-conditioning apparatus 0 then starts operating. The relay unit control device 200 records data obtained by the operation of the air-conditioning apparatus 0. The air-conditioning apparatus 0 repeats the above-described operation until the relay unit control device 200 records data obtained by driving each of the pumping-performance-control pumps 34. The air-conditioning apparatus 0 then finishes the test operation.

[0047] Fig. 4 is a flowchart illustrating processing for regular time control executed by a controller of the air-conditioning apparatus 0 of Embodiment 1. Air-conditioning processing in the air-conditioning apparatus 0 of Embodiment 1 will be described below. The processing shown in Fig. 4 is controlled mainly by the indoor unit control device 300 of each indoor unit 3 in collaboration with the outdoor unit control device 100 and the relay unit control device 200. However, this configuration is only an example, and one controller may intensively execute processing, for example. For the sake of simple description, an explanation will be given of a case in which the indoor units 3 (indoor units 3c and 3d) each provided with the pumping-performance-control pump 34 installed in a heat medium path are not in operation. An explanation will be given of a case in which the indoor unit 3 (indoor unit 3a or 3b) to which no pumping-performance-control pump 34 is connected is in operation.

[0048] In the indoor unit 3 that is to start operation, the indoor unit control device 300 opens the indoor flow rate adjusting device 32 to circulate a heat medium according to the corresponding operation mode and also starts the operation of the indoor fan 33 (step S1). In step S1, each indoor unit control device 300 opens the associated indoor flow rate adjusting device 32 to the degree that is calculated by multiplying the opening degree corresponding to the capacity of the indoor unit 3 by a correction value Cv_h. The correction value Cv_h is determined by the path pressure loss ΔPr_t in an individual indoor unit 3, which is recorded in the relay unit control device 200 at the time of the test operation. As the path pressure loss ΔPr_t is higher, the correction value Cv_h becomes greater, and the opening degree of the indoor flow rate adjusting device 32 accordingly becomes larger.

[0049] After the indoor unit control device 300 opens the indoor flow rate adjusting device 32, the indoor unit control device 300 sends a signal to the relay unit control device 200 of the relay unit 2. The relay unit control device 200 then starts driving the main pump 22 (step S2). At this time, the relay unit control device 200 determines the voltage to be applied to the main pump 22 from the total capacity of the indoor units 3 in operation.

[0050] After the relay unit control device 200 drives the main pump 22 and secures the flow rate of a heat medium in the heat-medium cycle circuit B, the relay unit control device 200 sends an operation signal to the outdoor unit control device 100 of the outdoor unit 1. The outdoor unit control device 100 starts driving the compressor 10 of the outdoor unit 1 (step S3).

[0051] After the compressor 10 has started driving, the indoor unit control device 300 executes regular time control processing to control the opening degree of the associated indoor flow rate adjusting device 32 at regular time intervals according to the load in the indoor space in which the associated indoor unit 3 is installed. Each indoor unit control device 300 calculates the temperature difference ΔTo between the temperature of the corresponding indoor temperature sensor 515 and a set indoor temperature To, and makes a determination by comparing the value ΔTo(t) of the temperature difference calculated this time and the value ΔTo(t-1) of the temperature difference ΔTo calculated the previous time (step S4). Then, according to the determination result, each indoor unit control device 300 controls the opening degree of the corresponding indoor flow rate adjusting device 32 at regular time intervals t.

[0052] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is greater than the previous value ΔTo(t-1), the indoor unit control device 300 determines that the indoor load is higher than the capacity of the corresponding indoor unit 3. Then, the indoor unit control device 300 provides an instruction to increase the opening degree of the corresponding indoor flow rate adjusting device 32 and thus raises the flow rate of a heat medium that passes through the corresponding indoor heat exchanger 31, thereby securing the capacity (step S5).

[0053] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is smaller than the previous value ΔTo(t-1), the indoor unit control device 300 determines that the indoor load is lower than the capacity of the corresponding indoor unit 3. Then, the indoor unit control device 300 provides an instruction to decrease the opening degree of the corresponding indoor flow rate adjusting device 32 and thus lowers the flow rate of a heat medium that passes through the corresponding indoor heat exchanger 31, thereby dropping the capacity (step S6).

[0054] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is the same as the previous value ΔTo(t-1), the indoor unit control device 300 closes the corresponding indoor flow rate adjusting device 32 to stop operating the corresponding indoor unit 3 (step S7).

[0055] Fig. 5 is a flowchart illustrating processing for controlling the main pump 22 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 1. As discussed, in step S2 of Fig. 4, the relay unit control device 200 determines the voltage to be applied to the main pump 22 of the relay unit 2 and starts driving the main pump 22. After the relay unit control device 200 drives the main pump 22, the relay unit control device 200 executes regular time control processing for controlling the driving of the main pump 22 at regular time intervals. A description will be given below of a control operation for the main pump 22 of the relay unit 2 in the air-conditioning apparatus 0 of Embodiment 1. The processing shown in Fig. 5 is executed mainly by the relay unit control device 200. However, this configuration is only an example, and one controller may intensively execute processing, for example.

[0056] After the relay unit control device 200 sends an operation signal to the outdoor unit control device 100 of the outdoor unit 1 in step S3 of Fig. 4, the relay unit control device 200 controls the voltage to be applied to the main pump 22 while the air-conditioning apparatus 0 is operating. With this control operation, the air-conditioning apparatus 0 controls the flow rate of a heat medium in all the indoor units 3.

[0057] The relay unit control device 200 determines whether the opening degree of the indoor flow rate adjusting device 32 of each indoor unit 3 is smaller than the initial opening degree that is set when the indoor unit 3 has started operating (step S11). When the opening degrees of all the indoor flow rate adjusting devices 32 are found to be smaller than the corresponding initial opening degrees, the relay unit control device 200 determines that the flow rate of a heat medium in the heat-medium cycle circuit B is sufficient. The relay unit control device 200 then lowers the voltage to be applied to the main pump 22 and decelerates the main pump 22 (step S12).

[0058] When even one of the opening degrees of the indoor flow rate adjusting devices 32 is larger than the corresponding initial opening degree, the relay unit control device 200 determines that the flow rate of the heat medium in the heat-medium cycle circuit B is not sufficient. The relay unit control device 200 then raises the voltage to be applied to the main pump 22 and accelerates the main pump 22 (step S13). The relay unit control device 200 repeats the above-described processing while regular time control is being executed, thereby adjusting the flow rate of a heat medium according to the load in each indoor unit 3.

[0059] Fig. 6 is a flowchart illustrating control processing for the pumping-performance-control pump 34 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 1. A description will be given below of a case in which the indoor unit 3 provided with the pumping-performance-control pump 34 installed in the heat medium path receives an operation instruction and starts operating. An explanation will be given mainly of drive processing for the pumping-performance-control pump 34 when the indoor unit 3 (indoor unit 3c or 3d) provided with the pumping-performance-control pump 34 installed in the heat medium path is operating.

[0060] After the relay unit control device 200 has executed steps S2 and S3 of Fig. 4, the indoor unit control device 300 starts driving a pumping-performance-control pump 34 to cause a heat medium to pass through the indoor unit 3 including this pumping-performance-control pump 34 installed in the heat medium path and also drives the indoor fan 33 (step S21). In step S21, according to the voltage applied to the main pump 22 and the map data recorded at the time of the test operation, the indoor unit control device 300 determines the applied voltage such that the pumping-performance-control pump 34 is driven to cause a heat medium to flow at the rated flow rate Q1.

[0061] After the compressor 10 is driven, the indoor unit control device 300 executes drive control for the corresponding pumping-performance-control pump 34 according to the air-conditioning load in the corresponding indoor unit 3. The indoor unit control device 300 calculates the temperature difference ΔTo between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To, and makes a determination by comparing the value ΔTo(t) of the temperature difference calculated this time and the value ΔTo(t-1) of the temperature difference ΔTo calculated the previous time (step S22). Then, according to the determination result, the indoor unit control device 300 executes drive control for the corresponding pumping-performance-control pump 34 at regular time intervals t.

[0062] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is greater than the previous value ΔTo(t-1), the indoor unit control device 300 determines that the indoor air-conditioning load is higher than the capacity of the corresponding indoor unit 3. Then, the indoor unit control device 300 provides an instruction to raise the voltage to be applied to the corresponding pumping-performance-control pump 34 to accelerate the pumping-performance-control pump 34 and thus increases the flow rate of a heat medium passing through the corresponding indoor heat exchanger 31, thereby securing the capacity (step S23).

[0063] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is smaller than the previous value ΔTo(t-1), the indoor unit control device 300 determines that the indoor air-conditioning load is lower than the capacity of the corresponding indoor unit 3. Then, the indoor unit control device 300 provides an instruction to lower the voltage to be applied to the corresponding pumping-performance-control pump 34 to decelerate the pumping-performance-control pump 34 and thus decreases the flow rate of the heat medium passing through the corresponding indoor heat exchanger 31, thereby dropping the capacity (step S24).

[0064] When the temperature difference ΔTo(t) between the temperature of the corresponding indoor temperature sensor 515 and the set indoor temperature To is the same as the previous value ΔTo(t-1), the indoor unit control device 300 stops the corresponding pumping-performance-control pump 34 to stop operating the corresponding indoor unit 3 (step S25).

