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(71) Applicant: **Mitsubishi Electric Corporation**
**Tokyo 100-8310 (JP)**

(72) Inventors:
- **MORIMOTO, Hiroyuki**
  **Tokyo 100-8310 (JP)**
- **YAMASHITA, Koji**
  **Tokyo 100-8310 (JP)**

(74) Representative: **Pfenning, Meinig & Partner GbR**
**Patent- und Rechtsanwälte**
**Theresienhöhe 13**
**80339 München (DE)**

# (54) AIR CONDITIONER DEVICE

(57) An air-conditioning apparatus 100 that includes a refrigeration cycle in which a compressor 10, a heat-source side heat exchanger 12, an expansion unit 16, and a load-side heat exchanger 15 are included and are connected with refrigerant pipes, includes cutoff units 37 and 38 capable of flowing or cut off a refrigerant circulating in the refrigeration cycle; a detection unit detecting leaking of the refrigerant on the basis of a resistance that changes with densities of plural kinds of leaked refrigerants; a concentration calculation unit 41 calculating a concentration of a refrigerant that has leaked, on the basis of the resistance of the detection unit; a concentration detection unit 39 outputting a calculation result of the concentration calculation unit 41 in order that the calculation result is used for controlling the cutoff units 37 and 38; and a cutoff control unit 40 controlling the cutoff units 37 and 38 on the basis of an output of the concentration detection unit 39.

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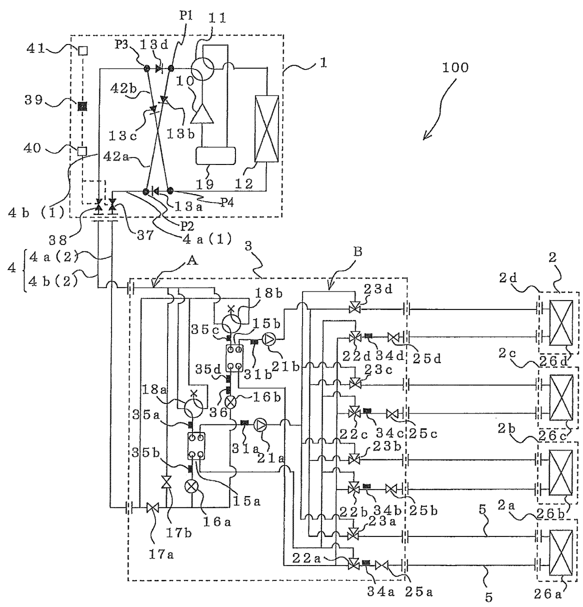


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## Description

Technical Field

**[0001]** The present invention relates to an air-conditioning apparatus applied to, for example, multi air-conditioners for buildings, and the like.

Background Art

**[0002]** Some air-conditioning apparatuses, such as multi air-conditioners for buildings, have a heat source unit (an outdoor unit) provided outside a building and an indoor unit provided inside the building. The refrigerant circulating in a refrigerant circuit of such an air-conditioning apparatus transfers heat to (or removes heat from) air supplied to a heat exchanger of the indoor unit, thereby heating or cooling the air. Then, the heated or cooled air is sent to an air-conditioned space, and consequently, heating or cooling is performed.
Since a building usually has a plurality of indoor spaces, such an air-conditioning apparatus has a plurality of indoor units in accordance with the number of the indoor spaces. Moreover, when a building is large, a refrigerant pipe that connects an outdoor unit and an indoor unit may be as long as 100 m long. When the refrigerant pipe that connects the outdoor unit and the indoor unit is long, the amount of refrigerant used to fill the refrigerant circuit increases in accordance with the length.
**[0003]** If the refrigerant used to fill the refrigerant circuit leaks for some reason, the refrigerant that has leaked may flow into an indoor space. In this case, if the refrigerant is flammable, the refrigerant may lead to a fire. Moreover, if the refrigerant is poisonous, the refrigerant may harm the human body.
As a result, an existing air-conditioning apparatus has been proposed, in which when the refrigerant leaks, the operation of a compressor is stopped (for example, see Patent Literature 1). In a technology described in Patent Literature 1, carbon dioxide is used as the refrigerant and the compressor is stopped when the refrigerant, carbon dioxide, leaks.

Citation List

Patent Literature

**[0004]** Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2000-320936 (for example, see paragraphs [0024] to [0033] and Figs. 2 to 4 in the specification)

Summary of Invention

Technical Problem

**[0005]** In the technology described in Patent Literature 1, carbon dioxide is used as the refrigerant and the system is designed to stop in the case where the carbon dioxide refrigerant leaks in the same way that other existing refrigerants leak; however, the system takes no measures against leaking of the carbon dioxide refrigerant. That is, in the case where carbon dioxide is used as the refrigerant, it is regarded as a major prerequisite that the refrigerant does not harm the human body and it is necessary to take some measures for decreasing leakage of the refrigerant. Moreover, similarly, a flammable refrigerant is flammable, and thus it is necessary to have some type of safety apparatuses in order to obtain a high degree of safety, similarly to as in the case of carbon dioxide.
**[0006]** Recently, there has been a tendency to restrict use of HFC refrigerants that have a high global warming potential (for example, R410A and R404A, R407C, R134a, and the like). Air-conditioning apparatuses that use a refrigerant that has a low global warming potential (for example, HFO1234yf, R32, HC, carbon dioxide, and the like) in terms of global warming have been proposed. Also in the case where a flammable refrigerant (HFO1234yf, R32, and HC) or carbon dioxide is used as the refrigerant in multi air-conditioners for buildings, a large amount of refrigerant is necessary. Thus, some measures need to be taken against leaking of the refrigerant into an indoor space.
**[0007]** An air-conditioning apparatus according to the present invention has been made in light of the above-described issues and aims to provide effective measures against leaking of a refrigerant in refrigeration cycle apparatuses. Solution to Problem
**[0008]** An air-conditioning apparatus according to the present invention includes a refrigeration cycle in which a compressor, a heat-source side heat exchanger, an expansion unit, and a load-side heat exchanger are included and are connected with refrigerant pipes, and includes: a cutoff unit capable of flowing or cutting off a refrigerant circulating in the refrigeration cycle; a detection unit detecting leaking of the refrigerant on the basis of a resistance that changes with densities of plural kinds of leaked refrigerants; a concentration calculation unit calculating a concentration of the refrigerant that has leaked, on the basis of the resistance of the detection unit; a concentration detection unit outputting a calculation result of the concentration calculation unit in order that the calculation result is used for controlling the cutoff unit; and a cutoff control unit controlling the cutoff unit on the basis of an output of the concentration detection unit.

