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FIG. 1

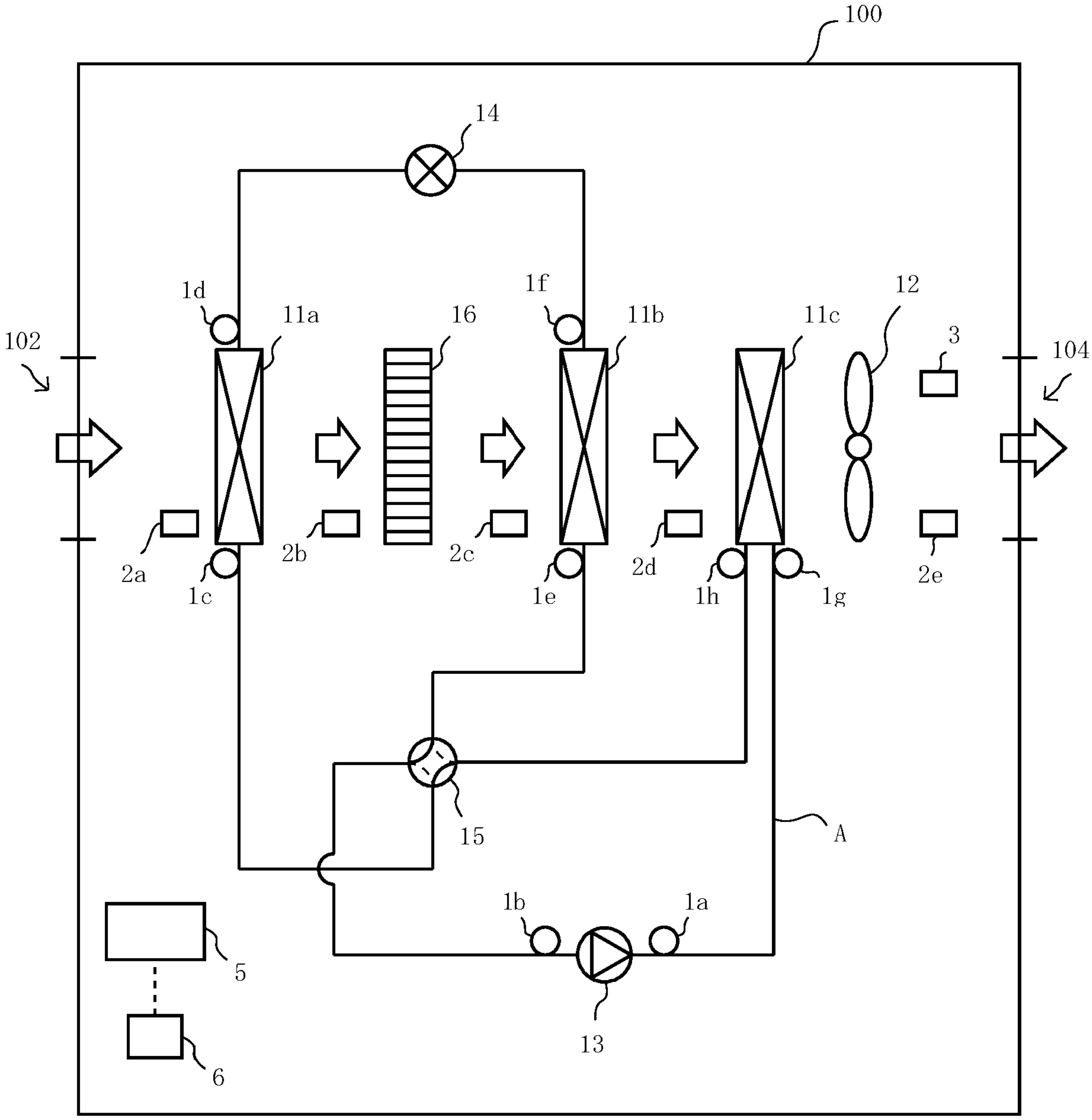

100
14
1d
11a
16
1f
11b
11c
12
3
102
104
2a
2b
2c
2d
2e
1c
1e
1h
1g
15
A
1b
1a
5
13
6