[0065] In the above-described operation, the indoor unit control device 300 executes drive control for the corresponding pumping-performance-control pump 34 according to the air-conditioning load in the indoor space in which the corresponding indoor unit 3 is installed. However, the disclosure is not restricted to this configuration. For example, according to the above-described map data representing the relationships between the applied voltage, rotation frequency, and flow rate, the indoor unit control device 300 may execute drive control by controlling the voltage to be applied to the corresponding pumping-performance-control pump 34 such that a heat medium flows in the corresponding indoor unit 3 at the rated flow rate Q1.

[0066] The control operation for the main pump 22 to be performed by the relay unit control device 200 in regular time control is basically similar to the control operation discussed with reference to Fig. 5. When the maximum possible voltage is being applied to one of the pumping-performance-control pumps 34, the relay unit control device 200 determines that the heat medium supplied to the indoor unit 3 provided with the pumping-performance-control pump 34 is not sufficient. The relay unit control device 200 then raises the voltage to be applied to the main pump 22 to accelerate the main pump 22. As long as the pumping-performance-control pump 34 is operating, the above-described drive control is repeated to adjust the flow rate of the heat medium in regular time control.

[0067] As described above, in the air-conditioning apparatus 0 of Embodiment 1, the pumping-performance-control pump 34, which serves as an auxiliary pump, is connected to the indoor unit 3 (indoor heat exchanger 31) installed in a heat medium path where the pumping performance of the main pump 22 of the relay unit 2 would become insufficient to supply a heat medium. The air-conditioning apparatus 0 of Embodiment 1 then drives the pumping-performance-control pump 34 to supply a heat medium of a required flow rate to the indoor heat exchanger 31. Hence, even without the use of a main pump 22 having a high pumping performance that can deal with an indoor unit 3 installed in a path, such as in a remote place or at a high level, where the pumping performance would become insufficient to supply a heat medium, a heat medium can be supplied to the indoor unit 3. It is thus possible to provide the air-conditioning apparatus 0 having a wide installation range of the indoor units 3 at low cost.

[0068] Additionally, during the test operation, the air-conditioning apparatus 0 is operated such that a heat medium can flow in the indoor unit 3 at the rated flow rate Q1, and data indicating the relationship between the pumping-performance-control pump 34 and the main pump 22 is stored in a storage of the relay unit control device 200. Then, map data concerning the rated flow rate Q1, which is created according to the stored data, is stored in the indoor unit control device 300. Then, when the indoor unit 3 provided with the pumping-performance-control pump 34 installed in a heat medium path starts operating in response to receiving an operation instruction, the indoor unit control device 300 drives the pumping-performance-control pump 34 according to the map data. It is thus possible to reduce variations in the capacity of the indoor units 3, which would be caused by the nonuniformity of the flow rate of a heat medium in the indoor unit 3 placed in the vicinity and that in the indoor unit 3 in a remote place. This makes it possible to circulate a heat medium in the indoor unit 3 according to the load in the indoor space in which the indoor unit 3 is installed. Moreover, a heat medium can pass through the indoor unit 3 at a flow rate suited to the load in the indoor space in which the indoor unit 3 is installed. It is thus possible to distribute the power to be consumed in the air-conditioning apparatus 0 to the individual indoor units 3.

[0069] When the indoor unit 3 is not in operation, for example, the pumping-performance-control pump 34 can prevent a heat medium from passing through. It is thus possible to prevent a heat medium from passing through the indoor unit 3 that does not require the supply of a heat medium.

Embodiment 2

[0070] Fig. 7 schematically illustrates an example of the configuration of an air-conditioning apparatus 0 according to Embodiment 2. With reference to Fig. 7, the configurations of devices and units of the air-conditioning apparatus 0 will be explained below. Devices and units that are not explained in Embodiment 2 perform operation and processing similarly to operation and processing described in Embodiment 1 discussed above.

[0071] As stated above, the outdoor unit 1 and the relay unit 2 are connected to each other by the refrigerant pipes 6, and the relay unit 2 and each indoor unit 3 are connected to each other by the heat medium pipe 5. In Fig. 7, four indoor units 3 are connected to the relay unit 2 via the heat medium pipes 5. However, the number of indoor units 3 connected to the relay unit 2 is not limited to four. In the air-conditioning apparatus 0 in Embodiment 2, basically, each indoor unit 3 can select one of the cooling mode and the heating mode as desired, on the condition that the operation mode of the indoor units 3c and 3d is the same.

<Outdoor Unit 1>

[0072] The outdoor unit 1 is a unit that transfers heat by causing heat-source-side refrigerant to circulate in the heat-source-side refrigerant cycle circuit A and that causes a heat-medium heat exchanger 21 of the relay unit 2 to exchange heat between the heat-source-side refrigerant and a heat medium. The outdoor unit 1 includes a compressor 10, a refrigerant flow switching device 11, a heat-source-side heat exchanger 12, an accumulator 14, and a heat-source-side fan 15 inside a housing.

[0073] The outdoor unit 1 also includes a first connecting pipe 16, a second connecting pipe 17, and first backflow preventing devices 18a through 18d. In this example, as the first backflow preventing devices 18a through 18d, check values are used. The first backflow preventing device 18a is a device that prevents high-temperature high-pressure gas refrigerant from flowing back from the first connecting pipe 16 to the heat-source-side heat exchanger 12 in the heating only operation mode or in the heating main operation mode. The first backflow preventing device 18b is a device that prevents high-pressure liquid or two-phase gas-liquid refrigerant from flowing back from the first connecting pipe 16 to the accumulator 14 in the cooling only operation mode or in the cooling main operation mode. The first backflow preventing device 18c is a device that prevents high-pressure liquid or two-phase gas-liquid refrigerant from flowing back from the second connecting pipe 17 to the accumulator 14 in the cooling only operation mode or in the cooling main operation mode. The first backflow preventing device 18d is a device that prevents high-temperature high-pressure gas refrigerant from flowing back from the path on the discharge side of the compressor 10 to the second connecting pipe 17 in the heating only operation mode or in the heating main operation mode.

[0074] In this manner, the provision of the first connecting pipe 16, the second connecting pipe 17, and the first backflow preventing devices 18a through 18d allows refrigerant to flow into the relay unit 2 in a fixed direction, regardless of the operation mode of the indoor unit 3. Although check valves are used as the first backflow preventing devices 18a through 18d in the above-described example, any device can be used when it is able to prevent the backflow of refrigerant. For example, an opening-closing device and an expansion device configured to be fully closed may be used as the first backflow preventing devices 18a through 18d.

<Indoor Unit 3>

[0075] The indoor unit 3 is a unit that sends conditioned air to the indoor space. The respective indoor units 3 of Embodiment 2 include indoor heat exchangers 31 (indoor heat exchangers 31a through 31d) and indoor fans 33 (indoor fans 33a through 33d). Among the indoor units 3, the indoor unit 3b and the indoor unit 3d include a pumping-performance-control pump 34b and a pumping-performance-control pump 34d, respectively. Unlike Embodiment 1, the provision of the indoor flow rate adjusting device 32 in the indoor unit 3 is unnecessary because the relay unit 2 includes heat-medium flow rate adjusting devices 28. This will be discussed later. The indoor heat exchangers 31 and the pumping-performance-control pumps 34 are devices included in the heat-medium cycle circuit B. The pumping-performance-control pump 34 is installed in the heat-medium cycle circuit B according to the system. For example, the pumping-performance-control pump 34 is installed to assist a main pump 22 in supplying a heat medium to deal with the indoor unit 3 installed at a high level or in a remote place.

[0076] According to the temperature of a heat medium flowing into the indoor unit 3 and the temperature of the heat medium flowing out of the indoor unit 3, the pumping-performance-control pump 34 adjusts the amount of heat medium to pass through the indoor heat exchanger 31. An indoor unit control device 300 has map data indicating the relationship between the applied voltage and the flow rate of the pumping-performance-control pump 34 and the applied voltage and the flow rate of the main pump 22, which is recorded during a test operation discussed later. The indoor unit control device 300 adjusts the voltage to be applied to the pumping-performance-control pump 34 at the start of the operation of the indoor unit 3 such that the flow rate of a heat medium passing through the indoor unit 3 becomes equal to the rated flow rate

Q1. In Fig. 7, the pumping-performance-control pump 34 is disposed in a pipe on the outflow side of the indoor heat exchanger 31 out of which a heat medium flows. However, the position of the pumping-performance-control pump 34 is not restricted to this position. For example, the pumping-performance-control pump 34 may be disposed on the inflow side of the indoor heat exchanger 31 into which a heat medium flows. When the indoor unit 3 stops operating, for example, the pumping-performance-control pump 34 in Embodiment 1 can prevent a heat medium from passing through to stop a flow of the heat medium. The pumping-performance-control pump 34 can thus serve, not only as a pressurizing device, but also as a flow rate adjusting device.

[0077] The indoor heat exchanger 31 includes a heat transfer tube and fins, for example. A heat medium passes through the heat transfer tube of the indoor heat exchanger 31. The indoor heat exchanger 31 exchanges heat between a heat medium and indoor space air supplied from the indoor fan 33. When a heat medium cooler than air passes through the heat transfer tube, the air is cooled and the indoor space is cooled. The indoor fan 33 produces a flow of indoor space air that passes through the indoor heat exchanger 31 and that returns to the indoor space.