Advantageous Effects of Invention

**[0009]** An air-conditioning apparatus according to the present invention has the above-described structure, and thus the degree of safety of the air-conditioning apparatus can be improved.

Brief Description of Drawings

**[0010]**

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

[Fig. 2] Fig. 2 illustrates an example of the structure of a refrigerant circuit of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 3] Fig. 3 is a diagram of a refrigerant circuit illustrating a flow of a refrigerant in the air-conditioning apparatus illustrated in Fig. 2 in a cooling only operation mode.

[Fig. 4] Fig. 4 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus illustrated in Fig. 2 in a heating only operation mode.

[Fig. 5] Fig. 5 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus illustrated in Fig. 2 in a cooling main operation mode.

[Fig. 6] Fig. 6 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus illustrated in Fig. 2 in a heating main operation mode.

[Fig. 7] Fig. 7 illustrates relationships between the resistance of a detection member of a concentration detection unit and the concentration of the refrigerant according to types of refrigerants.

[Fig. 8] Fig. 8 is a diagram illustrating an example of the structure of another refrigerant circuit of the air-conditioning apparatus according to Embodiment of the present invention.

Description of Embodiments

**[0011]** In the following, Embodiment according to the present invention will be described with reference to the drawings.

Embodiment

**[0012]** Fig. 1 is a schematic diagram illustrating an installation example of an air-conditioning apparatus 100 according to Embodiment of the present invention. With reference to Fig. 1, the installation example of the air-conditioning apparatus 100 will be described.

In the case where a refrigerant leaks, the air-conditioning apparatus 100 according to Embodiment has functions of detecting leaking and cutting off a flow of the refrigerant flowing out from an outdoor unit 1 (a heat source unit) and flowing into the outdoor unit 1. As a result, an amount of the refrigerant that will leak from the air-conditioning apparatus 100 is decreased, thereby assuring users' safety.

**[0013]** Moreover, the air-conditioning apparatus 100 according to Embodiment includes a refrigerant circuit A (see Fig. 2), which is a refrigeration cycle which circulates a heat-source side refrigerant, and a heat medium circulation circuit B (see Fig. 2), which circulates a heat medium. In each indoor unit, a cooling operation mode or a heating operation mode is selectable as an operation mode.

**[0014]** The air-conditioning apparatus 100 uses a method (an indirect method) in which the refrigerant (the heat-source side refrigerant) is indirectly utilized. That is, the air-conditioning apparatus 100 according to Embodiment transmits cooling energy or heating energy stored in the heat-source side refrigerant to a refrigerant (hereinafter referred to as a heat medium) different from the heat-source side refrigerant, and performs cooling or heating of an air-conditioned space by using the cooling energy or heating energy stored in the heat medium.

**[0015]** In Fig. 1, the air-conditioning apparatus 100 includes the outdoor unit 1, which is a heat source unit, a plurality of indoor units 2, and a heat medium relay unit 3 transmitting cooling energy or heating energy of the heat-source side refrigerant that flows in the outdoor unit 1 to the heat medium that flows in the indoor units 2. The heat medium relay unit 3 is a unit that exchanges heat from the heat-source side refrigerant to the heat medium. The outdoor unit 1 and the heat medium relay unit 3 are connected with refrigerant pipes 4 for conducting the heat-source side refrigerant. The heat medium relay unit 3 and the indoor units 2 are connected with heat medium pipes 5 for conducting the heat medium. The cooling energy or heating energy generated by the outdoor unit 1 is transmitted to the heat medium of the heat medium relay unit 3 and is distributed to the indoor units 2. The air-conditioning apparatus 100 according to Embodiment includes a first cutoff unit 37 and a second cutoff unit 38 (see Fig. 2) inside the outdoor unit 1, which will be described again with reference to Fig. 2.

**[0016]** The outdoor unit 1 is usually provided in outdoor space 6, which is space (for example, on the roof and the like) outside a building 9 such as buildings, and supplies cooling energy or heating energy to the indoor units 2 through the heat medium relay unit 3. The indoor units 2 are provided at positions so as to supply air for cooling or air for heating into a room space 7, which is an internal space (for example, a room and the like) of the building 9, and supply air for cooling or air for heating into the room space 7, which is an air-conditioned space. The heat medium relay unit 3 is configured to be able to be provided as a separate unit from the outdoor unit 1 and the indoor units 2 at a position that is not in the outdoor space 6 or in the room space 7. The heat medium relay unit 3 is connected to the outdoor unit 1 and the indoor units 2 by the refrigerant pipes 4 and the heat medium pipes 5, respectively, and transmits cooling energy or heating energy supplied from the outdoor unit 1 to the indoor units 2.

**[0017]** As illustrated in Fig. 1, in the air-conditioning apparatus 100 according to Embodiment, the outdoor unit 1 and the heat medium relay unit 3 are connected through the refrigerant pipes 4, and the heat medium relay unit 3 and each of the indoor units 2 are connected through the respective heat medium pipes 5. In this way, units (the outdoor unit 1, the indoor units 2, and the heat medium relay unit 3) are connected using the refrigerant pipes 4 and the heat medium pipes 5 in the air-conditioning apparatus 100, and thus construction is easy.