FIG. 2

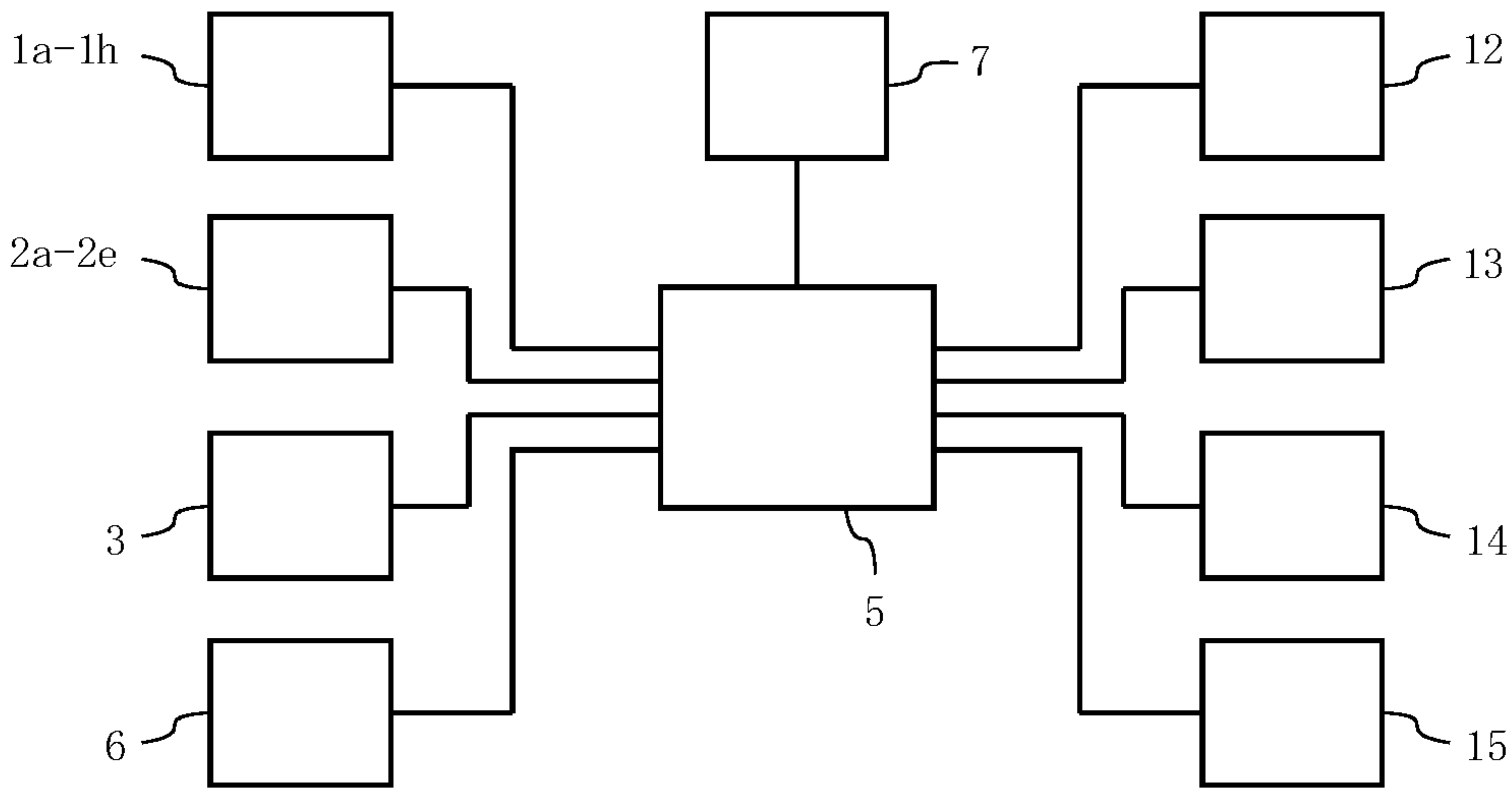

1a-1h
2a-2e
3
6
7
5
12
13
14
15

FIG. 3

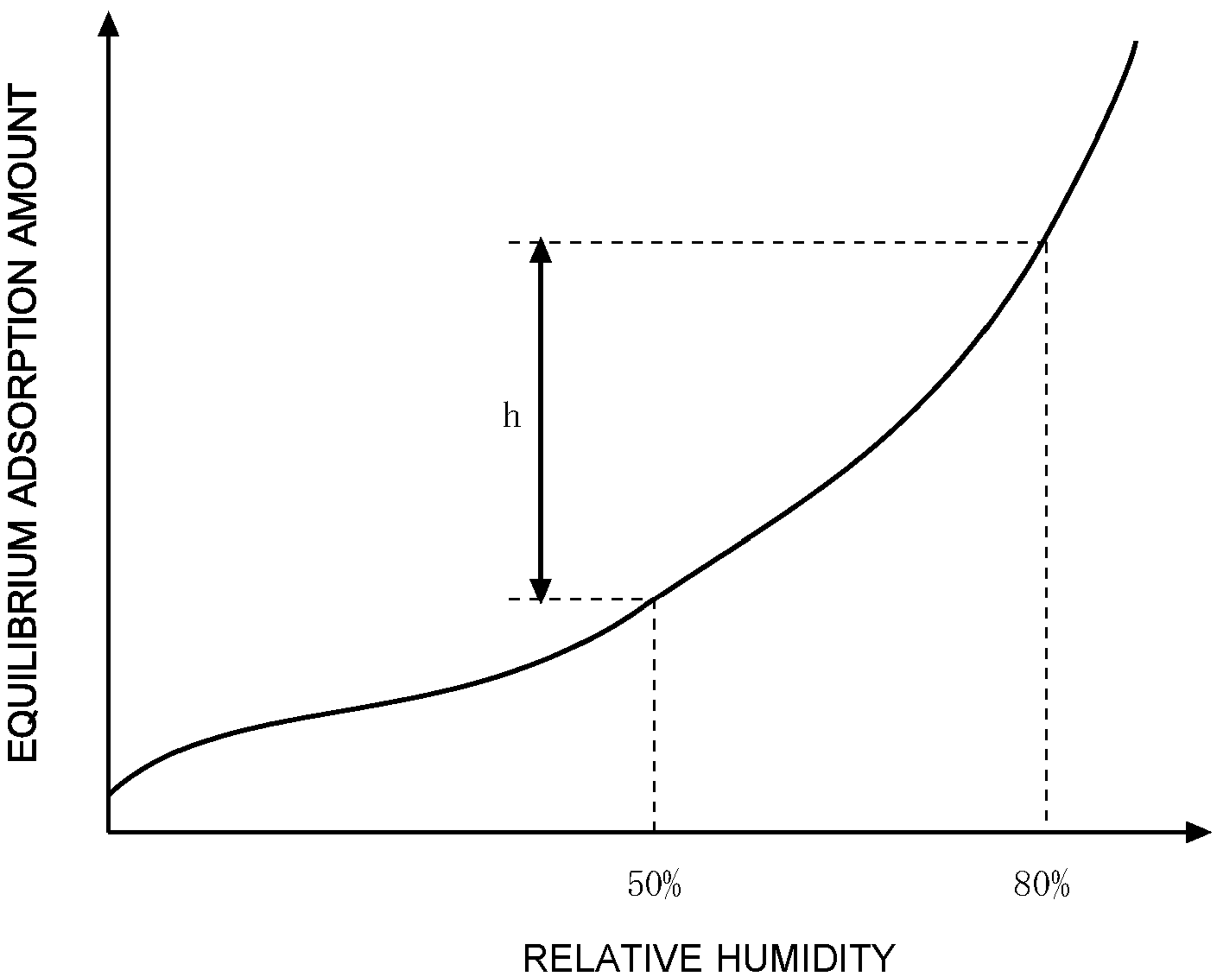

EQUILIBRIUM ADSORPTION AMOUNT
h
50%
80%
RELATIVE HUMIDITY

FIG. 4

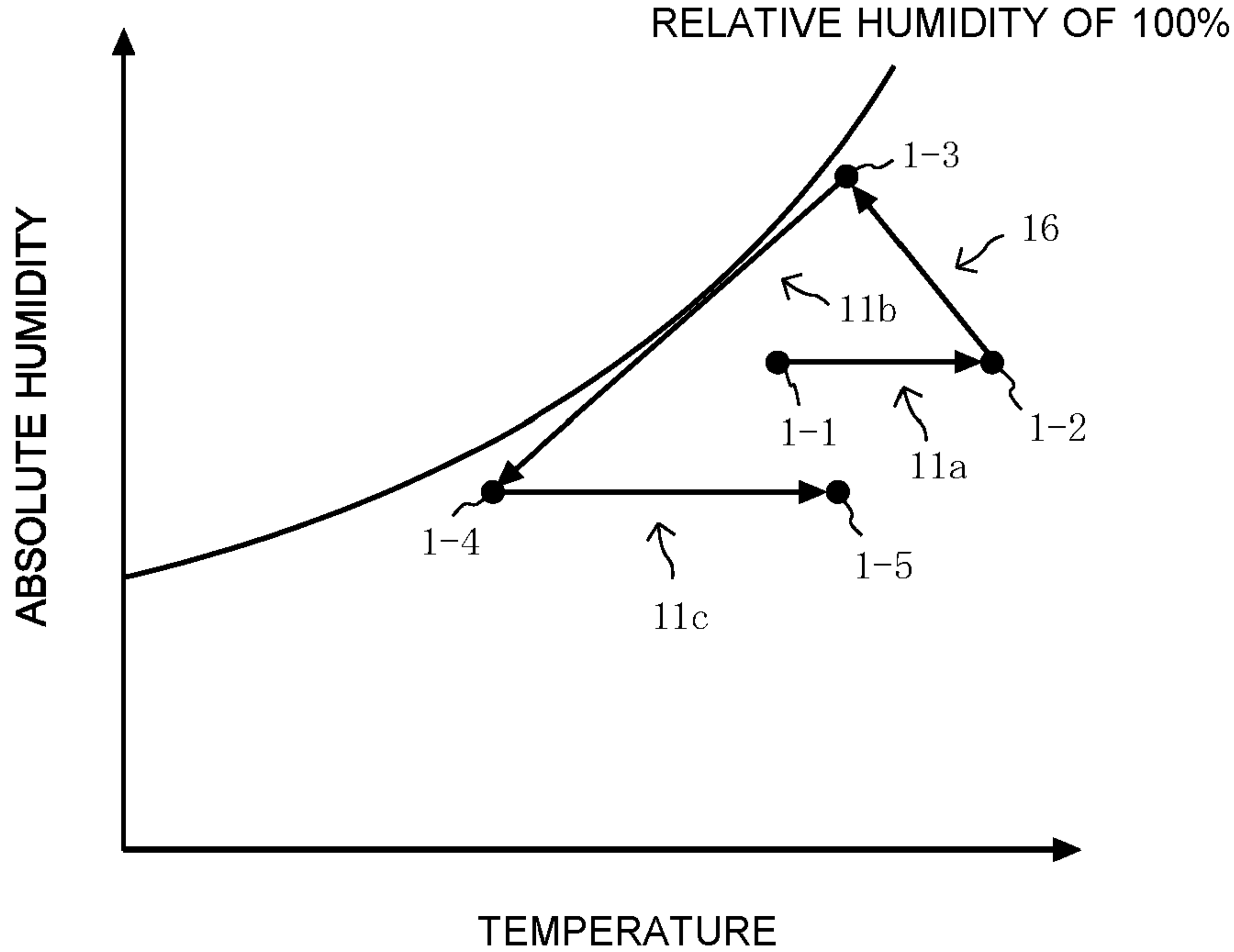

RELATIVE HUMIDITY OF 100%
ABSOLUTE HUMIDITY
TEMPERATURE
1-1
1-2
1-3
1-4
1-5
11a
11b
11c
16

FIG. 5

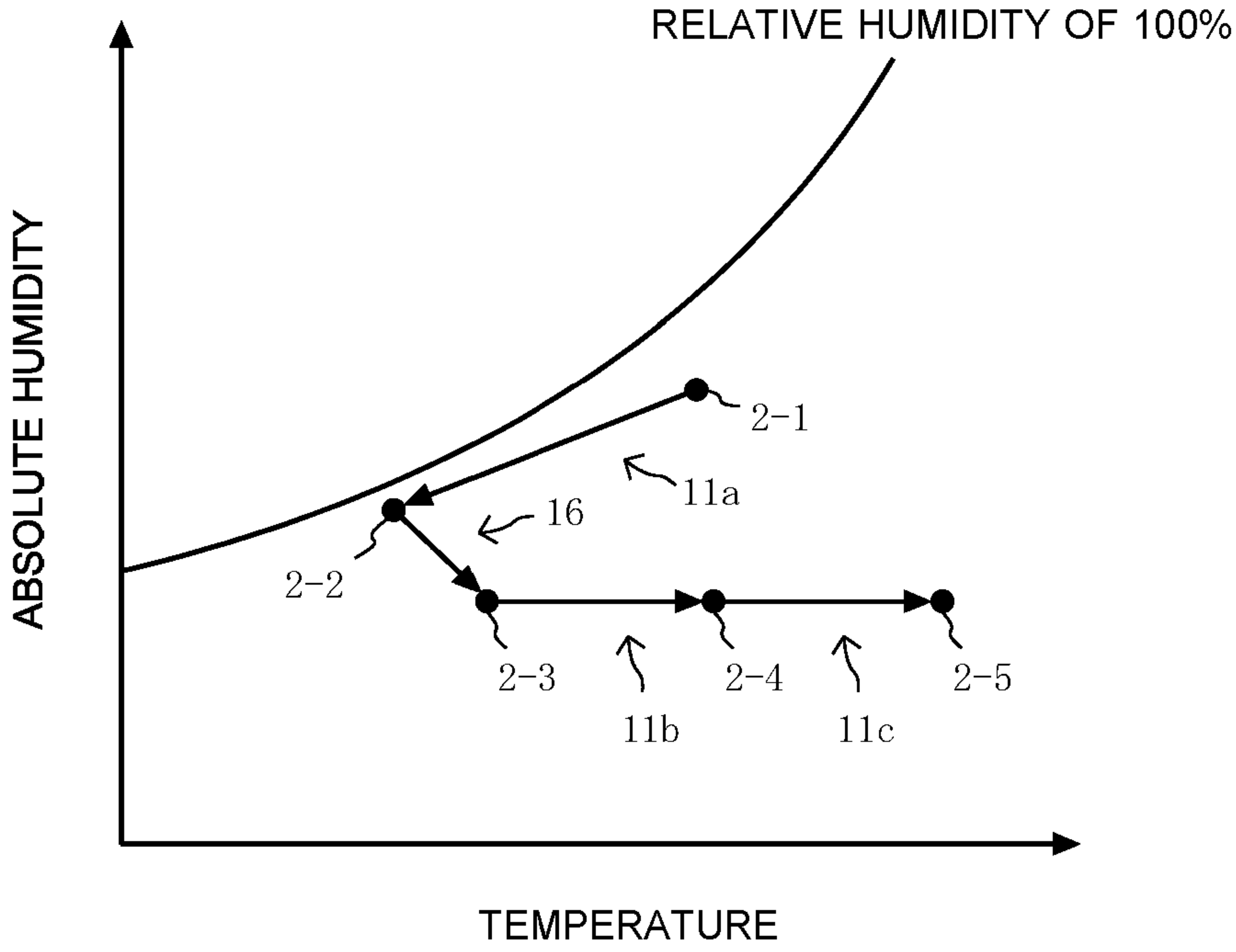

RELATIVE HUMIDITY OF 100%
ABSOLUTE HUMIDITY
TEMPERATURE
2-1
2-2
2-3
2-4
2-5
11a
11b
11c
16

FIG. 6

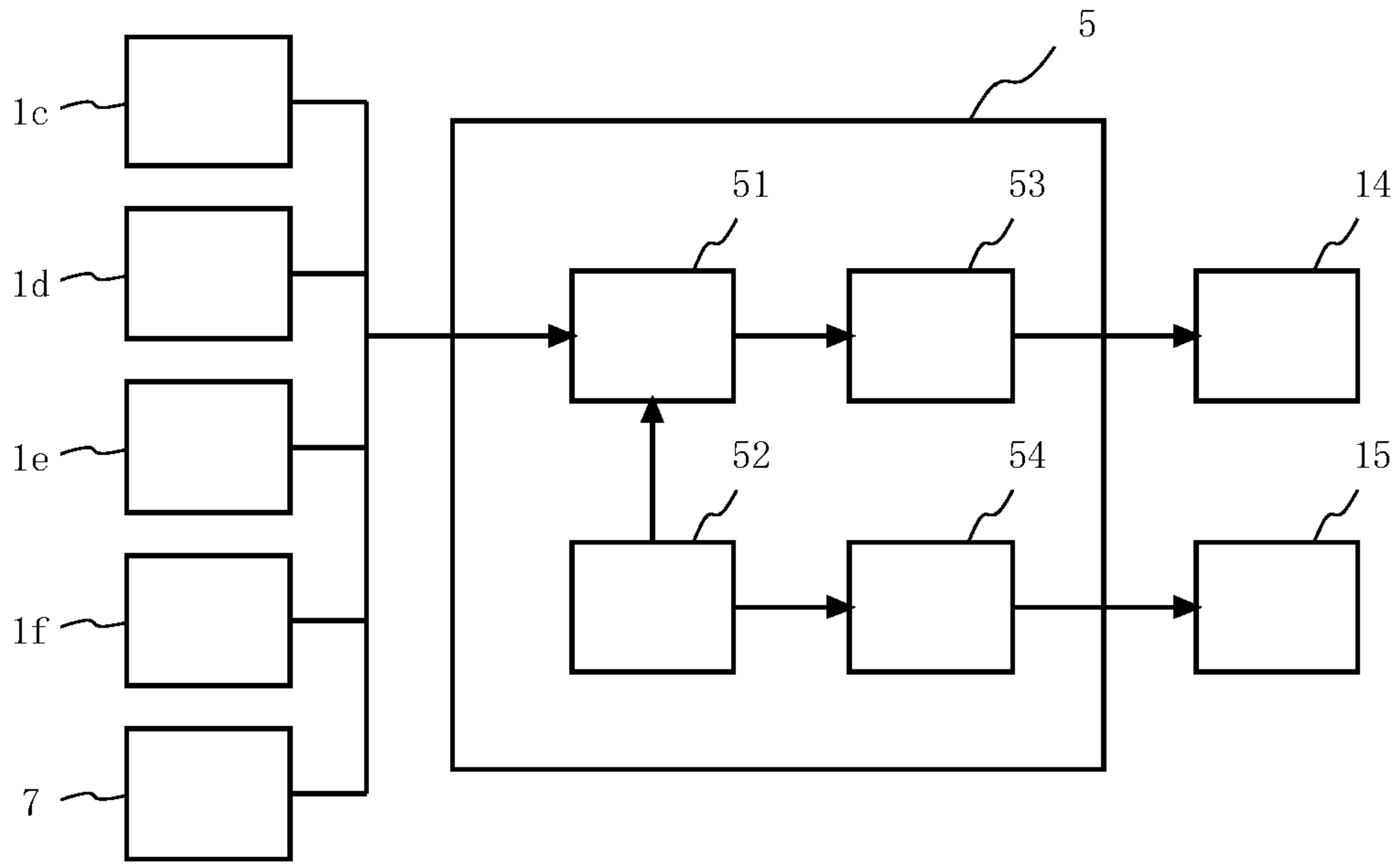
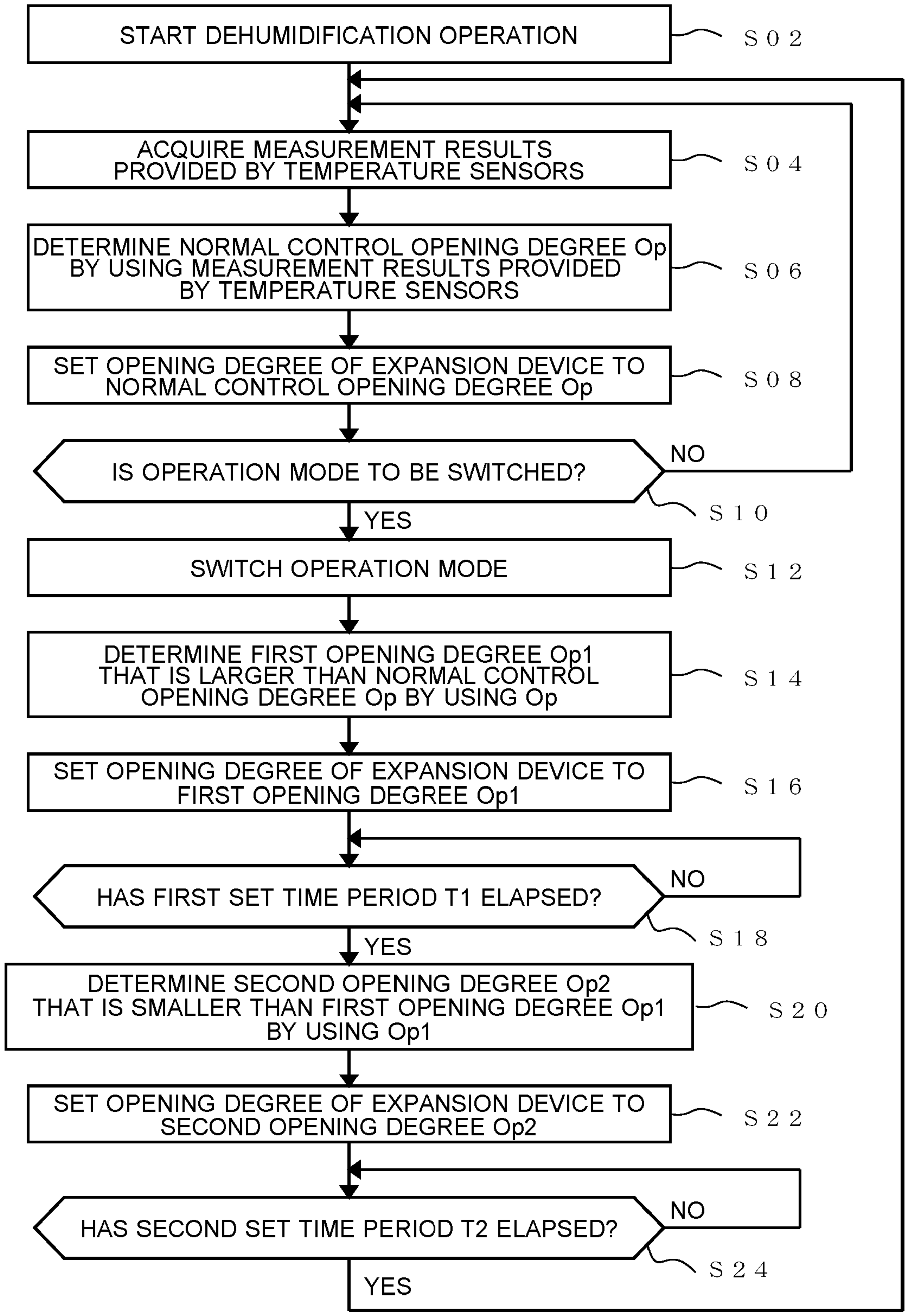


FIG. 7


START DEHUMIDIFICATION OPERATION
S02
ACQUIRE MEASUREMENT RESULTS PROVIDED BY TEMPERATURE SENSORS
S04
DETERMINE NORMAL CONTROL OPENING DEGREE Op BY USING MEASUREMENT RESULTS PROVIDED BY TEMPERATURE SENSORS
S06
SET OPENING DEGREE OF EXPANSION DEVICE TO NORMAL CONTROL OPENING DEGREE Op
S08
IS OPERATION MODE TO BE SWITCHED?
NO
S10
YES
SWITCH OPERATION MODE
S12
DETERMINE FIRST OPENING DEGREE Op1 THAT IS LARGER THAN NORMAL CONTROL OPENING DEGREE Op BY USING Op
S14
SET OPENING DEGREE OF EXPANSION DEVICE TO FIRST OPENING DEGREE Op1
S16
HAS FIRST SET TIME PERIOD T1 ELAPSED?
NO
S18
YES
DETERMINE SECOND OPENING DEGREE Op2 THAT IS SMALLER THAN FIRST OPENING DEGREE Op1 BY USING Op1
S20
SET OPENING DEGREE OF EXPANSION DEVICE TO SECOND OPENING DEGREE Op2
S22
HAS SECOND SET TIME PERIOD T2 ELAPSED?
NO
S24
YES

DESCRIPTION

Title of Invention

DEHUMIDIFICATION APPARATUS

Technical Field

[0001]

The present invention relates to a dehumidification apparatus including a refrigerant circuit and a moisture adsorption unit.