<Relay Unit 2>

[0078] The relay unit 2 includes two heat-medium heat exchangers 21 and two main pumps 22. The heat-medium heat exchangers 21 exchange heat between heat-source-side refrigerant and a heat medium. The main pumps 22 transfer heat to the indoor units 3. The relay unit 2 also includes two relay-side expansion devices 23, two opening-closing devices 24, and two relay-side refrigerant flow switching devices 25 in the heat-source-side refrigerant cycle circuit A. The relay unit 2 also includes first heat-medium flow switching devices 26, second heat-medium flow switching devices 27, and the heat-medium flow rate adjusting devices 28 in the heat-medium cycle circuit B.

[0079] The two heat-medium heat exchangers 21 (heat-medium heat exchangers 21a and 21b) serve as condensers (radiators) or evaporators. The heat-medium heat exchanger 21a is disposed between the relay-side expansion device 23a and the relay-side refrigerant flow switching device 25a in the heat-source-side refrigerant cycle circuit A. The heat-medium heat exchanger 21a serves as a heat exchanger that heats a heat medium in the cooling and heating mixed operation mode. The heat-medium heat exchanger 21b is disposed between the relay-side expansion device 23b and the relay-side refrigerant flow switching device 25b in the heat-source-side refrigerant cycle circuit A. The heat-medium heat exchanger 21b serves as a heat exchanger that cools a heat medium in the cooling and heating mixed operation mode.

[0080] The two relay-side expansion devices 23 (relay-side expansion devices 23a and 23b) each serve as a pressure reducing valve and also as an expansion valve to reduce the pressure of heat-source-side refrigerant and expand it. The relay-side expansion device 23a is disposed on the upstream side of the heat-medium heat exchanger 21a in a flow of heat-source-side refrigerant in the cooling operation. The relay-side expansion device 23b is disposed on the upstream side of the heat-medium heat exchanger 21b in a flow of heat-source-side refrigerant in the cooling operation. The two relay-side expansion devices 23 are electronic expansion valves, which can control the opening degree, for example.

[0081] The two opening-closing devices 24 (opening-closing devices 24a and 24b) are each a two-way valve, for example, and open and close the heat medium pipe 5. The opening-closing device 24a is disposed on the inlet side of the heat medium pipe 5 into which heat-source-side refrigerant flows. The opening-closing device 24b is disposed in a pipe connecting the inlet side of heat-source-side refrigerant and the outlet side of the heat-source-side refrigerant. The opening-closing devices 24 may be electronic expansion valves, such as those used as expansion devices.

[0082] The two relay-side refrigerant flow switching devices 25 (relay-side refrigerant flow switching devices 25a and 25b) are each a four-way valve, for example, and switch flows of heat-source-side refrigerant according to the operation mode. The relay-side refrigerant flow switching device 25a is disposed on the downstream side of the heat-medium heat exchanger 21a in a flow of heat-source-side refrigerant in the cooling operation. The relay-side refrigerant flow switching device 25b is disposed on the downstream side of the heat-medium heat exchanger 21b in a flow of heat-source-side refrigerant in the cooling only operation.

[0083] The two main pumps 22 (main pumps 22a and 22b) each pressurize a heat medium passing through the heat medium pipe 5 and cause the heat medium to circulate in the heat-medium cycle circuit B. The main pump 22a is disposed in the heat medium pipe 5 between the heat-medium heat exchanger 21a and the second heat-medium flow switching device 27. The main pump 22b is disposed in the heat medium pipe 5 between the heat-medium heat exchanger 21b and the second heat-medium flow switching device 27.

[0084] The first heat-medium flow switching devices 26 (first heat-medium flow switching devices 26a through 26c) are each a three-way valve, for example, and switch the flow paths of a heat medium. The number of first heat-medium flow switching devices 26 to be provided is determined according to the number of branching portions of the relay unit 2 to the indoor units 3. Multiple indoor units 3 may be connected to one branching portion of the relay unit 2 to the indoor units 3. Among three flow paths of each of the first heat-medium flow switching devices 26, one flow path is connected to the heat-medium heat exchanger 21a, another one is connected to the heat-medium heat exchanger 21b, and the remaining one is connected to the heat-medium flow rate adjusting device 28. The first heat-medium flow switching device 26 is disposed on the outlet side of the indoor heat exchanger 31 out of which a heat medium flows.

[0085] The second heat-medium flow switching devices 27 (second heat-medium flow switching devices 27a through 27c) are each a three-way valve, for example, and switch the flow paths of a heat medium. The number of second heat-medium flow switching devices 27 to be provided is determined according to the number of indoor units 3. Among three flow paths of each of the second heat-medium flow switching devices 27, one flow path is connected to the heat-medium heat exchanger 21a, another one is connected to the heat-medium heat exchanger 21b, and the remaining one is connected to the indoor heat exchanger 31. The second heat-medium flow switching device 27 is disposed on the inlet side of the indoor heat exchanger 31 into which a heat medium flows.

[0086] The heat-medium flow rate adjusting devices 28 (heat-medium flow rate adjusting devices 28a through 28c) are devices that each adjust the flow rate of a heat medium to flow in the indoor unit 3. The heat-medium flow rate adjusting devices 28 are each a two-way valve, for example, that can control the aperture area to adjust the flow rate of a heat medium flowing in the heat medium pipe 5. The number of heat-medium flow rate adjusting devices 28 to be provided is determined according to the number of branching portions of the relay unit 2 to the indoor units 3. One end of each of the heat-medium flow rate adjusting devices 28 is connected to the indoor heat exchanger 31, while the other end of the heat-medium flow rate adjusting device 28 is connected to the first heat-medium flow switching device 26. In this example, the heat-medium flow rate adjusting device 28 is disposed on the outlet side of the indoor heat exchanger 31 out of which a heat medium flows. Alternatively, the heat-medium flow rate adjusting device 28 may be disposed on the inlet side of the indoor heat exchanger 31 into which a heat medium flows.

[0087] A test operation of the heat-medium cycle circuit B in the air-conditioning apparatus 0 of Embodiment 1 will be discussed below. An explanation will be given of a case in which the relay unit control device 200 controls the devices related to the test operation by controlling the devices of the relay unit control device 200 or sending instructions to the indoor unit control device 300. However, this is only an example, and another controller may execute processing.

[0088] First, the relay unit control device 200 switches the first heat-medium flow switching device 26b and the second heat-medium flow switching device 27b such that the branching portion of the relay unit 2 corresponding to the indoor unit 3b to which the pumping-performance-control pump 34b is connected is switched to the main pump 22a. The relay unit control device 200 fully opens the heat-medium flow rate adjusting device 28b.

[0089] Then, the relay unit control device 200 drives the main pumps 22 of the relay unit 2 and all the pumping-performance-control pumps 34b with the maximum possible applied voltage. Then, the relay unit control device 200 lowers the voltage to be applied to the pumping-performance-control pump 34 until the flow rate of a heat medium becomes equal to a rated flow rate Q1b corresponding to the capacity of the indoor unit 3b. The relay unit control device 200 then records data of the voltage Vb_t_100% applied to the pumping-performance-control pump 34 while the maximum possible voltage is applied to the main pump 22 of the relay unit 2.

[0090] Then, the relay unit control device 200 lowers the voltage to be applied to the main pump 22a and adjusts the voltage Vb_t_x% to be applied to the pumping-performance-control pump 34b such that the flow rate of a heat medium becomes equal to the rated flow rate Q1b corresponding to the capacity of the indoor unit 3b. The relay unit control device 200 then records data of the applied voltage Vb_t_x%.

[0091] The air-conditioning apparatus 0 repeats the above-described operation. The relay unit control device 200 then records, as map data, data indicating the relationship between the applied voltage of the main pump 22 of the relay unit 2 and the applied voltage of the pumping-performance-control pump 34c that can make a heat medium flow at the rated flow rate Q1b corresponding to the capacity of the indoor unit 3b.

[0092] Then, the air-conditioning apparatus 0 stops the pumping-performance-control pump 34b of the indoor unit 3b and drives the pumping-performance-control pump 34d of the indoor unit 3d. The air-conditioning apparatus 0 then starts operating. The relay unit control device 200 records data obtained by the operation of the air-conditioning apparatus 0. The air-conditioning apparatus 0 repeats the above-described operation until the relay unit control device 200 records data obtained by driving each of the pumping-performance-control pumps 34. The air-conditioning apparatus 0 then finishes the test operation.

[0093] Fig. 8 is a flowchart illustrating processing for regular time control executed by a controller of the air-conditioning apparatus 0 of Embodiment 2. Air-conditioning processing in the air-conditioning apparatus 0 of Embodiment 1 will be described below. The processing shown in Fig. 8 is controlled mainly by the relay unit control device 200 in collaboration with the outdoor unit control device 100 and the indoor unit control device 300 of each indoor unit 3. However, this configuration is only an example, and another controller may execute processing, for example. For the sake of simple description, an explanation will be given of a case in which, in a state in which the indoor units 3 (indoor units 3b and 3d) provided with the pumping-performance-control pump 34 in a heat medium path are not in operation, the indoor unit 3a, to which no pumping-performance-control pump 34 is connected, starts operating.

[0094] For the indoor unit 3a that is to start operation, the relay unit control device 200 opens the heat-medium flow rate adjusting device 28a connected at its branching portion to the indoor unit 3a by a pipe to circulate a heat medium according to the operation mode of the indoor unit 3a. The relay unit control device 200 also switches the first heat-medium flow switching device 26a and the second heat-medium flow switching device 27a to the main pump 22 corresponding to the operation mode (step S31). The heat-medium flow rate adjusting device 28a connected at its branching portion to the indoor unit 3 is controlled according to the capacity of the indoor unit 3a. The indoor unit control device 300a starts the operation of the indoor fan 33.