**[0018]** Note that, in Fig. 1, a state in which the heat medium relay unit 3 is provided in a space different from the room space 7 but in the inside the building 9, such a space above a ceiling (for example, a space such as a space above a ceiling in the building 9, hereinafter referred to simply as a space 8) is illustrated as an example. In addition, the heat medium relay unit 3 may be provided, for example, in a common space such as elevators and the like. Moreover, in Fig. 1, a case in which the indoor units 2 are ceiling cassette units is illustrated as an example; however, the indoor units 2 are not limited thereto. The indoor units 2 may be ceiling concealed units, ceiling suspended units, or the like, and are not particularly limited as long as supplying air for cooling or air for heating into the room space 7 directly or through ducts and the like into the room space 7.

**[0019]** Moreover, in Fig. 1, a case in which the outdoor unit 1 is provided in the outdoor space 6 is illustrated as an example; however, the outdoor unit 1 is not limited thereto. For example, the outdoor unit 1 may be provided in a closed space such as a machine room with a ventilating hole, and may also be provided inside the building 9 if waste heat may be exhausted to the outside the building 9 through an exhaust duct. Alternatively, in the case where a water-cooled outdoor unit 1 is used, the water-cooled outdoor unit 1 may also be provided inside the building 9.

**[0020]** The heat medium relay unit 3 may be provided at a position near the outdoor unit 1 and away from the indoor units 2. Note that if the distance from the heat medium relay unit 3 to each of the indoor units 2 is long, power (energy) needed to transfer the heat medium becomes quite large. Thus, the heat medium relay unit 3 is desirably provided under the consideration that the effect of energy conservation decreases. Furthermore, the number of outdoor units 1 to be connected, that of the indoor units 2 to be connected, and that of heat medium relay units 3 to be connected are not particularly predetermined, and the number of units is desirably set depending on the building 9.

**[0021]** Fig. 2 illustrates an example of the structure of a refrigerant circuit of the air-conditioning apparatus 100 according to Embodiment 1 of the present invention. With reference to Fig. 2, the structure of the refrigerant circuit of the air-conditioning apparatus 100 will be described. As illustrated in Fig. 2, a heat exchanger related to heat medium 15a and a heat exchanger related to heat medium 15b that are included in the heat medium relay unit 3 and the outdoor unit 1 are connected through the refrigerant pipes 4 (a high-pressure side refrigerant pipe 4a(2) and a low-pressure side refrigerant pipe 4b(2)). Moreover, the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b are connected to indoor units 2a to 2d (which may be simply referred to as the indoor unit 2) through the heat medium pipes 5.

[Structure of Outdoor Unit 1]

**[0022]** In the outdoor unit 1, a compressor 10, a first refrigerant channel switch unit 11, a heat-source side heat exchanger 12, an accumulator 19, the first cutoff unit 37, and the second cutoff unit 38 are connected with the refrigerant pipes and provided.

The compressor 10 sucks and compresses the refrigerant and makes the refrigerant be in a high-temperature high-pressure state, and then transfers the refrigerant to the refrigerant circuit A. The discharge side of the compressor 10 is connected to the first refrigerant channel switch unit 11 and the suction side thereof is connected to the accumulator 19. It is desirable that the compressor 10 be formed with, for example, an inverter compressor capable of controlling a capacity, or the like.

**[0023]** The first refrigerant channel switch unit 11 connects the discharge side of the compressor 10 and a check valve 13b and connects the heat-source side heat exchanger 12 and the suction side of the accumulator 19 in a heating only operation mode and in a heating main operation mode of a cooling and heating mixed operation mode. Moreover, the first refrigerant channel switch unit 11 connects the discharge side of the compressor 10 and the heat-source side heat exchanger 12 and connects a check valve 13d and the suction side of the accumulator 19 in a cooling operation mode and in a cooling main operation mode of the cooling and heating mixed operation mode. It is desirable that the first refrigerant channel switch unit 11 be formed with, for example, a four-way valve and the like.

**[0024]** The heat-source side heat exchanger 12 functions as an evaporator when a heating operation is performed, functions as a radiator (a gas cooler) when a cooling operation is performed, and exchanges heat between air supplied from an air-sending device such as a fan, not illustrated in the drawings, and a refrigerant. In the heating operation mode, one side of the heat-source side heat exchanger 12 is connected to a check valve 13c and the other side thereof is connected to the suction side of the accumulator 19. Moreover, in the cooling operation mode, one side of the heat-source side heat exchanger 12 is connected to the discharge side of the compressor 10 and the other side thereof is connected to a check valve 13a. It is desirable that the heat-source side heat exchanger 12 be formed with a plate-fin-and-tube type heat exchanger, which may exchange heat, for example, between the refrigerant that flows in the refrigerant pipes and air that passes through the fan.

**[0025]** The accumulator 19 holds an excessive refrigerant resulting due to a difference between the heating operation mode and the cooling operation mode and an excessive refrigerant for a transitive change in operation (for example, a change in the number of operating indoor units 2). In the heating operation mode, the suction side of the accumulator 19 is connected to the heat-source side heat exchanger 12 and the discharge side thereof is connected to the suction side of the compressor 10. Moreover, in the cooling operation mode, the suction side of the accumulator 19 is connected to the check valve 13d and the discharge side thereof is connected to the suction side of the compressor 10.

**[0026]** Moreover, the outdoor unit 1 includes a first connection pipe 42a, a second connection pipe 42b, the check valve 13a, the check valve 13b, the check valve 13c, and the check valve 13d. By including the first connection pipe 42a, the second connection pipe 42b, the check valve 13a, the check valve 13b, the check valve 13c, and the check valve 13d, the heat-source side refrigerant that flows from the outdoor unit 1 into the heat medium relay unit 3 can keep in a certain direction regardless of whether in the heating operation mode or in the cooling operation mode.