Background Art

[0002]

There are existing dehumidification apparatuses including a refrigerant circuit through which refrigerant circulates and a moisture adsorption unit that adsorbs and desorbs moisture (for example, see Patent Literature 1). An existing dehumidification apparatus described in Patent Literature 1 alternately switches a first operation mode in which moisture adsorbed by a moisture adsorption unit is desorbed and a second operation mode in which the moisture adsorption unit adsorbs moisture contained in the air to thus perform dehumidification operation.

Citation List

Patent Literature

[0003]

Patent Literature 1: Japanese Patent No. 5452565

Summary of Invention

Technical Problem

[0004]

In dehumidification apparatuses, to obtain high dehumidifying effect is a major challenge, and further improvements are desired.

[0005]

The present invention has been accomplished against a backdrop of the above-described challenge to obtain a dehumidification apparatus that is improved in dehumidifying effect.

Solution to Problem

[0006]

A dehumidification apparatus according to an embodiment of the present invention includes a refrigerant circuit in which a compressor, a flow switching device, a first heat exchanger, an expansion device, and a second heat exchanger are connected with refrigerant pipes, an air passage in which the first heat exchanger, a moisture adsorption unit configured to adsorb and desorb moisture, and the second heat exchanger are sequentially disposed, an air-sending device configured to send air in a space to be dehumidified to the first heat exchanger, the moisture adsorption unit, and the second heat exchanger in sequence, and a controller configured to perform dehumidification operation including a first operation mode in which the first heat exchanger acts as a condenser or a radiator, the second heat exchanger acts as an evaporator, and moisture held in the moisture adsorption unit is desorbed, and a second operation mode in which the first heat exchanger acts as an evaporator, the second heat exchanger acts as a condenser or a radiator, and the moisture adsorption unit is configured to absorb moisture from air that passes through the air passage. The first operation mode and the second operation mode are alternately switched by flow switching by the flow switching device. When an operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode, the controller is configured to set an opening degree of the expansion device to a first opening degree that is larger than a normal control opening degree of time before the operation mode is switched, and cause the refrigerant circuit to operate for a first set time period that is predetermined. After the first set time period elapses, the controller is configured to set the opening degree of the expansion device to a second opening degree that is smaller than the first opening degree, and cause the refrigerant circuit to operate for a second set time period that is predetermined.

[0007]

A dehumidification apparatus according to an embodiment of the present invention includes a refrigerant circuit in which a compressor, a flow switching device, a first heat exchanger, an expansion device, a second heat exchanger, and a third heat exchanger are connected with refrigerant pipes, an air passage in which the first heat exchanger, a moisture adsorption unit configured to adsorb and desorb moisture, and the second heat exchanger are sequentially disposed, and an air-sending device configured to send air in a space to be dehumidified to the first heat exchanger, the moisture adsorption unit, and the second heat exchanger in sequence. The third heat exchanger is disposed between a discharge side of the compressor and the flow switching device in the refrigerant circuit. A first operation mode in which the third heat exchanger and the first heat exchanger each act as a condenser or a radiator, the second heat exchanger acts as an evaporator, and moisture held in the moisture adsorption unit is desorbed, and a second operation mode in which the first heat exchanger acts as an evaporator, the third heat exchanger and the second heat exchanger each act as a condenser or a radiator, and the moisture adsorption unit is configured to absorb moisture from air that passes through the air passage are alternately switched by flow switching by the flow switching device.

Advantageous Effects of Invention

[0008]

An embodiment of the present invention can stabilize operation of the refrigerant circuit quickly after the operation mode is switched, therefore enabling the moisture adsorption unit to adsorb and desorb moisture efficiently. Thus, in an embodiment of the present invention, a dehumidification apparatus that is improved in dehumidifying effect is obtained.

Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 schematically illustrates an example of the configuration of a dehumidification apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 illustrates a controller illustrated in Fig. 1.

[Fig. 3] Fig. 3 illustrates an example of the relationship between the adsorption amount of a moisture adsorption unit illustrated in Fig. 1 and relative humidity.

[Fig. 4] Fig. 4 illustrates an example of changes in the state of air in a first operation mode of the dehumidification apparatus illustrated in Fig. 1.

[Fig. 5] Fig. 5 illustrates an example of changes in the state of air in a second operation mode of the dehumidification apparatus illustrated in Fig. 1.

[Fig. 6] Fig. 6 schematically illustrates an example of the configuration of the controller illustrated in Fig. 1.

[Fig. 7] Fig. 7 illustrates an example of operation of the dehumidification apparatus illustrated in Fig. 1.

Description of Embodiments

[0010]

Embodiment of the present invention will be described below with reference to the drawings. In figures, elements that are the same or correspond to one another are denoted by the same reference signs, and descriptions of the elements are appropriately omitted or simplified. Aspects of elements illustrated in each figure, such as its shape, its size, and its location may be appropriately changed within the scope of the present invention.

[0011]

Embodiment 1

[Dehumidification Apparatus]

Fig. 1 schematically illustrates an example of the configuration of a dehumidification apparatus according to Embodiment 1 of the present invention. Fig. 2 illustrates a controller illustrated in Fig. 1. A dehumidification apparatus 100 illustrated in Fig. 1 is installed, for example, in the interior of a room, and dehumidifies the interior. The dehumidification apparatus 100 includes a refrigerant circuit A and a moisture adsorption unit 16.

[0012]

<Refrigerant Circuit>

The refrigerant circuit A is formed of a compressor 13, a third heat exchanger 11c, a flow switching device 15, a first heat exchanger 11a, an expansion device 14, and a second heat exchanger 11b that are sequentially connected with refrigerant pipes, and refrigerant circulates through the refrigerant circuit A.

[0013]

(Refrigerant)

A refrigerant used in the refrigerant circuit A according to Embodiment is, for example, an HFC-series refrigerant, such as R410A, R407C, R404A, and R134a. A refrigerant used in the refrigerant circuit A according to Embodiment may be an HCFC-series refrigerant, such as R22, or may be a natural refrigerant, such as hydrocarbon and helium. For example, when a CO_2 refrigerant is used, in the case of operation under high pressure that is higher than or equal to a critical pressure, a condenser acts as a radiator.

[0014]

(Compressor)

The compressor 13 sucks and compresses refrigerant to bring it into a high-temperature high-pressure state and discharges the refrigerant. The compressor 13 is, for example, an inverter compressor in which control is performed by an inverter, and the capacity (the flow rate of refrigerant delivered per unit time) can be changed by changing an operating frequency to any operating frequency. Although one compressor 13 is illustrated in the example of Fig. 1, the dehumidification apparatus 100 in the example of Embodiment may include, for example, two or more compressors connected in parallel or in series.

[0015]

(First Heat Exchanger, Second Heat Exchanger, Third Heat Exchanger)

The first heat exchanger 11a, the second heat exchanger 11b, and the third heat exchanger 11c each cause refrigerant to exchange heat with air. The first heat exchanger 11a, the second heat exchanger 11b, and the third heat exchanger 11c are each, for example, a fin-and-tube type heat exchanger including heat-transfer tubes through which refrigerant flows and many fins attached to the heat-transfer tubes. The first heat exchanger 11a, the expansion device 14, and the second heat exchanger 11b are connected in series. The third heat exchanger 11c is disposed between a discharge side of the compressor 13 and the flow switching device 15. That is, one side of the third heat exchanger 11c is connected to the discharge side of the compressor 13, and the other side is connected to the flow switching device 15.

[0016]

(Expansion Device)

The expansion device 14 reduces the pressure of refrigerant, and the expansion device 14 is, for example, an electronic expansion valve whose opening degree can be regulated with a stepping motor. When the opening degree of the expansion device 14 is regulated, a flow rate of refrigerant that flows in the refrigerant circuit A is regulated. The expansion device 14 may be a mechanical expansion valve using a diaphragm device for a pressure receiving portion, or may be a capillary tube. The expansion device 14 is disposed between the first heat exchanger 11a and the second heat exchanger 11b. That is, one side of the expansion device 14 is connected to the first heat exchanger 11a, and the other side is connected to the second heat exchanger 11b.

[0017]

(Flow Switching Device)

The flow switching device 15 switches directions of the flow of refrigerant that flows in the refrigerant circuit A by switching flow paths to a solid line state or a dashed line state as illustrated in Fig. 1, and the flow switching device 15 is composed of a four-way valve, for example. Also, the flow switching device 15 can be composed of a combination of a plurality of two-way valves, for example. The flow switching device 15 is connected to a side of the first heat exchanger 11a to which the expansion device 14 is not connected, a side of the second heat exchanger 11b to which the expansion device 14 is not connected, a side of the third heat exchanger 11c to which the discharge side of the compressor 13 is not connected, and a suction side of the compressor 13. When the flow switching device 15 is switched to the solid line state, the flow switching device 15 causes the side of the third heat exchanger 11c to which the discharge side of the compressor 13 is not connected to communicate with the side of the first heat exchanger 11a to which the expansion device 14 is not connected, and causes the side of the second heat exchanger 11b to which the expansion device 14 is not connected to communicate with the suction side of the compressor 13. Furthermore, when the flow switching device 15 is switched to the dashed line state, the flow switching device 15 causes the side of the third heat exchanger 11c to which the discharge side of the compressor 13 is not connected to communicate with the side of the second heat exchanger 11b to which the expansion device 14 is not connected, and causes the side of the first heat exchanger 11a to which the expansion device 14 is not connected to communicate with the suction side of the compressor 13.