[0095] In response to an operation signal from the indoor unit control device 300 of the indoor unit 3, the relay unit control device 200 starts driving the main pump 22 corresponding to the operation mode (step S32). After the relay unit control device 200 drives the main pump 22 and secures the flow rate of a heat medium in the heat-medium cycle circuit B, the relay unit control device 200 sends an operation signal to the outdoor unit control device 100 of the outdoor unit 1. The outdoor unit control device 100 then starts driving the compressor 10 of the outdoor unit 1 (step S33).

[0096] After the compressor 10 has started driving, the relay unit control device 200 controls the heat-medium flow rate adjusting device 28a of the relay unit 2 according to the air-conditioning load in the indoor unit 3a. From a signal sent from the indoor unit control device 300, the relay unit control device 200 calculates the temperature difference ΔTa between the temperature detected by the indoor inlet temperature sensor 513a of the indoor unit 3a and the temperature detected by the indoor outlet temperature sensor 514a of the indoor unit 3a. Then, the relay unit control device 200 makes a determination by comparing the temperature difference ΔTa with a preset rated temperature difference ΔT_t (step S34).

[0097] When the temperature difference ΔTa is greater than the rated temperature difference ΔT_t, the relay unit control device 200 determines that the indoor load is higher than the capacity of the indoor unit 3. Then, the relay unit control device 200 increases the opening degree of the heat-medium flow rate adjusting device 28a and thus raises the flow rate of a heat medium that passes through the indoor heat exchanger 31a, thereby securing the capacity (step S35).

[0098] When the temperature difference ΔTa is smaller than the rated temperature difference ΔT_t, the relay unit control device 200 determines that the indoor load is lower than the capacity of the indoor unit 3. Then, the relay unit control device 200 decreases the opening degree of the heat-medium flow rate adjusting device 28a and thus lowers the flow rate of a heat medium that passes through the indoor heat exchanger 31a, thereby dropping the capacity (step S36). When the temperature difference ΔTa is the same as the rated temperature difference ΔT_t, the relay unit control device 200 returns to step S34 to continue regular time control processing. In this manner, the relay unit control device 200 executes regular time control according to the indoor load by adjusting the opening degree of the heat-medium flow rate adjusting device 28a.

[0099] During regular time control, the relay unit control device 200 of the relay unit 2 also controls the voltage to be applied to each main pump 22 of the relay unit 2 and thus controls the flow rate of a heat medium to be supplied to all indoor units 3 in operation. When the largest one of the opening degrees of the heat-medium flow rate adjusting devices 28 that cause a heat medium supplied from the main pump 22 to pass through is smaller than the initial opening degree, the relay unit control device 200 determines that the flow rate of the heat medium is sufficient and lowers the voltage to be applied to the main pump 22 and decelerates the main pump 22. When even one of the opening degrees of the heat-medium flow rate adjusting devices 28 that cause a heat medium supplied from the main pump 22 to pass through is larger than the initial opening degree, the relay unit control device 200 determines that the flow rate of the heat medium in the heat medium path is insufficient and raises the voltage to be applied to the main pump 22 and accelerates the main pump 22. The relay unit control device 200 repeats the above-described processing while regular time control is being executed, thereby adjusting the flow rate of a heat medium according to the load in the indoor unit 3.

[0100] Fig. 9 is a flowchart illustrating control processing for the pumping-performance-control pump 34 in regular time control executed by the air-conditioning apparatus 0 of Embodiment 2. A description will be given below of a case in which the indoor unit 3 provided with the pumping-performance-control pump 34 installed in a heat medium path receives an operation instruction and starts operating. For the indoor unit 3 that is to start operation, the relay unit control device 200 opens the heat-medium flow rate adjusting device 28 connected at its branching portion to this indoor unit 3 by a pipe to circulate a heat medium according to the operation mode of this indoor unit 3. The relay unit control device 200 also switches the first heat-medium flow switching device 26 and the second heat-medium flow switching device 27 to the main pump 22 corresponding to the operation mode (step S41).

[0101] In step S41, when the indoor unit 3 provided with the pumping-performance-control pump 34, such as the indoor unit 3b, is only disposed in the branched heat medium path, the relay unit control device 200 fully opens the heat-medium flow rate adjusting device 28. When indoor units 3 to which no pumping-performance-control pump 34 is connected, such as the indoor units 3c and d, are also disposed in the branched heat medium path, the relay unit control device 200 determines the initial opening degree according to the total capacity of the indoor units 3 in the heat medium path.

[0102] In response to an operation signal from the indoor unit control device 300 of the indoor unit 3, the relay unit control device 200 starts driving the main pump 22 corresponding to the operation mode (step S42). After the relay unit control device 200 drives the main pump 22 and secures the flow rate of a heat medium in the heat-medium cycle circuit B, the relay unit control device 200 sends an operation signal to the outdoor unit control device 100 of the outdoor unit 1. The outdoor unit control device 100 then starts driving the compressor 10 of the outdoor unit 1 (step S43).

[0103] To cause a heat medium to pass through the indoor unit 3 provided with the pumping-performance-control pump 34 in the heat medium path, the relay unit control device 200 also drives the pumping-performance-control pump 34 (step S44).

[0104] When the indoor unit 3 provided with the pumping-performance-control pump 34, such as the indoor unit 3b, is only disposed in the branched heat medium path, after the compressor 10 has started driving, the relay unit control device 200 controls the pumping-performance-control pump 34 according to the air-conditioning load in the indoor unit 3. From a signal sent from the indoor unit control device 300b, the relay unit control device 200 calculates the temperature difference ΔTb between the temperature detected by the indoor inlet temperature sensor 513b of the indoor unit 3b and the temperature detected by the indoor outlet temperature sensor 514b of the indoor unit 3b. Then, the relay unit control device 200 makes a determination based on the temperature difference ΔTb (step S45).

[0105] When the temperature difference ΔTb is greater than the preset rated temperature difference ΔT_t, the relay unit control device 200 determines that the indoor load is higher than the capacity of the indoor unit 3b. Then, the relay unit control device 200 raises the voltage to be applied to the pumping-performance-control pump 34b and thus increases the flow rate of a heat medium that passes through the indoor heat exchanger 31b, thereby securing the capacity (step S46).

[0106] When the temperature difference ΔTb is smaller than the rated temperature difference ΔT_t, the relay unit control device 200 determines that the indoor load is lower than the capacity of the indoor unit 3b. Then, the relay unit control device 200 lowers the voltage to be applied to the pumping-performance-control pump 34b and thus decreases the flow rate of a heat medium that passes through the indoor heat exchanger 31b, thereby dropping the capacity (step S47).

[0107] When the temperature difference ΔTb is the same as the rated temperature difference ΔT_t, the relay unit control device 200 returns to step S45 to continue regular time control processing. In this manner, the relay unit control device 200 executes regular time control according to the indoor load by adjusting the opening degree of the heat-medium flow rate adjusting device 28b.

[0108] A description will be given below of a case in which indoor units 3 to which no pumping-performance-control pump 34 is connected, such as the indoor units 3c and 3d, are also disposed in the branched heat medium path. Regarding the indoor unit 3d to which the pumping-performance-control pump 34d is connected, the relay unit control device 200 controls the voltage to be applied to the pumping-performance-control pump 34d, according to the temperature difference ΔTd between the temperature detected by the indoor inlet temperature sensor 513d and the temperature detected by the indoor outlet temperature sensor 514d. Regarding the indoor unit 3c to which no pumping-performance-control pump 34 is connected, the relay unit control device 200 controls the opening degree of the heat-medium flow rate adjusting device 28c, according to the temperature difference ΔTc between the temperature detected by the indoor inlet temperature sensor 513c and the temperature detected by the indoor outlet temperature sensor 514c.

[0109] In the above-described operation, the relay unit control device 200 executes drive control for the pumping-performance-control pump 34 according to the load in the indoor space in which the indoor unit 3 is installed. However, the disclosure is not restricted to this configuration. For example, according to the above-described map data representing the relationships between the applied voltage, rotation frequency, and flow rate, the indoor unit control device 300 may execute drive control by controlling the voltage to be applied to the pumping-performance-control pump 34 such that the flow rate of a heat medium to pass through the indoor unit 3 becomes equal to the rated flow rate Q1.

[0110] The control operation for the main pump 22 performed by the relay unit control device 200 in regular time control when the indoor unit 3 provided with the pumping-performance-control pump 34 installed in a heat medium path is operated is basically similar to that when the indoor unit 3 to which no pumping-performance-control pump 34 is connected in a heat medium path is operated. When the maximum possible voltage is being applied to the pumping-performance-control pump 34, the relay unit control device 200 determines that the heat medium supplied to the indoor unit 3 provided with the pumping-performance-control pump 34 is not sufficient. The relay unit control device 200 then raises the voltage to be applied to the corresponding main pump 22 and accelerates the main pump 22. As long as the pumping-performance-control pump 34 is operating, the above-described drive control is repeated to adjust the flow rate of the heat medium in regular time control.