That is, the refrigerant discharged from the compressor 10 flows into the high-pressure side refrigerant pipe 4a (2). The refrigerant that has flown into the high-pressure side refrigerant pipe 4a(2) flows into the heat medium relay unit 3. The refrigerant that has flown in the heat medium relay unit 3 flows from the low-pressure side refrigerant pipe 4b(2) into the outdoor unit 1.

**[0027]** Here, a high-pressure side refrigerant pipe 4a (1) is a pipe in the outdoor unit 1, and is a pipe on a downstream side from a point P2 illustrated in Fig. 4. The high-pressure side refrigerant pipe 4a(2) is a pipe connected to the high-pressure side refrigerant pipe 4a(1) among the refrigerant pipes 4.

Moreover, a low-pressure side refrigerant pipe 4b(1) is a pipe in the outdoor unit 1, and is a pipe on an upstream side from a point P3 illustrated in Fig. 4. The low-pressure side refrigerant pipe 4b(2) is a pipe connected to the low-pressure side refrigerant pipe 4b(1) among the refrigerant pipes 4.

**[0028]** The first cutoff unit 37 and the second cutoff unit 38 are capable of flowing the refrigerant (in an open state) or cutting off the flow of the refrigerant (in a closed state) on the basis of operation of a cutoff control unit 40 to be described below.

It is preferable to provide the first cutoff unit 37 and the second cutoff unit 38 in the outdoor unit 1 or near the outdoor unit 1. That is, it is desirable that the first cutoff unit 37 be connected to the high-pressure side refrigerant pipe 4a(1) and the second cutoff unit 38 is connected to the low-pressure side refrigerant pipe 4b(1). Moreover, it is also desirable that the first cutoff unit 37 be connected to the high-pressure side refrigerant pipe 4a(2) and the second cutoff unit 38 is connected to the low-pressure side refrigerant pipe 4b(2).

It is desirable that the first cutoff unit 37 and the second cutoff unit 38 be each formed with, for example, a two-way valve that includes a valve body, a sealing material that seals the valve body, a coil that opens and closes the valve body by electromagnetic force, and the like. In the following description, the first cutoff unit 37 and the second cutoff unit 38 are each assumed to be a two-way valve that includes a valve body, and a sealing material that seals the valve body, and a coil that opens and closes the valve body by electromagnetic force, and the description will be made.

[Concentration Detection Mechanism of Outdoor Unit 1]

**[0029]** This air-conditioning apparatus 100 includes a concentration detection unit 39 that has a detection member (not illustrated) whose resistance changes in accordance with the concentration of the refrigerant, a concentration calculation unit 41 that calculates the concentration of the refrigerant on the basis of the resistance of the detection member, and the cutoff control unit 40 that controls opening and closing of the first cutoff unit 37 and the second cutoff unit 38 on the basis of the calculated concentration of the refrigerant.

Moreover, the concentration detection unit 39 outputs a predetermined signal to the cutoff control unit 40 on the basis of a calculation result regarding the concentration of the refrigerant from the concentration calculation unit 41.

Specifically, the concentration calculation unit 41 is designed not to output the predetermined signal to the cutoff control unit 40 in the case where the calculation result regarding the concentration of the refrigerant from the concentration calculation unit 41 is smaller than a predetermined concentration value.

On the other hand, the concentration calculation unit 41 is designed to output the predetermined signal to the cutoff control unit 40 in the case where the calculation result regarding the concentration of the refrigerant from the concentration calculation unit 41 is greater than or equal to the predetermined concentration value.

**[0030]** The concentration detection unit 39 is electrically connected to the concentration calculation unit 41 and the cutoff control unit 40. An output to the cutoff control unit 40 is not particularly limited; however, for example, a direct-current voltage (5 V, 12 V, 24 V, and the like), an alternating-current voltage, a current, or other output is available. Note that, in the air-conditioning apparatus 100 according to Embodiment, a description will be made by considering the output to the cutoff control unit 40 to be DC 5 V.

Note that the predetermined concentration corresponds to a leak limiting concentration of or a lower explosive limit of the refrigerant used in the air-conditioning apparatus 100. For example, in the case where carbon dioxide is used as the refrigerant, it is preferable to set the predetermined concentration to about 1/10 of the leak limiting concentration. Moreover, in the case where a flammable refrigerant (HFO1234yf, R32, or HC) is used, it is preferable to set the predetermined concentration to about 1/10 of the lower explosive limit.

**[0031]** The position at which the detection member of the concentration detection unit 39 is provided is not particularly limited; however, for example, it is desirable to arrange the detection member in the outdoor unit 1 as illustrated in Fig. 1, near the outdoor unit 1, in the heat medium relay unit 3, in the outdoor space 6, in the room space 7, in the space 8, and the like.

**[0032]** Fig. 7 illustrates relationships between the resistance of the detection member of the concentration detection unit 39 and the concentration of the refrigerant according to different types of refrigerants. It is desirable that the detection member be formed with, for example, a stannic oxide semiconductor ($SnO^2$). As illustrated in Fig. 7, it is clear that as the gas concentration of the refrigerant increases, the resistance of the stannic oxide semiconductor ($SnO^2$) gradually decreases. That is, the concentration of the refrigerant can be uniquely obtained by calculating the resistance of the detection member.

Note that it is clear that in the case where the detection member is formed with the stannic oxide semiconductor ($SnO^2$), relationships between the resistance of major refrigerants (R410A, R407C, R32, and HFO1234yf) and the concentration of the refrigerant tend to be almost the same. That is, for the major refrigerants, the concentration of the refrigerant can be detected by using the same calibration curve. In other words, a single detection member makes it possible to detect densities of a plurality of refrigerants, and thus the concentration detection unit 39 can be standardized.