[0018]

<Moisture Adsorption Unit>

The moisture adsorption unit 16 adsorbs and desorbs moisture contained in air. The moisture adsorption unit 16 is formed of, for example, a porous material through which air can pass, and an adsorbent that covers the surface of the porous material. The adsorbent is attached to the surface of the porous material by, for example, coating, surface treatment, an impregnation process, or other methods. As the adsorbent, a substance, such as zeolite, silica gel, and activated charcoal, having a function of absorbing moisture from air with relatively high humidity and releasing moisture to air with relatively low humidity is used.

[0019]

The moisture adsorption unit 16 is disposed in an air passage between the first heat exchanger 11a and the second heat exchanger 11b. The air passage will be described later. The moisture adsorption unit 16 has a cross-sectional shape that is substantially the same as, for example, a cross-sectional shape of the air passage so that the cross-sectional area of the moisture adsorption unit 16 is larger than the cross-sectional area of the air passage. The moisture adsorption unit 16 is a plate-shaped unit having, for example, a quadrangular cross-sectional shape, but may be a plate-shaped unit having, for example, a polygonal or circular cross-sectional shape other than the quadrangular cross-sectional shape. Air that passes through the air passage passes through the moisture adsorption unit 16 in the thickness direction of the moisture adsorption unit 16, for example.

[0020]

<Air Passage>

The dehumidification apparatus 100 includes an air passage between an air inlet 102 that sucks air in the interior, which is a space to be dehumidified, and an air outlet 104 that discharges dehumidified air obtained by dehumidifying the air sucked from the air inlet 102. As indicated by arrows in Fig. 1, the air passage is formed so that air sucked from the air inlet 102 is caused to pass through the first heat exchanger 11a, the moisture adsorption unit 16, the second heat exchanger 11b, and the third heat exchanger 11c in sequence and is discharged from the air outlet 104.

[0021]

The dehumidification apparatus 100 further includes temperature sensors 1a to 1h, temperature-humidity sensors 2a to 2e, a wind velocity sensor 3, a controller 5, an input device 6, and an air-sending device 12.

[0022]

(Air-Sending Device)

The air-sending device 12 is disposed in the air passage of the dehumidification apparatus 100, and produces an air flow so that air is sucked from the air inlet 102, the sucked air is caused to pass through the air passage, and the air having passed through the air passage is discharged from the air outlet 104. When the air-sending device 12 operates, air sucked from the air inlet 102 passes through the first heat exchanger 11a, the moisture adsorption unit 16, the second heat exchanger 11b, and the third heat exchanger 11c in sequence, and is discharged from the air outlet 104. The air-sending device 12 is composed of, for example, a motor, such as a DC fan motor, and a fan, such as a centrifugal fan and a multi-blade fan, attached to the motor, and can regulate air flow rate. The air-sending device 12 may be, for example, a device that includes an AC fan motor and provides a constant air flow rate. Although, in the example of Fig. 1, the air-sending device 12 is disposed downstream of the third heat exchanger 11c, that is, most downstream of the air passage, the position where the air-sending device 12 is disposed is not limited to particular positions. For example, the air-sending device 12 may be disposed upstream of the first heat exchanger 11a, that is, most upstream of the air passage.

[0023]

(Temperature Sensor)

The temperature sensors 1a to 1h each measure a temperature of refrigerant that flows in the refrigerant circuit A. The temperature sensor 1a measures a temperature of the refrigerant on the discharge side of the compressor 13. The temperature sensor 1b measures a temperature of the refrigerant on the suction side of the compressor 13. The temperature sensor 1c and the temperature sensor 1d measure a temperature of the refrigerant that flows into the first heat exchanger 11a or a temperature of the refrigerant that flows out of the first heat exchanger 11a. The temperature sensor 1e and the temperature sensor 1f measure a temperature of the refrigerant that flows into the second heat exchanger 11b or a temperature of the refrigerant that flows out of the second heat exchanger 11b. The temperature sensor 1g and the temperature sensor 1h measure a temperature of the refrigerant that flows into the third heat exchanger 11c or a temperature of the refrigerant that flows out of the third heat exchanger 11c.

[0024]

(Temperature-humidity Sensor)

The temperature-humidity sensors 2a to 2e each measure a temperature and a humidity of air that passes through the air passage. The temperature-humidity sensor 2a measures a temperature and a humidity of air before the air passes through the first heat exchanger 11a after flowing into the dehumidification apparatus 100 from the interior, which is a space to be dehumidified. The temperature-humidity sensor 2b measures a temperature and a humidity of the air after the air passes through the first heat exchanger 11a and before the air passes through the moisture adsorption unit 16. The temperature-humidity sensor 2c measures a temperature and a humidity of the air after the air passes through the moisture adsorption unit 16 and before the air passes through the second heat exchanger 11b. The temperature-humidity sensor 2d measures a temperature and a humidity of the air after the air passes through the second heat exchanger 11b and before the air passes through the third heat exchanger 11c. The temperature-humidity sensor 2e measures a temperature and a humidity of the air having passed through the third heat exchanger 11c.

[0025]

(Wind Velocity Sensor)

The wind velocity sensor 3 measures a velocity of air passing through the air passage. Although, in the example of Fig. 1, the wind velocity sensor 3 is disposed downstream of the third heat exchanger 11c, that is, most downstream of the air passage, the position where the wind velocity sensor 3 is disposed is not limited to particular positions. For example, the wind velocity sensor 3 may be disposed at any position where a velocity of air passing through the air passage can be measured, and may be disposed upstream of the first heat exchanger 11a, that is, most upstream of the air passage.

[0026]

(Input Device)

The input device 6 is a device to which an instruction to the dehumidification apparatus 100 is input, and the input device 6 is a sensor that receives a signal from a remote controller, which is not illustrated, for example. For example, the user can provide instructions to start and stop dehumidification operation, instructions on the intensity of dehumidification, and other instructions by using the remote controller, which is not illustrated. An instruction input to the input device 6 is input to the controller 5.

[0027]

(Controller)

The controller 5 controls the entire dehumidification apparatus 100, and includes, for example, hardware, such as an analog circuit and a digital circuit, or software, such as a program, executed by an arithmetic unit, such as a microcomputer and a CPU. As illustrated in Fig. 2, the controller 5 acquires, for example, measurement results provided by the temperature sensors 1a to 1h, measurement results provided by the temperature-humidity sensors 2a to 2e, a measurement result provided by the wind velocity sensor 3, an instruction input to the input device 6, and information stored in a storage unit 7, and controls the air-sending device 12, the compressor 13, the expansion device 14, the flow switching device 15, and other elements by using the acquired measurement results, instruction, and information, for example. The storage unit 7 includes, for example, a non-volatile memory, and stores a program for controlling the dehumidification apparatus 100, and information, such as parameters for controlling the dehumidification apparatus 100.

[0028]

Fig. 3 illustrates an example of the relationship between the adsorption amount of the moisture adsorption unit illustrated in Fig. 1 and relative humidity. In Fig. 3, the horizontal axis represents the relative humidity of air flowing into the moisture adsorption unit 16, and the vertical axis represents the equilibrium adsorption amount of the moisture adsorption unit 16, that is, the amount of moisture that can be adsorbed by the adsorbent of the moisture adsorption unit 16. As illustrated in Fig. 3, the equilibrium adsorption amount of the moisture adsorption unit 16 varies depending on the relative humidity of air flowing into the moisture adsorption unit 16. That is, when the relative humidity of air flowing into the moisture adsorption unit 16 is high, moisture adsorbed by the moisture adsorption unit 16 is not easily released, and the amount of moisture that can be adsorbed by the moisture adsorption unit 16 is large. On the other hand, when the relative humidity of air flowing into the moisture adsorption unit 16 is low, moisture adsorbed by the moisture adsorption unit 16 is easily released, and the amount of moisture that can be adsorbed by the moisture adsorption unit 16 is small.

[0029]

In the example of Embodiment, for example, the moisture adsorption unit 16 is used in which the difference between an equilibrium adsorption amount when the relative humidity of air flowing into the moisture adsorption unit 16 is not less than 80% and an equilibrium adsorption amount when the relative humidity of air flowing into the moisture adsorption unit 16 ranges from 40 to 60% is large. That is, the adsorbent used in the moisture adsorption unit 16 is an adsorbent in which the difference between an equilibrium adsorption amount when the relative humidity of air flowing into the moisture adsorption unit 16 is not less than 80% and an equilibrium adsorption amount when the relative humidity of air flowing into the moisture adsorption unit 16 ranges from 40 to 60% is large. The use of the moisture adsorption unit 16 in which the difference between an equilibrium adsorption amount at high humidity and an equilibrium adsorption amount at low humidity is large improves adsorption capacity and desorption capacity of the moisture adsorption unit 16. In Fig. 3, h denotes the difference between an equilibrium adsorption amount at a relative humidity of 80% and an equilibrium adsorption amount at a relative humidity of 50%.

[0030]

[Operation of Dehumidification Apparatus]

Next, one example of operation of the dehumidification apparatus 100 in the example of Embodiment will be described. As described below, the dehumidification apparatus 100 in the example of Embodiment implements a first operation mode and a second operation mode alternately to thereby perform dehumidification operation. Because there is a limit to the amount of moisture that can be adsorbed by the moisture adsorption unit 16, when operation in which the moisture adsorption unit 16 adsorbs moisture contained in air is continuously performed for a long time, moisture is not adsorbed by the moisture adsorption unit 16. Thus, the dehumidification apparatus 100 in the example of Embodiment performs dehumidification operation in which an operation mode in which moisture held in the moisture adsorption unit 16 is desorbed and an operation mode in which the moisture adsorption unit 16 adsorbs moisture contained in air is alternately switched.