[0111] As described above, in the air-conditioning apparatus 0 of Embodiment 2, the pumping-performance-control pump 34, which serves as an auxiliary pump, is connected to a heat medium path leading to the indoor unit 3 (indoor heat exchanger 31) where the pumping performance of the main pump 22 of the relay unit 2 would become insufficient to supply a heat medium. The air-conditioning apparatus 0 of Embodiment 2 then drives the pumping-performance-control pump 34 to supply a heat medium of a required flow rate to the indoor heat exchanger 31. Hence, even without the use of a main pump 22 having a high pumping performance that can deal with an indoor unit 3 installed in a path, such as in a remote place or at a high level, where the pumping performance would become insufficient to supply a heat medium, a heat medium can be supplied to the indoor unit 3. It is thus possible to provide the air-conditioning apparatus 0 having a wide installation range of the indoor units 3 at low cost.

Reference Signs List

[0112] 0: air-conditioning apparatus, 1: outdoor unit, 2: relay unit, 3, 3a, 3b, 3c, 3d: indoor unit, 5: heat medium pipe, 6: refrigerant pipe, 10: compressor, 11: refrigerant flow switching device, 12: heat-source-side heat exchanger, 13: expansion device, 14: accumulator, 15: heat-source-side fan, 16: first connecting pipe, 17: second connecting pipe, 18a, 18b, 18c, 18d: first backflow preventing device, 21, 21a, 21b: heat-medium heat exchanger, 22, 22a, 22b: main pump, 23, 23a, 23b: relay-side expansion device, 24, 24a, 24b: opening-closing device, 25, 25a, 25b: relay-side refrigerant flow switching device, 26, 26a, 26b, 26c: first heat-medium flow switching device, 27, 27a, 27b, 27c: second heat-medium flow switching device, 28, 28a, 28b, 28c: heat-medium flow rate adjusting device, 31, 31a, 31b, 31c, 31d: indoor heat exchanger, 32, 32a, 32b: indoor flow rate adjusting device, 33, 33a, 33b, 33c, 33d: indoor fan, 34, 34b, 34c, 34d: pumping-performance-control pump, 100: outdoor unit control device, 200: relay unit control device, 300, 300a, 300b, 300c, 300d: indoor unit control device, 501: discharge temperature sensor, 502: discharge pressure sensor, 503: outdoor temperature sensor, 504: first refrigerant temperature sensor, 505: second refrigerant temperature sensor, 511: heat-medium inlet temperature sensor, 512: heat-medium outlet temperature sensor, 513, 513a, 513b, 513c, 513d: indoor inlet temperature sensor, 514, 514a, 514b, 514c, 514d: indoor outlet temperature sensor, 515, 515a, 515b, 515c, 515d: indoor temperature sensor, 521, 521a, 521b: indoor inflow pressure sensor, 522, 522a, 522b: indoor outflow pressure sensor

Claims

1. An air-conditioning apparatus comprising:

a heat-medium cycle circuit configured to cause a heat medium to circulate in the heat-medium cycle circuit, the heat-medium cycle circuit including
a heat-source-side device configured to heat or cool the heat medium, the heat medium serving as a heat transfer medium,
a plurality of indoor heat exchangers exchanging heat between the heat medium and indoor air to be conditioned, and
a main pump configured to pressurize the heat medium and supply the pressurized heat medium to the plurality of indoor heat exchangers, the heat-source-side device, the plurality of indoor heat exchangers, and the main pump being connected to each other by a pipe in the heat-medium cycle circuit,
the air-conditioning apparatus further comprising:
a pumping-performance-control pump installed in the heat-medium cycle circuit and configured to support pumping performance of the main pump.

2. The air-conditioning apparatus of claim 1, wherein, in the heat-medium cycle circuit, the pumping-performance-control pump is installed for one of the plurality of indoor heat exchangers disposed in a heat medium path in which the pumping performance of the main pump is insufficient.

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

a controller configured to control driving of the pumping-performance-control pump,
wherein the controller is configured to drive the pumping-performance-control pump to adjust a flow rate of the heat medium passing through the plurality of indoor heat exchangers.

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

a controller configured to control driving of the pumping-performance-control pump,
wherein the controller is configured to detect a flow rate of the heat medium supplied from the pumping-performance-control pump.

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

a controller configured to control driving of the pumping-performance-control pump,
wherein the pumping-performance-control pump is configured to prevent the heat medium from passing through the pumping-performance-control pump, and
wherein the controller is configured to cause the pumping-performance-control pump to prevent the heat medium from passing through one of the plurality of indoor heat exchangers that stops exchanging heat.

6. The air-conditioning apparatus of any one of claims 1 to 5, further comprising:

an indoor temperature sensor configured to detect temperature of the indoor air; and

a controller configured to control driving of the pumping-performance-control pump,
wherein the controller is configured to control a voltage to be applied to the pumping-performance-control pump according to a temperature difference between the temperature of the indoor air and a set indoor temperature.

7. The air-conditioning apparatus of any one of claims 1 to 5, further comprising:

an indoor inlet temperature sensor configured to detect temperature of the heat medium flowing into one of the plurality of indoor heat exchangers;
an indoor outlet temperature sensor configured to detect temperature of the heat medium flowing out of the one of the plurality of indoor heat exchangers; and
a controller configured to control driving of the pumping-performance-control pump,
wherein the controller is configured to control a voltage to be applied to the pumping-performance-control pump according to a temperature difference between the temperature detected by the indoor inlet temperature sensor and the temperature detected by the indoor outlet temperature sensor.

8. The air-conditioning apparatus of any one of claims 1 to 7, wherein the heat medium caused by the heat-medium cycle circuit to circulate in the heat-medium cycle circuit includes water or brine.

FIG. 1

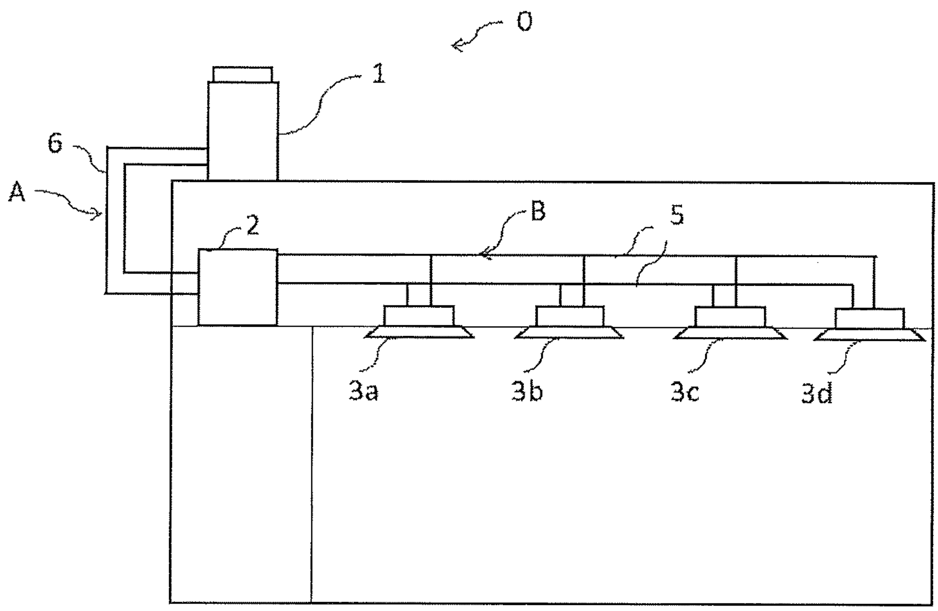
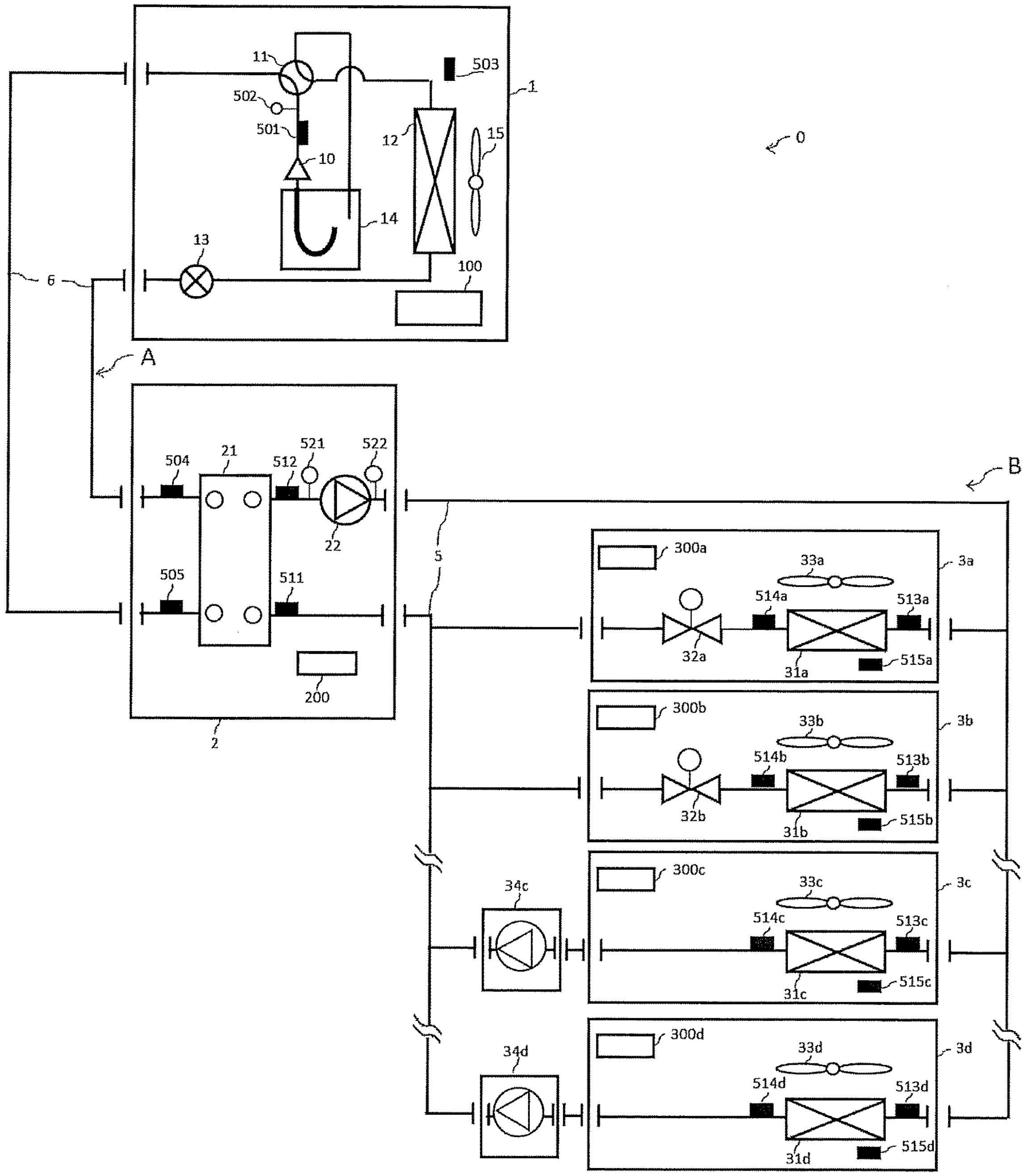