Moreover, in the case where the concentration detection unit 39 can be standardized in this way, there is no need to provide a plurality of detecting members for the kinds of refrigerant, thereby reducing the cost of the air-conditioning apparatus 100.

**[0033]** HFO1234yf has the chemical formula $CF_3$- CF = $CH_2$. HFO1234ze, which is an isomer of HFO1234yf, has the chemical formula $CHF_2$ - CF = CHF. Since HFO1234ze has similar chemical characteristics to HFO1234yf, the characteristics of the electrical resistance of the detection unit of the concentration detection unit 39 according to the present invention show almost the same characteristics. Thus, the concentration detection unit 39 according to Embodiment can perform a detection operation.

Moreover, in the case where R32 and HFO1234yf are mixed, a non-azeotropic refrigerant mixture is obtained. In the case where such a refrigerant leaks, R32, which is a low boiling point component, has a greater leakage. That is, since R32 reaches the limiting concentration faster than HFO1234yf, leaking of the refrigerant can be detected in the safe side by detecting leaking of the refrigerant through measuring of leakage of R32.

Moreover, even in the case where other refrigerant mixtures are used, if any one among R410A, R407C, R32, HFO1234yf, and HFO1234ze is included as a component, the electrical resistance of the detection member changes and then the concentration detection unit 39 can perform the detection operation. That is, leaking of refrigerant mixtures containing HFC, HFO, and HFC and HFO can be detected by using the concentration detection unit 39 according to Embodiment.

**[0034]** On the other hand, in order to further improve the detection accuracy of the concentration detection unit 39, such an improvement can be achieved by generating calibration curves varying from refrigerant to refrigerant instead of the calibration curve used in Fig. 7. In other words, it is desirable that the calibration curves varying from refrigerant to refrigerant be utilized instead of using single calibration curve.

**[0035]** The concentration calculation unit 41 calculates (computes) the concentration of the refrigerant on the basis of the resistance of the detection member of the concentration detection unit 39. The concentration calculation unit 41 is electrically connected to the concentration detection unit 39.

The relationship between the concentration of the refrigerant and the resistance of the detection member, as illustrated in Fig. 7, is stored in the concentration calculation unit 41. As a result of this, the concentration of the refrigerant used in the air-conditioning apparatus 100 can be calculated on the basis of the resistance of the detection member of the concentration detection unit 39.

Note that the position at which the concentration calculation unit 41 is provided is not particularly limited; however, it is desirable that the concentration calculation unit 41 be provided, for example, in the outdoor unit 1, near the outdoor unit 1, or the like. In the following, the air-conditioning apparatus 100 will be described with reference to Fig. 2 again.

**[0036]** The cutoff control unit 40 controls opening and closing of the first cutoff unit 37 and the second cutoff unit 38 on the basis of an output (the predetermined signal) from the concentration detection unit 39.

In the case where the concentration of the refrigerant is greater than or equal to the predetermined concentration value, the concentration detection unit 39 outputs the predetermined signal to the cutoff control unit 40. As a result of this, the electrical connection between a voltage supply (not illustrated) and the first cutoff unit 37 and second cutoff unit 38 is cut off. That is, a voltage is not applied to the first cutoff unit 37 and the second cutoff unit 38 (feeding is not performed). Then, the coil of the first cutoff unit 37 and the second cutoff unit 38 are not excited, and thus the valve bodies close. That is, both the first cutoff unit 37 and the second cutoff unit 38 are in the closed state.

**[0037]** On the other hand, in the case where the concentration of the refrigerant is smaller than the predetermined concentration value, a voltage is not output from the concentration detection unit 39 to the cutoff control unit 40. As a result of this, the voltage supply (not illustrated) and the first cutoff unit 37 and second cutoff unit 38 are electrically connected. That is, a voltage is applied to the first cutoff unit 37 and the second cutoff unit 38 (feeding is performed). Then, the coils of the first cutoff unit 37 and the second cutoff unit 38 are excited, and thus the valve bodies open. That is, both the first cutoff unit 37 and the second cutoff unit 38 are in the open state. Note that the position at which the cutoff control unit 40 is provided is not particularly limited; however, it is desirable that the cutoff control unit 40 be provided, for example, in the outdoor unit 1, near the outdoor unit 1, or the like.

**[0038]** As described above, the first cutoff unit 37 and the second cutoff unit 38 are two-way valves that each include a valve body, a sealing material that seals the valve body, and a coil that opens and closes the valve body by electromagnetic force.

The coil of each of the first cutoff unit 37 and the second cutoff unit 38 is connected to the voltage supply through the cutoff control unit 40. When the air-conditioning apparatus 100 is in normal operation, the cutoff control unit 40 puts in a state (an energized state) in which the voltage supply is electrically connected to the first cutoff unit 37 and second cutoff unit 38. As a result of this, the coil of each of the first cutoff unit 37 and the second cutoff unit 38 is applied with a voltage by the voltage supply and becomes an electromagnet. Then, each valve body is attracted by electromagnetic force, and the first cutoff unit 37 and the second cutoff unit 38 are in the open state.

**[0039]** On the other hand, when detecting leaking of the refrigerant of the air-conditioning apparatus 100, the cutoff control unit 40 electrically cuts off the connection between the voltage supply and the first cutoff unit 37 and second cutoff unit 38 (a non-energized state). As a result of this, the coil of each of the first cutoff unit 37 and the second cutoff unit 38 is not applied with a voltage by the voltage supply. Then, each valve body is not attracted by the coil, and the first cutoff unit 37 and the second cutoff unit 38 are in the closed state.