[0031]

<First Operation Mode>

First, the first operation mode will be described. In the first operation mode, moisture held in the moisture adsorption unit 16 is desorbed.

[0032]

(Operation of Refrigerant Circuit in First Operation Mode)

In the first operation mode, the flow switching device 15 is switched to a state indicated by solid lines in Fig. 1. That is, the flow switching device 15 connects the third heat exchanger 11c and the first heat exchanger 11a and also connects the second heat exchanger 11b and the suction side of the compressor 13.

[0033]

Refrigerant is sucked into and compressed by the compressor 13 to turn into high-temperature high-pressure refrigerant, and the high-temperature high-pressure refrigerant flows into the third heat exchanger 11c. The refrigerant having flowed into the third heat exchanger 11c exchanges heat with air to transfer heat to the air, and part of the refrigerant is then condensed and liquefied. The refrigerant having the part condensed and liquefied in the third heat exchanger 11c passes through the flow switching device 15 and flows into the first heat exchanger 11a. The refrigerant having flowed into the first heat exchanger 11a exchanges heat with air to transfer heat to the air, and the refrigerant is then condensed and liquefied, and flows into the expansion device 14. The refrigerant having flowed into the expansion device 14 is reduced in pressure by the expansion device 14 and flows into the second heat exchanger 11b. The refrigerant having flowed into the second heat exchanger 11b exchanges heat with air to receive heat from the air, and then evaporates. The refrigerant having evaporated in the second heat exchanger 11b passes through the flow switching device 15, and is sucked into and compressed by the compressor 13 again.

[0034]

(Changes in State of Air in First Operation Mode)

Fig. 4 illustrates an example of changes in the state of air in the first operation mode of the dehumidification apparatus illustrated in Fig. 1. In Fig. 4, the horizontal axis represents the dry-bulb temperature of air, the vertical axis represents the absolute humidity of air, and a curve represents saturated air, that is, a relative humidity of 100%. Furthermore, in Fig. 4, a point 1-1 represents the state of air sucked into the dehumidification apparatus 100 from the air inlet 102, a point 1-2 represents the state of air having passed through the first heat exchanger 11a, a point

1-3 represents the state of air having passed through the moisture adsorption unit 16, a point 1-4 represents the state of air having passed through the second heat exchanger 11b, and a point 1-5 represents the state of air having passed through the third heat exchanger 11c.

[0035]

Air in a space to be dehumidified that has been sucked into the dehumidification apparatus 100 from the air inlet 102 illustrated in Fig. 1 (point 1-1 in Fig. 4) passes through the first heat exchanger 11a acting as a condenser and is heated by heat exchange with refrigerant to turn into high-temperature low-relative humidity air (point 1-2).

[0036]

The high-temperature low-relative humidity air (point 1-2) having passed through the first heat exchanger 11a passes through the moisture adsorption unit 16 to thereby turn into humidified air (point 1-3). That is, the air that passes through the moisture adsorption unit 16 is air with low relative humidity, for example, relative humidity ranging from 40 to 60% RH, as represented by the point 1-2, and thus the moisture adsorption unit 16 desorbs (releases) moisture contained in the moisture adsorption unit 16. Furthermore, desorption heat caused by desorption of moisture is removed from the air having flowed into the moisture adsorption unit 16, and the air is thereby cooled to change into a point 1-3 state.

[0037]

The air having passed through the moisture adsorption unit 16 (point 1-3) passes through the second heat exchanger 11b acting as an evaporator and is cooled by heat exchange with refrigerant (point 1-4). In the first operation mode, the refrigerant circuit A is operated so that the temperature of refrigerant that flows to the second heat exchanger 11b falls below a dew point temperature of the air having passed through the moisture adsorption unit 16 (point 1-3). When the air having passed through the moisture adsorption unit 16 (point 1-3) passes through the second heat exchanger 11b, the air is cooled and dehumidified to turn into low-temperature high-relative humidity air (point 1-4). The air having passed through the second heat exchanger 11b (point 1-4) passes through the third heat exchanger 11c acting as a condenser, is heated by heat exchange with refrigerant (point 1-5), and is discharged from the air outlet 104 into the space to be dehumidified.

[0038]

<Second Operation Mode>

Next, the second operation mode will be described. In the second operation mode, the moisture adsorption unit 16 adsorbs moisture contained in air.

[0039]

(Operation of Refrigerant Circuit in Second Operation Mode)

In the second operation mode, the flow switching device 15 is switched to a state indicated by dashed lines in Fig. 1. That is, the flow switching device 15 connects the third heat exchanger 11c and the second heat exchanger 11b and also connects the first heat exchanger 11a and the suction side of the compressor 13.

[0040]

Refrigerant is sucked into and compressed by the compressor 13 to turn into high-temperature high-pressure refrigerant, and the high-temperature high-pressure refrigerant flows into the third heat exchanger 11c. The refrigerant having flowed into the third heat exchanger 11c exchanges heat with air to transfer heat to the air, and part of the refrigerant is then condensed and liquefied. The refrigerant having the part condensed and liquefied in the third heat exchanger 11c passes through the flow switching device 15 and flows into the second heat exchanger 11b. The refrigerant having flowed into the second heat exchanger 11b exchanges heat with air to transfer heat to the air, and the refrigerant is then condensed and liquefied, and flows into the expansion device 14. The refrigerant having flowed into the expansion device 14 is reduced in pressure by the expansion device 14 and flows into the first heat exchanger 11a. The refrigerant having flowed into the first heat exchanger 11a exchanges heat with air to receive heat from the air, and then evaporates. The refrigerant having evaporated in the first heat exchanger 11a passes through the flow switching device 15, and is sucked into and compressed by the compressor 13 again.

[0041]

(Changes in State of Air in Second Operation Mode)

Fig. 5 illustrates an example of changes in the state of air in the second operation mode of the dehumidification apparatus illustrated in Fig. 1. In Fig. 5, the horizontal axis represents the dry-bulb temperature of air, the vertical axis represents the absolute humidity of air, and a curve represents saturated air, that is, a relative humidity of 100%. Furthermore, in Fig. 5, a point 2-1 represents the state of air sucked into the dehumidification apparatus 100 from the air inlet 102, a point 2-2 represents the state of air having passed through the first heat exchanger 11a, a point 2-3 represents the state of air having passed through the moisture adsorption unit 16, a point 2-4 represents the state of air having passed through the second heat exchanger 11b, and a point 2-5 represents the state of air having passed through the third heat exchanger 11c.

[0042]

Air in a space to be dehumidified that has been sucked into the dehumidification apparatus 100 from the air inlet 102 illustrated in Fig. 1 (point 2-1 in Fig. 5) passes through the first heat exchanger 11a acting as an evaporator and is cooled by heat exchange with refrigerant (point 2-2). For example, in the second operation mode, the refrigerant circuit A is operated so that the temperature of refrigerant that flows to the first heat exchanger 11a falls below a dew point temperature of the air in the space to be dehumidified (point 2-1). When the air in the space to be dehumidified (point 2-1) passes through the first heat exchanger 11a, the air is cooled and dehumidified to turn into low-temperature high-relative humidity air (point 2-2).

[0043]

The low-temperature high-relative humidity air having passed through the first heat exchanger 11a (point 2-2) passes through the moisture adsorption unit 16 to turn into further dehumidified air (point 2-3). That is, the air that passes through the moisture adsorption unit 16 is air with high relative humidity, for example, relative humidity ranging from 70 to 90% RH, as represented by the point 2-2, and thus the moisture adsorption unit 16 adsorbs moisture contained in the air. The air that passes through the moisture adsorption unit 16 is heated by adsorption heat generated when the moisture adsorption unit 16 adsorbs moisture to change into a point 2-3 state.

[0044]

The air having passed through the moisture adsorption unit 16 passes through the second heat exchanger 11b acting as a condenser and is heated by heat exchange with refrigerant (point 2-4). The air having passed through the second heat exchanger 11b (point 2-4) passes through the third heat exchanger 11c acting as a condenser, is heated by heat exchange with refrigerant (point 2-5), and is discharged from the air outlet 104 into the space to be dehumidified.

[0045]

Incidentally, switching of an operation mode between the first operation mode and the second operation mode is implemented by switching the flow switching device 15 as described above to switch directions in which refrigerant flows in the refrigerant circuit A. Thus, when the operation mode is switched, refrigerant stagnates in a heat exchanger that acts as a condenser before the operation mode is switched and acts as an evaporator before the operation mode is switched, and it therefore takes a long time before distribution of refrigerant in the refrigerant circuit A is adjusted. Consequently, after the operation mode is switched, it takes a long time before operation of the refrigerant circuit A in the switched operation mode is stabilized. Thus, the dehumidification apparatus 100 in the example of Embodiment is configured as follows.

[0046]

[Configuration of Controller]

Fig. 6 schematically illustrates an example of the configuration of the controller illustrated in Fig. 1. As illustrated in Fig. 6, the controller 5 includes an opening degree determination unit 51, an operation mode switching determination unit 52, an expansion device control unit 53, and a flow switching device control unit 54. The opening degree determination unit 51 determines an opening degree of the expansion device 14 by using, for example, measurement results provided by the temperature sensor 1c, the temperature sensor 1d, the temperature sensor 1e, and the temperature sensor 1f, parameters stored in the storage unit 7, and a determination result provided by the operation mode switching determination unit 52. The expansion device control unit 53 controls the expansion device 14 by using information on the opening degree determined by the opening degree determination unit 51.