FIG. 2



11
502
501
10
503
1
12
15
14
13
100
0
6
A
504
21
512
521
522
22
505
511
200
2
5
B
300a
33a
3a
514a
513a
32a
31a
515a
300b
33b
3b
514b
513b
32b
31b
515b
34c
300c
33c
3c
514c
513c
31c
515c
34d
300d
33d
3d
514d
513d
31d
515d

FIG. 3

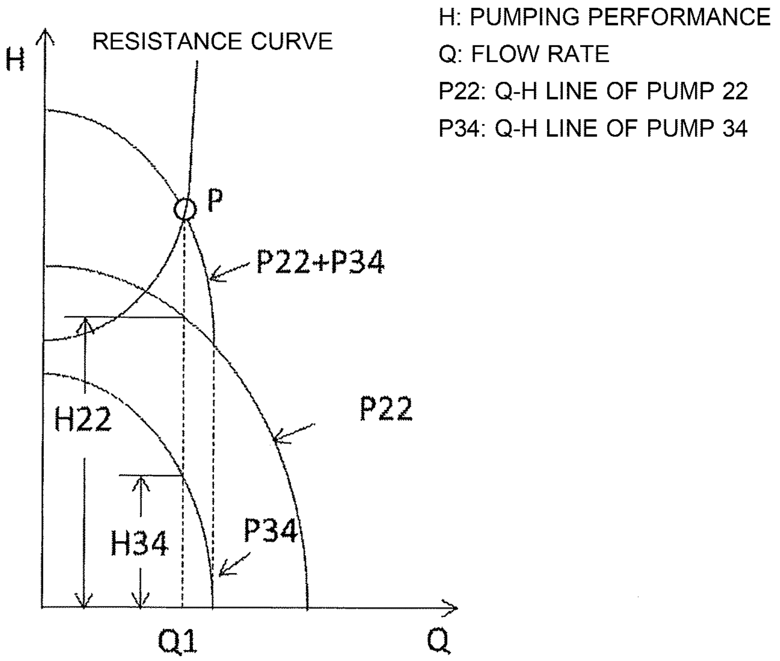

H: PUMPING PERFORMANCE
Q: FLOW RATE
P22: Q-H LINE OF PUMP 22
P34: Q-H LINE OF PUMP 34
H
RESISTANCE CURVE
P
P22+P34
P22
H22
H34
P34
Q1
Q

FIG. 4

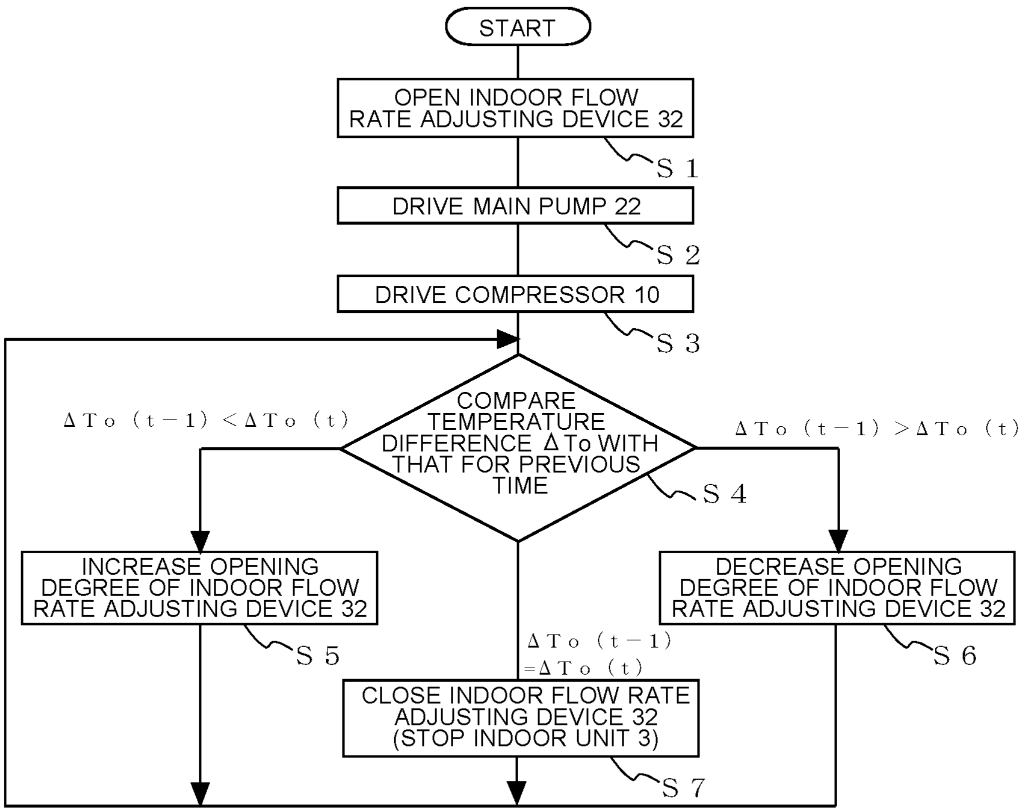

START
OPEN INDOOR FLOW RATE ADJUSTING DEVICE 32
S1
DRIVE MAIN PUMP 22
S2
DRIVE COMPRESSOR 10
S3
COMPARE TEMPERATURE DIFFERENCE ΔTo WITH THAT FOR PREVIOUS TIME
S4
ΔTo (t−1) < ΔTo (t)
ΔTo (t−1) > ΔTo (t)
INCREASE OPENING DEGREE OF INDOOR FLOW RATE ADJUSTING DEVICE 32
S5
DECREASE OPENING DEGREE OF INDOOR FLOW RATE ADJUSTING DEVICE 32
S6
ΔTo (t−1) =ΔTo (t)
CLOSE INDOOR FLOW RATE ADJUSTING DEVICE 32 (STOP INDOOR UNIT 3)
S7

FIG. 5

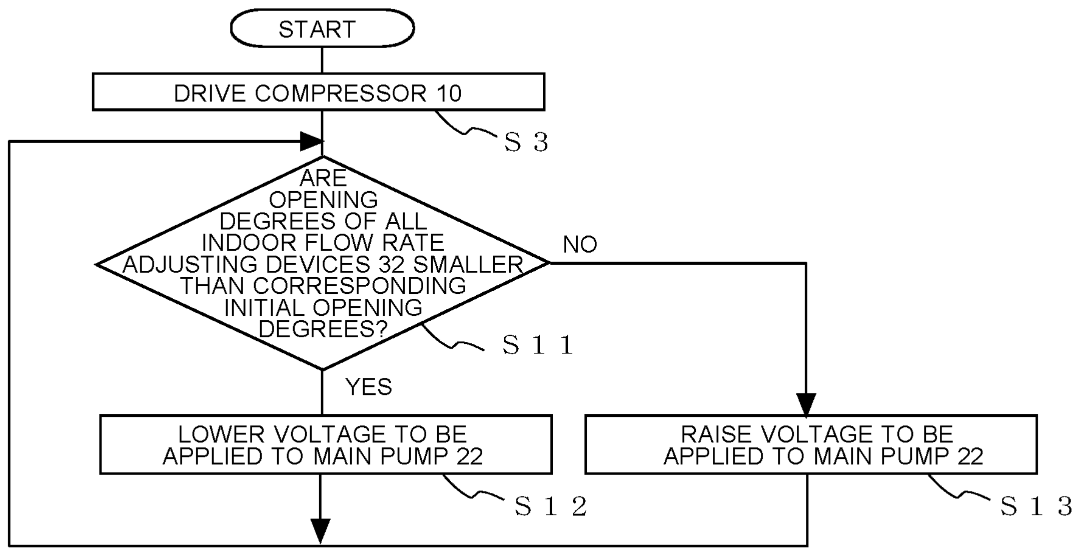

START
DRIVE COMPRESSOR 10
S3
ARE OPENING DEGREES OF ALL INDOOR FLOW RATE ADJUSTING DEVICES 32 SMALLER THAN CORRESPONDING INITIAL OPENING DEGREES?
NO
S11
YES
LOWER VOLTAGE TO BE APPLIED TO MAIN PUMP 22
RAISE VOLTAGE TO BE APPLIED TO MAIN PUMP 22
S12
S13