**[0040]** Note that, when a mechanical electromagnetic relay is employed to perform switching between electrical connection and disconnection between the voltage supply and the first cutoff unit 37 and second cutoff unit 38, in the case where a flammable refrigerant (HFO1234yf, R32, or HC) is used as the refrigerant, sparks may be emitted and may ignite the refrigerant. Thus, in the case where a flammable refrigerant is used, it is desirable to employ, as the cutoff control unit 40, an SRR (solid state relay), which is a non-contact relay using a semiconductor element. As a result of this, there is no mechanical operation, and thus it is possible to reduce the possibility of sparking. As a result of this, even if a flammable refrigerant leaks into the outdoor unit 1, switching between electrical connection and disconnection between the voltage supply and the first cutoff unit 37 and second cutoff unit 38 may be safely performed.

**[0041]** Moreover, it is desirable that the coils for opening and closing the valve bodies of the first cutoff unit 37 and the second cutoff unit 38 be excited by a direct current. It is because the lifetime of the coils can be sustained longer when excitation is performed with a direct-current voltage. Thus, a description will be made by considering that a direct-current voltage is applied to the first cutoff unit 37 and the second cutoff unit 38 as an operation voltage. Note that a description will be made by assuming that the operation voltage is DC 12 V; however, the operation voltage may be DC 24 V or the like and is not limited thereto.

Moreover, the cutoff control unit 40 also includes a converter that can convert an output from a commercial power supply (an alternating-current voltage, AC 200 V in Embodiment) into a predetermined direct-current voltage (DC 12V in Embodiment). The above-described voltage supply corresponds to the commercial power supply and the converter.

**[0042]** Since the first cutoff unit 37 and the second cutoff unit 38 are provided in main pipes (the refrigerant pipes 4) of the refrigerant circuit, the main pipes need to have a large aperture. That is, the main pipes need to have a large value of a flow coefficient Cv. Thus, it is desirable to employ not a direct-acting valve but a pilot valve as the first cutoff unit 37 and the second cutoff unit 38.

It is desirable that the value of Cv for the first cutoff unit 37 through which a high-pressure refrigerant flows be set to, for example, 1 or higher, and the value of Cv for the second cutoff unit 38 through which a low-pressure refrigerant flows be set to, for example, 5 or higher.

Even if the first cutoff unit 37 and the second cutoff unit 38 are provided in the refrigerant circuit, the values of Cv described above can make a pressure loss small, and make performance degradation small. That is, the amount of the refrigerant circulating in the refrigerant circuit A decreases in normal operation.

**[0043]** Moreover, it is desirable that the sealing material that seals the valve body be composed of rubber or PTFE (polytetrafluoroethylene). As a result of this, in case of emergency, the sealing material immediately conforms (closely adheres) to the valve body. That is, in the case where the first cutoff unit 37 and the second cutoff unit 38 are closed, the possibility of the refrigerant leak decreases.

Note that the first cutoff unit 37 and the second cutoff unit 38 do not open or close as often as a normal valve. Thus, it is not always necessary to employ a metal seal, which has a high durability, as the sealing material.

**[0044]** Moreover, it is desirable that the first cutoff unit 37 and the second cutoff unit 38 be designed in such a manner that leakage of the refrigerant in the closed state is set to, for example, $1.0 \times 10^{-6}$ [$m^3$/s] or smaller. The reason will be described below.

When a large amount of a refrigerant leaks into a space, there is a danger of burning, an oxygen deficiency, and the like. For each kind of refrigerant, a corresponding limiting concentration is defined, which is the maximum concentration for leakage of the refrigerant so as to safely use the refrigerant. The limiting concentration is, for example, 0.44 [$m^3$/kg] for R410A, 0.061 [$m^3$/kg] for R32, 0.0578 [$m^3$/kg] for HFO1234yf, and 0.008 [$m^3$/kg] for propane.

**[0045]** When a refrigerant leaks into a room, leaking of the refrigerant is stopped by closing the first cutoff unit 37 and the second cutoff unit 38 provided in the refrigerant pipes. In this case, if a measure to stop leaking of the refrigerant is taken when the refrigerant reaches the limiting concentration, it is late. Thus, when the concentration of the refrigerant in a room reaches 95% of the limiting concentration, the first cutoff unit 37 and the second cutoff unit 38 are designed to be closed. That is, after the first cutoff unit 37 and the second cutoff unit 38 are closed and until the concentration of the refrigerant reaches the limiting concentration, the amount of the refrigerant that may further leak is 5%.

**[0046]** Here, in the case where a location in which the multi air-conditioners for buildings is expected to be installed is the smallest room, which is a single room of a hotel, it is assumed that the room has a capacity of 25 $m^3$, the pressure difference between before and after the first cutoff unit 37 and the second cutoff unit 38 operate is 1.0 MPa, a substantial space capacity of the room except for the unit bath and other items is $0.5 \times 25 = 12.5$ $m^3$. In this case, the amount of the refrigerant that may leak after the first cutoff unit 37 and the second cutoff unit 38 are closed is $12.5\ m^3 \times 0.05 = 0.625\ m^3$. It is expected that users do not notice the refrigerant leaking while sleeping or the like and that the space is closed in a state in which windows are closed. Thus, leakage that does not reach the limiting concentration within 24 hours after the first cutoff unit 37 and the second cutoff unit 38 are operated is calculated to be $0.625/(24 \times 60 \times 60) = 7.2 \times 10^{-6}$ [$m^3$/s]. If leakage after the first cutoff unit 37 and the second cutoff unit 38 are closed is smaller than this value, the safety is considered to be kept.

**[0047]** Moreover, a position is unpredictable where the refrigerant leaks in a high-pressure pipe or in a fluid pipe,. Thus, assuming that leaking occurs in a high-pressure pipe, leakage needs to be smaller than the limiting concentration described above, at a pressure difference of about 5 MPa. Leakage of the refrigerant is in proportion to the pressure difference to the power of 0.5 according to Bernoulli's theorem, which is commonly known in the field of fluid dynamics. Thus, leakage of the refrigerant is $7.2 \times 10^{-6}$ [$m^3$/s]/$(5/1)^{0.5} = 3.2 \times 10^{-6}$. If leakage is smaller than this value, the safety is ensured. In order to achieve a higher degree of safety, leakage should be $1.0 \times 10^{-6}$ [$m^3$/s] or smaller.