[0047]

The operation mode switching determination unit 52 determines whether to switch the operation mode from the first operation mode to the second operation mode or to switch the operation mode from the second operation mode to the first operation mode. A determination of whether to switch the operation mode between the first operation mode and the second operation mode is made by using, for example, a temperature difference between the temperature of air before the air passes through the moisture adsorption unit 16 and the temperature of the air having passed through the moisture adsorption unit 16. The determination of whether to switch the first operation mode and the second operation mode is not limited to the above-described example. The determination can be made by using, for example, a time period, a temperature difference between before and after the moisture adsorption unit 16, an absolute humidity difference between before and after the moisture adsorption unit 16, or the amount of change in relative humidity between before and after the moisture adsorption unit 16. Furthermore, the determination of whether to switch the first operation mode and the second operation mode can be made by using, for example, a variation in pressure loss in the air passage. Because the moisture adsorption unit 16 adsorbs moisture and then swells, pressure loss in the air passage varies depending on the amount of moisture adsorbed by the moisture adsorption unit 16. The flow switching device control unit 54 causes the flow switching device 15 to switch flow path by using a determination result provided by the operation mode switching determination unit 52.

[0048]

[Specific Operation of Dehumidification Apparatus]

Fig. 7 illustrates an example of operation of the dehumidification apparatus illustrated in Fig. 1. As illustrated in Fig. 7, for example, when the dehumidification apparatus 100 starts dehumidification operation in step S02, superheat degree control of the refrigerant circuit A is performed in step S04 to step S08. That is, in step S04, the opening degree determination unit 51 illustrated in Fig. 6 acquires measurement results provided by the temperature sensors. In step S06, the opening degree determination unit 51 determines a normal control opening degree Op of the expansion device 14 by using the measurement results provided by the temperature sensors so that a degree of superheat is appropriate. Then, in step S06, the expansion device control unit 53 sets the opening degree of the expansion device 14 to the normal control opening degree Op determined by the opening degree determination unit 51.

For example, in the first operation mode, a degree of superheat (SH) is calculated by using a low-pressure saturation temperature in the refrigerant circuit A that is a temperature measured by the temperature sensor 1f and a temperature at an outlet of the second heat exchanger 11b that is a temperature measured by the temperature sensor 1e. Specifically, in the first operation mode, a degree of superheat is calculated by subtracting a low-pressure saturation temperature in the refrigerant circuit A that is a temperature measured by the temperature sensor 1f from a temperature at the outlet of the second heat exchanger 11b that is a temperature measured by the temperature sensor 1e. Then, for example, it is determined where the calculated degree of superheat is located in or out of an appropriate region around an appropriate value of the degree of superheat, control is performed to increase, reduce, or maintain the opening degree of the expansion device 14, and thus superheat degree control is performed in which the degree of superheat in the refrigerant circuit A falls within an appropriate range.

Furthermore, for example, in the second operation mode, a degree of superheat (SH) is calculated by using a low-pressure saturation temperature in the refrigerant circuit A that is a temperature measured by the temperature sensor 1d and a temperature at an outlet of the first heat exchanger 11a that is a temperature measured by the temperature sensor 1c. Specifically, in the second operation mode, a degree of superheat is calculated by subtracting a low-pressure saturation temperature in the refrigerant circuit A that is a temperature measured by the temperature sensor 1d from a temperature at the outlet of the first heat exchanger 11a that is a temperature measured by the temperature sensor 1c. Then, for example, it is determined where the calculated degree of superheat is located in or out of an appropriate region around an appropriate value of the degree of superheat, control is performed to increase, reduce, or maintain the opening degree of the expansion device 14, and thus superheat degree control is performed in which the degree of superheat in the refrigerant circuit A falls within an appropriate range.

Note that a range in which a degree of superheat is appropriate differs depending on, for example, the configuration of the refrigerant circuit A and is not a fixed value.

[0049]

In step S10 in Fig. 7, the operation mode switching determination unit 52 illustrated in Fig. 6 determines whether to switch the operation mode. When it is determined that the operation mode is not to be switched, the operation flow returns to step S04, and the superheat degree control of the refrigerant circuit A is continued. In step S10, when it is determined that the operation mode is to be switched, the operation flow proceeds to step S12, the flow switching device control unit 54 switches the flow switching device 15, and thus the operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode.

[0050]

In step S14, the opening degree determination unit 51 determines a first opening degree Op1 that is larger than the normal control opening degree Op by using the normal control opening degree Op that is the opening degree of the expansion device 14 of time before the operation mode is switched. Information on a control amount for increasing the opening degree of the expansion device 14 from the normal control opening degree Op to the first opening degree Op1 is predetermined and is stored in the storage unit 7. For example, the first opening degree Op1 is two or more times larger than the normal control opening degree Op and is extremely larger than the normal control opening degree Op. Note that a control amount by which the opening degree of the expansion device 14 is increased from the normal control opening degree Op to the first opening degree Op1 differs depending on, for example, the configuration of the refrigerant circuit A and is not a fixed value. In step S16, the expansion device control unit 53 sets the opening degree of the expansion device 14 to the first opening degree Op1 determined by the opening degree determination unit 51 in step S14. Then, in step S18, the operation flow waits until a first set time period T1 elapses. The first set time period T1 is predetermined and is stored in the storage unit 7. For example, the first set time period T1 is 60 seconds. Note that the first set time period T1 differs depending on, for example, the configuration of the refrigerant circuit A and is not a fixed value. As described above, when the operation mode is switched, the opening degree of the expansion device 14 is set to the first opening degree Op1 that is larger than the normal control opening degree Op of time before the operation mode is switched, the refrigerant circuit A is caused to operate over the first set time period T1, and thus distribution of refrigerant in the refrigerant circuit A is quickly adjusted. This is because, when the opening degree of the expansion device 14 is increased and the refrigerant circuit A is caused to operate, refrigerant stagnating in a heat exchanger that acts as a condenser before the operation mode is switched and acts as an evaporator after the operation mode is switched is quickly circulated through the refrigerant circuit A.

[0051]

When the first set time period T1 elapses in step S18, the opening degree determination unit 51 determines a second opening degree Op2 that is smaller than the first opening degree Op1 by using the first opening degree Op1 in step S20. Information on a control amount for reducing the opening degree of the expansion device 14 from the first opening degree Op1 to the second opening degree Op2 is predetermined and is stored in the storage unit 7. For example, the second opening degree Op2 is one third or less of the first opening degree Op1 and is smaller than the normal control opening degree Op that is the opening degree of the expansion device 14 of time before the operation mode is switched. That is, the second opening degree Op2 is extremely smaller than the first opening degree Op1. Note that a control amount by which the opening degree of the expansion device 14 is reduced from the first opening degree Op1 to the second opening degree Op2 differs depending on, for example, the configuration of the refrigerant circuit A and is not a fixed value. In step S22, the expansion device control unit 53 sets the opening degree of the expansion device 14 to the second opening degree Op2 determined by the opening degree determination unit 51 in step S20. Then, in step S24, the operation flow waits until a second set time period T2 elapses. The second set time period T2 is predetermined and is stored in the storage unit 7. For example, the second set time period T2 is 60 seconds. Note that the second set time period T2 differs depending on, for example, the configuration of the refrigerant circuit A and is not a fixed value. As described above, after the first set time period T1 elapses, the opening degree of the expansion device 14 is set to the second opening degree Op2 that is smaller than the first opening degree Op1, the refrigerant circuit A is caused to operate over the second set time period T2, and thus operation of the refrigerant circuit A can be quickly stabilized.

[0052]

When the second set time period T2 elapses in step S24, the operation flow returns to step S04, and the superheat degree control of the refrigerant circuit A is resumed.

[0053]

As described above, the dehumidification apparatus 100 according to Embodiment includes the refrigerant circuit A in which the compressor 13, the flow switching device 15, the first heat exchanger 11a, the expansion device 14, and the second heat exchanger 11b are connected with the refrigerant pipes, the air passage in which the first heat exchanger 11a, the moisture adsorption unit 16 configured to adsorb and desorb moisture, and the second heat exchanger 11b are sequentially disposed, the air-sending device 12 configured to send air in a space to be dehumidified to the first heat exchanger 11a, the moisture adsorption unit 16, and the second heat exchanger 11b in sequence, and the controller 5 configured to perform dehumidification operation including the first operation mode in which the first heat exchanger 11a acts as a condenser or a radiator, the second heat exchanger 11b acts as an evaporator, and moisture held in the moisture adsorption unit 16 is desorbed, and the second operation mode in which the first heat exchanger 11a acts as an evaporator, the second heat exchanger 11b acts as a condenser or a radiator, and the moisture adsorption unit 16 adsorbs moisture from air that passes through the air passage. The first operation mode and the second operation mode are alternately switched by flow switching by the flow switching device 15. When the operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode, the controller 5 sets the opening degree of the expansion device 14 to the first opening degree Op1 that is larger than the normal control opening degree Op of the expansion device 14 of time before the operation mode is switched, and causes the refrigerant circuit A to operate for the first set time period T1 that is predetermined. After the first set time period T1 elapses, the controller 5 sets the opening degree of the expansion device 14 to the second opening degree Op2 that is smaller than the first opening degree Op1, and causes the refrigerant circuit A to operate for the second set time period T2 that is predetermined.

In the dehumidification apparatus 100 in the example of Embodiment, when the operation mode is switched, the opening degree of the expansion device 14 is set to the first opening degree Op1 that is larger than the normal control opening degree Op of time before the operation mode is switched, the refrigerant circuit A is caused to operate for the first set time period T1, and thus distribution of refrigerant is quickly adjusted. This is because, when the opening degree of the expansion device 14 is increased and the refrigerant circuit A is caused to operate, refrigerant stagnating in a heat exchanger that acts as a condenser before the operation mode is switched and acts as an evaporator after the operation mode is switched can be quickly circulated through the refrigerant circuit A.