FIG. 6

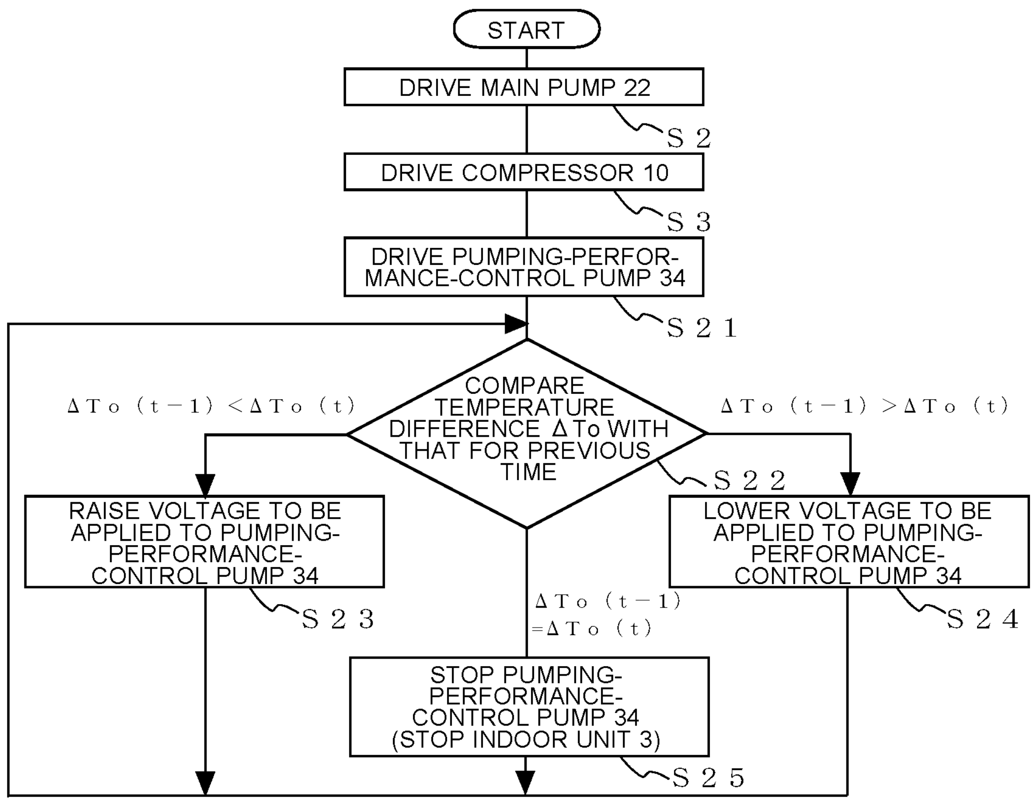

START
DRIVE MAIN PUMP 22
S2
DRIVE COMPRESSOR 10
S3
DRIVE PUMPING-PERFORMANCE-CONTROL PUMP 34
S21
COMPARE TEMPERATURE DIFFERENCE ΔTo WITH THAT FOR PREVIOUS TIME
ΔTo (t−1) < ΔTo (t)
ΔTo (t−1) > ΔTo (t)
S22
RAISE VOLTAGE TO BE APPLIED TO PUMPING-PERFORMANCE-CONTROL PUMP 34
LOWER VOLTAGE TO BE APPLIED TO PUMPING-PERFORMANCE-CONTROL PUMP 34
S23
ΔTo (t−1) =ΔTo (t)
S24
STOP PUMPING-PERFORMANCE-CONTROL PUMP 34 (STOP INDOOR UNIT 3)
S25

FIG. 7

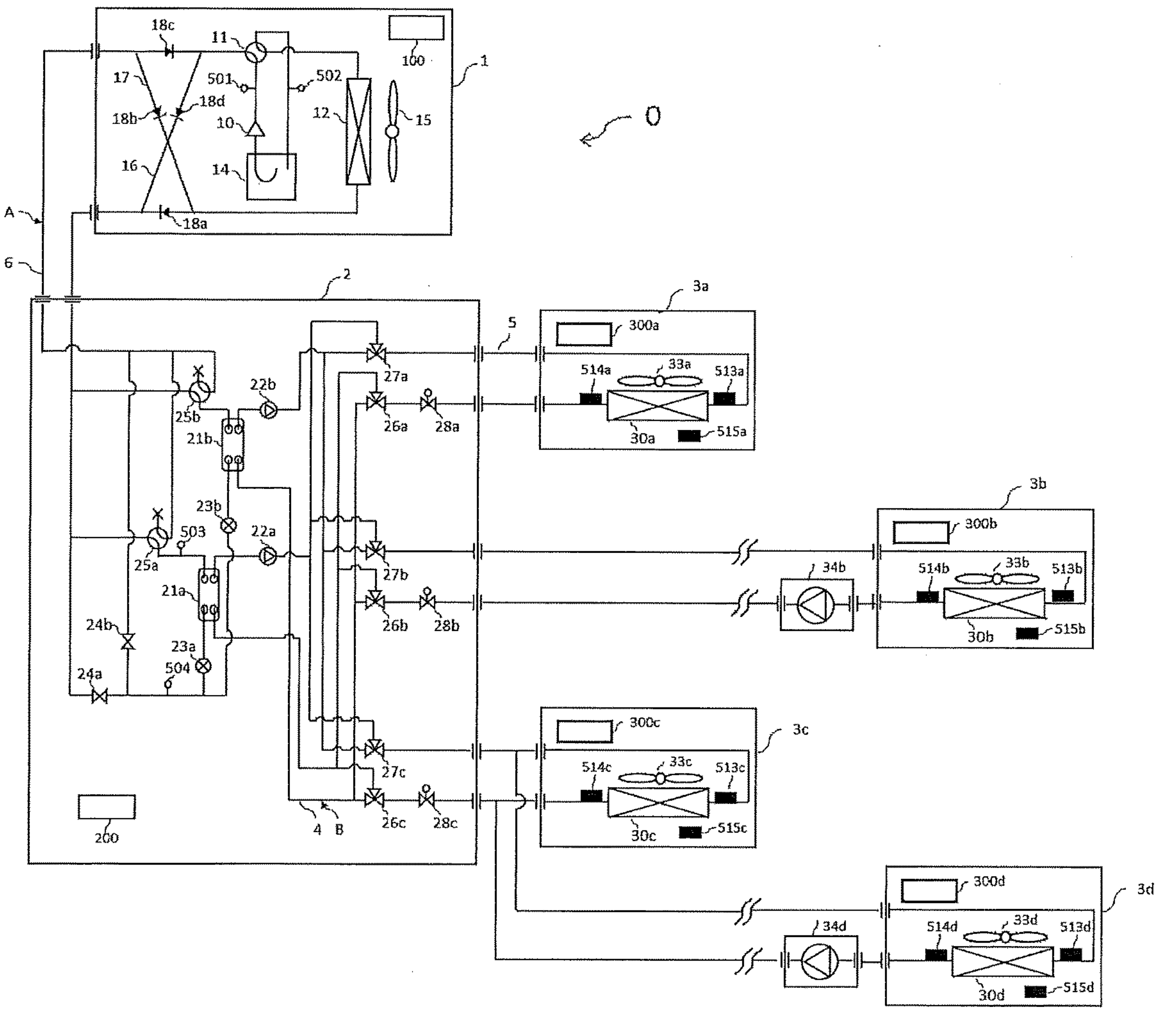

18c
11
100
1
17
501
502
18d
18b
10
12
15
0
16
14
A
18a
6
2
3a
5
300a
33a
514a
513a
27a
22b
25b
26a
28a
21b
30a
515a
3b
23b
300b
503
22a
33b
25a
514b
513b
27b
34b
21a
26b
28b
24b
30b
515b
23a
504
24a
300c
3c
33c
514c
513c
27c
30c
515c
200
4
B
26c
28c
300d
3d
34d
33d
514d
513d
30d
515d