Note that it is desirable that the first cutoff unit 37 and the second cutoff unit 38 have a minimum operation pressure difference of about 0 (kgf/$cm^2$).

**[0048]** In the case where the heat-source side refrigerant leaks from a channel (the refrigerant circuit A) in which the heat-source side refrigerant circulates, the concentration of the refrigerant increases in an external portion (see the outdoor space 6, the room space 7, and the space 8 in Fig. 1) affected by leaking. The resistance of the detecting member of the concentration detection unit 39 changes in accordance with the concentration of the refrigerant that has leaked. Then, the concentration calculation unit 41 calculates the concentration of the refrigerant that has leaked, on the basis of the resistance.

**[0049]** In the case where the calculation result from the concentration calculation unit 41 is smaller than a predetermined concentration value, which means that the refrigerant does not leak, the concentration detection unit 39 does not output the predetermined signal to the cutoff control unit 40. Thus, since the predetermined signal is not output to the cutoff control unit 40, the cutoff control unit 40 maintains an electrical connection between the voltage supply and the first cutoff unit 37 and second cutoff unit 38. That is, a voltage is applied to the coil of each of the first cutoff unit 37 and the second cutoff unit 38 by the voltage supply. As a result of this, the first cutoff unit 37 and the second cutoff unit 38 stay in a state in which the valve bodies of the first cutoff unit 37 and the second cutoff unit 38 are opened. That is, both the first cutoff unit 37 and the second cutoff unit 38 are in the open state.

**[0050]** In the case where the calculation result from the concentration calculation unit 41 is greater than or equal to a predetermined concentration value, which means that the refrigerant leaks, the concentration detection unit 39 outputs the predetermined signal to the cutoff control unit 40. The cutoff control unit 40 cuts off the electrical connection between the voltage supply and the first cutoff unit 37 and second cutoff unit 38 on the basis of this output (the predetermined signal). That is, no voltage is applied to the coil of each of the first cutoff unit 37 and the second cutoff unit 38 by the voltage supply. As a result of this, the valve bodies of the first cutoff unit 37 and the second cutoff unit 38 are closed. That is, both the first cutoff unit 37 and the second cutoff unit 38 are in the closed state.

As a result of this, the refrigerant flow that flows out from the outdoor unit 1 and the refrigerant flow that flows into the outdoor unit 1 are cut off. That is, the heat-source side refrigerant is prevented from circulating in the refrigerant circuit A. As a result of this, the amount of the refrigerant that will leak is decreased, thereby improving the degree of safety of the air-conditioning apparatus 100.

[Indoor Unit 2]

**[0051]** The indoor unit 2 includes use-side heat exchangers 26a to 26d (also simply referred to as use-side heat exchangers 26). The use-side heat exchangers 26 are designed to be connected to heat medium flow control devices 25a to 25d (also simply referred to as heat medium flow control devices 25) through the second heat medium pipes 5 and to second heat medium channel switch units 23a to 23d (also simply referred to as second heat medium channel switch units 23) through the heat medium pipes 5. The use-side heat exchangers 26 each exchange heat between air supplied from the air-sending device such as a fan, not illustrated, and the heat medium, and generate air for heating or air for cooling to be supplied to the room space 7.

**[0052]** Fig. 2 illustrates an example in the case where four indoor units 2a to 2d are connected to the heat medium relay unit 3 through the heat medium pipes 5. Moreover, the use-side heat exchangers 26 are the use-side heat exchanger 26a, the use-side heat exchanger 26b, the use-side heat exchanger 26c, and the use-side heat exchanger 26d from the bottom of the sheet in accordance with the indoor units 2a to 2d, respectively. Note that the number of the indoor units 2 to be connected is not limited to four.

[Heat Medium Relay Unit 3]

**[0053]** The heat medium relay unit 3 includes two heat exchangers related to heat medium 15a and 15b (also simply referred to as heat exchangers related to heat medium 15), two expansion units 16a and 16b (also simply referred to as expansion units 16), two on-off units 17a and 17b (also simply referred to as on-off units 17), two second refrigerant channel switch units 18a and 18b (also simply referred to as second refrigerant channel switch units 18), two pumps 21 a and 21 b (also simply referred to as pumps 21), four first heat medium channel switch units 22a to 22d (also simply referred to as first heat medium channel switch units 22), the four second heat medium channel switch units 23a to 23d (also simply referred to as second heat medium channel switch units 23), and the four heat medium flow control devices 25a to 25d (also simply referred to as heat medium flow control devices 25).

**[0054]** The heat exchangers related to heat medium 15 (load-side heat exchangers) function as condensers (radiators) or evaporators, and exchange heat between the heat-source side refrigerant and the heat medium. The heat exchangers related to heat medium 15 transmit cooling energy or heating energy generated by the outdoor unit 1 and stored in the heat-source side refrigerant, to the heat medium. The heat exchanger related to heat medium 15a is connected to a pipe that connects the expansion unit 16a and the second refrigerant channel switch unit 18a in the refrigerant circuit A illustrated in Fig. 2, and cools the heat medium in the cooling and heating mixed operation mode. The heat exchanger related to heat medium 15b is connected to a pipe that connects the expansion unit 16b and the second refrigerant channel switch unit 18b in the refrigerant circuit A illustrated in Fig. 2, and heats the heat medium in the cooling and heating mixed operation mode.

**[0055]** The expansion units 16 function as pressure reducing valves or expansion valves, and reduce pressure to expand the heat-source side refrigerant. The expansion unit 16a is provided on an upstream side of the heat exchanger related to heat medium 15a in the flow of the heat-source side refrigerant in the cooling only operation mode. The expansion unit 16b is provided on an upstream side of the heat exchanger related to heat medium 15b in the flow of the heat-source side refrigerant in the cooling only operation mode. It is desirable that the expansion units 16 be formed with something that may variably control its opening degree; for example, an electronic expansion valve or the like.