Furthermore, in the dehumidification apparatus 100 in the example of Embodiment, after the first set time period T1 elapses, the opening degree of the expansion device 14 is set to the second opening degree Op2 that is smaller than the first opening degree Op1, the refrigerant circuit A is caused to operate for the second set time period T2 that is predetermined, and thus operation of the refrigerant circuit A can be quickly stabilized. For example, when normal control of the expansion device 14 (the above-described superheat degree control) is performed in a first opening degree Op1 state in which the opening degree of the expansion device 14 is large, it takes a long time before the opening degree of the expansion device 14 reaches the normal control opening degree Op and operation of the refrigerant circuit A is stabilized. In the dehumidification apparatus 100 in the example of Embodiment, when the operation mode is switched, the opening degree of the expansion device 14 is set to the first opening degree Op1 that is larger than the normal control opening degree Op, and the refrigerant circuit A is caused to operate over the first set time period T1, and, after the first set time period T1 elapses, the opening degree of the expansion device 14 is set to the second opening degree Op2 that is smaller than the first opening degree Op1, and the refrigerant circuit A is caused to operate over the second set time period T2 that is predetermined, thereby enabling quick stabilization of operation of the refrigerant circuit A.

As described above, the dehumidification apparatus 100 in the example of Embodiment enables quick stabilization of operation of the refrigerant circuit A after the operation mode is switched, and the moisture adsorption unit 16 can therefore efficiently adsorb and desorb moisture. Thus, the dehumidification apparatus 100 in the example of Embodiment is improved in dehumidifying effect.

[0054]

For example, the second opening degree Op2 is configured to be smaller than the normal control opening degree Op of time before the operation mode is switched, and operation of the refrigerant circuit A can be stabilized more quickly.

[0055]

Furthermore, for example, the dehumidification apparatus 100 further includes the third heat exchanger 11c disposed between the discharge side of the compressor 13 and the flow switching device 15 and acting as a condenser or a radiator in both the first operation mode and the second operation mode. The configuration in which there is provided the third heat exchanger 11c acting as a condenser or a radiator in both the first operation mode and the second operation mode enables a reduction in the amount of refrigerant stagnating in a heat exchanger acting as a condenser before the operation mode is switched and acting as an evaporator after the operation mode is switched, and thus distribution of refrigerant after the operation mode is switched is quickly adjusted.

[0056]

The present invention is not limited to Embodiment described above, and various modifications can be made within the scope of the present invention. That is, the configuration according to Embodiment described above may be appropriately improved, and another configuration may be substituted for at least part of the configuration. Furthermore, the placement of an element whose placement is not limited to a particular placement is not limited to the placement described in Embodiment, and the element can be placed at a position where the function of the element can be implemented.

[0057]

For example, the third heat exchanger 11c illustrated in Fig. 1 may be omitted, and a heating device, such as an electric heater, that heats air may be disposed downstream of the second heat exchanger 11b in the air passage. The third heat exchanger 11c illustrated in Fig. 1 may be simply omitted.

[0058]

Furthermore, for example, although the dehumidification apparatus 100 including the temperature sensors 1a to 1h, the temperature-humidity sensors 2a to 2e, and the wind velocity sensor 3 has been described above, sensors included in the dehumidification apparatus 100 are appropriately changed in accordance with, for example, specifications of the dehumidification apparatus 100, and are not limited to the above-described sensors. For example, the dehumidification apparatus 100 may not include one or more sensors among the temperature sensors 1a to 1h, the temperature-humidity sensors 2a to 2e, and the wind velocity sensor 3, or alternatively, may include another sensor that measures temperature, humidity, wind velocity, or pressure, for example.

Reference Signs List

[0059]

1a to 1h temperature sensor 2a to 2e temperature-humidity sensor 3 wind velocity sensor 5 controller 6 input device 7 storage unit 11a first heat exchanger 11b second heat exchanger 11c third heat exchanger 12 air-sending device 13 compressor 14 expansion device 15 flow switching device 16 moisture adsorption unit 51 opening degree determination unit 52 operation mode switching determination unit 53 expansion device control unit 54 flow switching device control unit 100 dehumidification apparatus 102 air inlet 104 air outlet A refrigerant circuit Op normal control opening degree Op1 first opening degree Op2 second opening degree T1 first set time period T2 second set time period

CLAIMS

[Claim 1]

A dehumidification apparatus comprising:

a refrigerant circuit in which a compressor, a flow switching device, a first heat exchanger, an expansion device, and a second heat exchanger are connected with refrigerant pipes;

an air passage in which the first heat exchanger, a moisture adsorption unit configured to adsorb and desorb moisture, and the second heat exchanger are sequentially disposed;

an air-sending device configured to send air in a space to be dehumidified to the first heat exchanger, the moisture adsorption unit, and the second heat exchanger in sequence; and

a controller configured to perform dehumidification operation including a first operation mode in which the first heat exchanger acts as a condenser or a radiator, the second heat exchanger acts as an evaporator, and moisture held in the moisture adsorption unit is desorbed, and a second operation mode in which the first heat exchanger acts as an evaporator, the second heat exchanger acts as a condenser or a radiator, and the moisture adsorption unit is configured to absorb moisture from air that passes through the air passage, the first operation mode and the second operation mode being alternately switched by flow switching by the flow switching device;

the expansion device having a normal control opening degree before the operation mode is switched; and

when an operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode, the controller being configured to:

set an opening degree of the expansion device to a first opening degree that is larger than the normal control opening degree, and cause the refrigerant circuit to operate for a first set time period that is predetermined, after the first set time period elapses, the controller being configured to set the opening degree of the expansion device to a second opening degree that is smaller than the first opening degree, and cause the refrigerant circuit to operate for a second set time period that is predetermined,

the second opening degree being smaller than the normal control opening degree.

[Claim 2]

A dehumidification apparatus comprising:

a refrigerant circuit in which a compressor, a flow switching device, a first heat exchanger, an expansion device, and a second heat exchanger are connected with refrigerant pipes;

an air passage in which the first heat exchanger, a moisture adsorption unit configured to adsorb and desorb moisture, and the second heat exchanger are sequentially disposed;

an air-sending device configured to send air in a space to be dehumidified to the first heat exchanger, the moisture adsorption unit, and the second heat exchanger in sequence; and

a controller configured to perform dehumidification operation including a first operation mode in which the first heat exchanger acts as a condenser or a radiator, the second heat exchanger acts as an evaporator, and moisture held in the moisture adsorption unit is desorbed, and a second operation mode in which the first heat exchanger acts as an evaporator, the second heat exchanger acts as a condenser or a radiator, and the moisture adsorption unit is configured to absorb moisture from air that passes through the air passage, the first operation mode and the second operation mode being alternately switched by flow switching by the flow switching device;

the expansion device having a normal control opening degree before the operation mode is switched; and when an operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode, the controller being configured to:

set an opening degree of the expansion device to a first opening degree that is larger than the normal control opening degree, and cause the refrigerant circuit to operate for a first set time period that is predetermined,

after the first set time period elapses, the controller being configured to set the opening degree of the expansion device to a second opening degree that is smaller than the first opening degree, and cause the refrigerant circuit to operate for a second set time period that is predetermined,

the dehumidification apparatus further comprising a third heat exchanger disposed between a discharge side of the compressor and the flow switching device in the refrigerant circuit and acting as a condenser or a radiator in both the first operation mode and the second operation mode.

[Claim 3]

The dehumidification apparatus of claim 1 or 2, wherein the first opening degree is two or more times larger than the normal control opening degree, and the second opening degree is one third or less of the first opening degree.

[Claim 4]

The dehumidification apparatus of claim 2, wherein the third heat exchanger is disposed downstream of the second heat exchanger in the air passage.

[Claim 5]

A dehumidification apparatus comprising:

a refrigerant circuit in which a compressor, a flow switching device, a first heat exchanger, an expansion device, a second heat exchanger, and a third heat exchanger are connected with refrigerant pipes;

an air passage in which the first heat exchanger, a moisture adsorption unit configured to adsorb and desorb moisture, and the second heat exchanger are sequentially disposed; and

an air-sending device configured to send air in a space to be dehumidified to the first heat exchanger, the moisture adsorption unit, and the second heat exchanger in sequence,

the third heat exchanger being disposed between a discharge side of the compressor and the flow switching device in the refrigerant circuit,

a first operation mode in which the third heat exchanger and the first heat exchanger each act as a condenser or a radiator, the second heat exchanger acts as an evaporator, and moisture held in the moisture adsorption unit is desorbed, and a second operation mode in which the first heat exchanger acts as an evaporator, the third heat exchanger and the second heat exchanger each act as a condenser or a radiator, and the moisture adsorption unit is configured to absorb moisture from air that passes through the air passage, the first operation mode and the second operation mode being alternately switched by flow switching by the flow switching device.

[Claim 6]

The dehumidification apparatus of claim 5, comprising a controller,

the expansion device having a normal control opening degree before the operation mode is switched; and

wherein, when an operation mode is switched from the first operation mode to the second operation mode or from the second operation mode to the first operation mode, the controller is configured to set an opening degree of the expansion device to a first opening degree that is larger than the normal control opening degree, and cause the refrigerant circuit to operate for a first set time period that is predetermined, and

wherein, after the first set time period elapses, the controller is configured to set the opening degree of the expansion device to a second opening degree that is smaller than the first opening degree, and cause the refrigerant circuit to operate for a second set time period that is predetermined.