FIG. 8

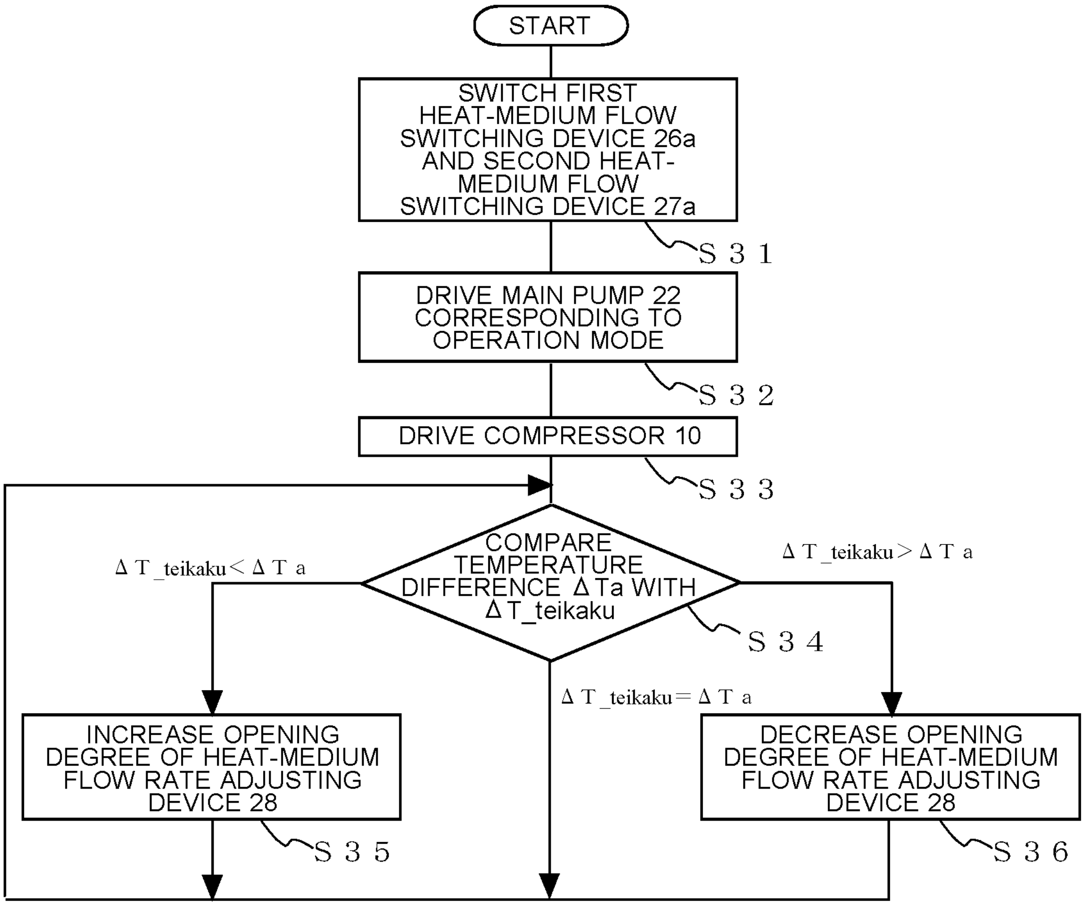
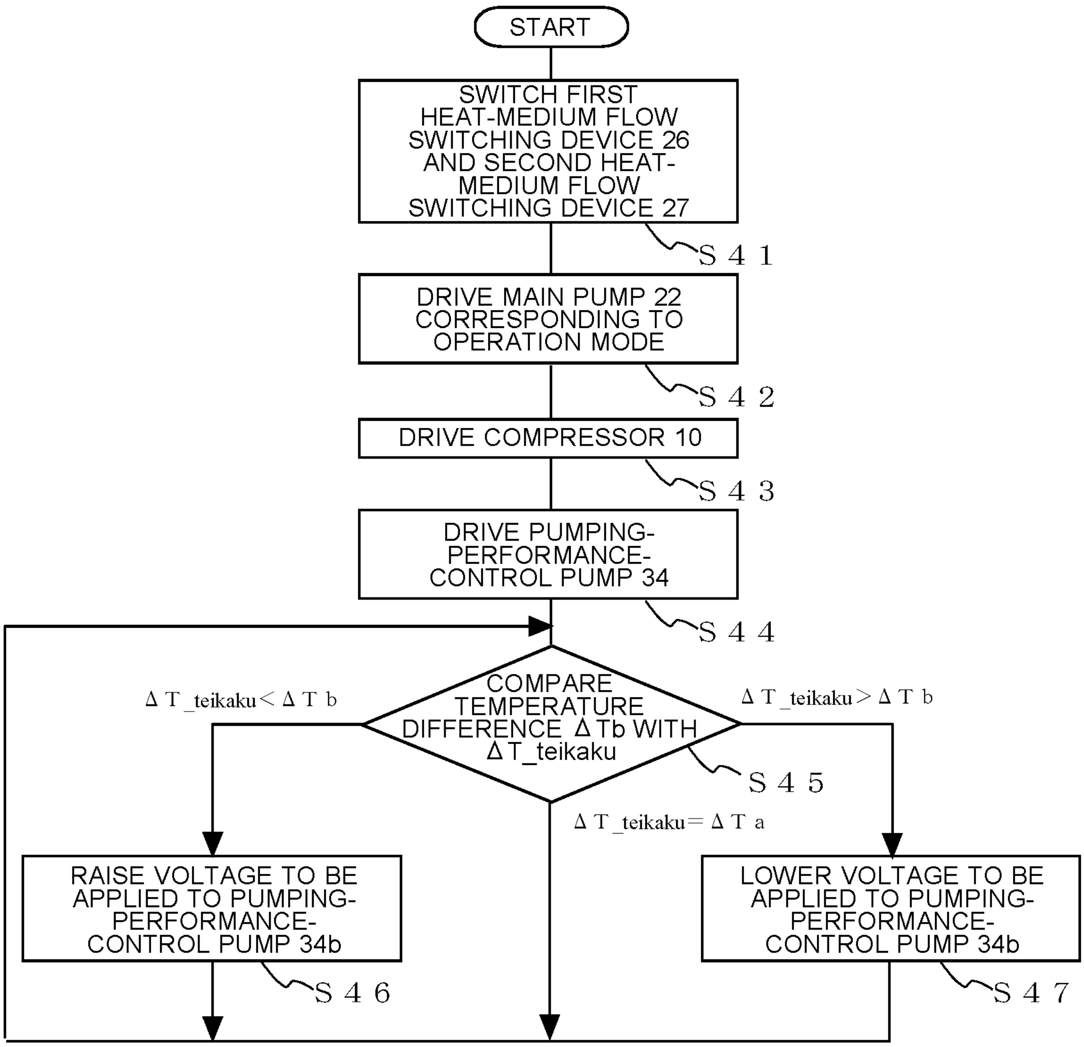

START
SWITCH FIRST HEAT-MEDIUM FLOW SWITCHING DEVICE 26a AND SECOND HEAT-MEDIUM FLOW SWITCHING DEVICE 27a
S31
DRIVE MAIN PUMP 22 CORRESPONDING TO OPERATION MODE
S32
DRIVE COMPRESSOR 10
S33
COMPARE TEMPERATURE DIFFERENCE ΔTa WITH ΔT_teikaku
S34
ΔT_teikaku<ΔTa
ΔT_teikaku>ΔTa
ΔT_teikaku=ΔTa
INCREASE OPENING DEGREE OF HEAT-MEDIUM FLOW RATE ADJUSTING DEVICE 28
S35
DECREASE OPENING DEGREE OF HEAT-MEDIUM FLOW RATE ADJUSTING DEVICE 28
S36

FIG. 9


START
SWITCH FIRST HEAT-MEDIUM FLOW SWITCHING DEVICE 26 AND SECOND HEAT-MEDIUM FLOW SWITCHING DEVICE 27
S41
DRIVE MAIN PUMP 22 CORRESPONDING TO OPERATION MODE
S42
DRIVE COMPRESSOR 10
S43
DRIVE PUMPING-PERFORMANCE-CONTROL PUMP 34
S44
COMPARE TEMPERATURE DIFFERENCE ΔTb WITH ΔT_teikaku
S45
ΔT_teikaku < ΔTb
ΔT_teikaku > ΔTb
ΔT_teikaku = ΔTa
RAISE VOLTAGE TO BE APPLIED TO PUMPING-PERFORMANCE-CONTROL PUMP 34b
S46
LOWER VOLTAGE TO BE APPLIED TO PUMPING-PERFORMANCE-CONTROL PUMP 34b
S47

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/021843

A. CLASSIFICATION OF SUBJECT MATTER
F24F 5/00(2006.01)i; F24F 11/85(2018.01)i
FI: F24F5/00 101Z; F24F11/85
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)
F24F5/00; F24F11/00-11/89

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2011-2180 A (TOYO NETSU KOGYO KK) 06 January 2011 (2011-01-06) paragraphs [0018]-[0030], fig. 1-8	1 2-8
Y	JP 2021-46952 A (TOSHIBA CARRIER CORP) 25 March 2021 (2021-03-25) paragraph [0054], fig. 3	2-8
Y	JP 57-124645 A (YAMATAKE HONEYWELL KK) 03 August 1982 (1982-08-03) page 1, lower left column, lines 5-9, page 2, upper left column, line 5 to upper right column, line 2, fig. 2	5-8
Y	JP 2010-112699 A (SANKI ENG CO LTD) 20 May 2010 (2010-05-20) paragraph [0035], fig. 1-4	6, 8
Y	JP 2021-46953 A (TOSHIBA CARRIER CORP) 25 March 2021 (2021-03-25) paragraphs [0039], [0060]	7-8

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 August 2021 (20.08.2021)	31 August 2021 (31.08.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application no.
PCT/JP2021/021843

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2011-2180 A	06 Jan. 2011	(Family: none)	
JP 2021-46952 A	25 Mar. 2021	(Family: none)	
JP 57-124645 A	03 Aug. 1982	(Family: none)	
JP 2010-112699 A	20 May 2010	(Family: none)	
JP 2021-46953 A	25 Mar. 2021	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2017053507 A **[0003]**