**[0056]** The on-off units 17 open and close channels to which the on-off units 17 are provided. The on-off unit 17a is provided on an upstream side of the expansion units 16 in the flow of the heat-source side refrigerant in the cooling only operation mode. The on-off unit 17b is provided on a downstream side of the expansion unit 16a in the flow of the heat-source side refrigerant in the heating only operation mode. It is desirable that the on-off units 17 be formed with, for example, a two-way valve or the like.

**[0057]** The second refrigerant channel switch units 18 select the flow of the refrigerant in the heating only operation mode, the flow of the refrigerant in the cooling only operation mode, or the flow of the refrigerant in the cooling and heating mixed operation mode. The second refrigerant channel switch unit 18b connects the high-pressure side refrigerant pipe 4a(2) and the heat exchanger related to heat medium 15b in the heating only operation mode. The second refrigerant channel switch unit 18a connects the heat exchanger related to heat medium 15a and the low-pressure side refrigerant pipe 4b(2) in the cooling only operation mode and in the cooling and heating mixed operation mode. It is desirable that the second refrigerant channel switch units 18 be formed with, for example, a four-way valve or the like.

**[0058]** The pumps 21 make the heat medium that flows in the heat medium pipes 5 circulate. The pump 21 a is connected to a pipe that connects the heat exchanger related to heat medium 15a and the second heat medium channel switch units 23, among the heat medium pipes 5. The pump 21 b is connected to a pipe that connects the heat exchanger related to heat medium 15b and the second heat medium channel switch units 23, among the heat medium pipes 5. It is desirable that the two pumps 21 be formed with, for example, a pump that may control its capacity, or the like. Note that the pump 21 a may be connected to a pipe that connects the heat exchanger related to heat medium 15a and the first heat medium channel switch units 22, among the heat medium pipes 5. Moreover, the pump 21 b may be connected to a pipe that connects the heat exchanger related to heat medium 15b and the first heat medium channel switch units 22, among the heat medium pipes 5.

**[0059]** The first heat medium channel switch units 22 perform switching between channels of the heat medium. The first heat medium channel switch units 22, the number of which corresponds to the number (here, four) of the indoor units 2 provided, are provided. One of three-way terminals of each of the first heat medium channel switch units 22 is connected to the heat exchanger related to heat medium 15a, another one of three-way terminals thereof is connected to the heat exchanger related to heat medium 15b, and the other one of three-way terminals thereof is connected to a corresponding one of the heat medium flow control devices 25. The first heat medium channel switch units 22 are each provided on an outlet side of a corresponding heat medium passage of the use-side heat exchangers 26. Note that the first heat medium channel switch units are the first heat medium channel switch unit 22a, the first heat medium channel switch unit 22b, the first heat medium channel switch unit 22c, and the first heat medium channel switch unit 22d from the bottom of the sheet in accordance with the indoor units 2. It is desirable that the first heat medium channel switch units 22 be formed with, for example, a three-way valve or the like.

**[0060]** The second heat medium channel switch units 23 perform switching between channels of the heat medium. The second heat medium channel switch units 23, the number of which corresponds to the number (here, four) of the indoor units 2 provided, are provided. One of three-way terminals of each of the second heat medium channel switch units 23 is connected to the heat exchanger related to heat medium 15a, another one of three-way terminals thereof is connected to the heat exchanger related to heat medium 15b, and the other one of three-way terminals thereof is connected to a corresponding one of the use-side heat exchangers 26. The second heat medium channel switch units 23 are each provided on an inlet side of the corresponding heat medium passage of the use-side heat exchangers 26. Note that the second heat medium channel switch units are the second heat medium channel switch unit 23a, the second heat medium channel switch unit 23b, the second heat medium channel switch unit 23c, and the second heat medium channel switch unit 23d from the bottom of the sheet in accordance with the indoor units 2. It is desirable that the second heat medium channel switch units 23 be formed with, for example, a three-way valve or the like.

**[0061]** The heat medium flow control devices 25 control the amount of the heat medium that flows in the heat medium pipes 5. The heat medium flow control devices 25, the number of which corresponds to the number (here, four) of the indoor units 2 provided, are provided. One terminal of each of the heat medium flow control devices 25 is connected to a corresponding one of the use-side heat exchangers 26, and the other terminal thereof is connected to a corresponding one of the first heat medium channel switch units 22. The heat medium flow control devices 25 are each provided on the outlet side of the corresponding heat medium passage of the use-side heat exchangers 26. Note that the heat medium flow control devices are illustrated as the heat medium flow control device 25a, the heat medium flow control device 25b, the heat medium flow control device 25c, and the heat medium flow control device 25d from the bottom of the sheet in accordance with the indoor units 2. Moreover, the heat medium flow control devices 25 may be each provided on the inlet side of the corresponding heat medium passage of the use-side heat exchangers 26. It is desirable that the heat medium flow control devices 25 be formed with, for example, a two-way valve that may control, for example, its opening area or the like.

**[0062]** Moreover, the heat medium relay unit 3 includes various detection units (two first temperature sensors 31 a and 31 b, four second temperature sensors 34a to 34d, four third temperature sensors 35a to 35d, and a pressure sensor 36 in Fig. 5). Information (temperature information and pressure information) detected by these detection units is sent to a control device (not illustrated) that performs central control on the operation of the air-conditioning apparatus 100, and is used to control a driving frequency of the compressor 10, the rotation speed of the air-sending device, which is not illustrated in the drawings but provided near the heat-source side heat exchanger 12 and the use-side heat exchangers 26, switching performed by the first refrigerant channel switch unit 11, a driving frequency of the pumps 21, switching performed by the second refrigerant channel switch units 18, switching between channels of heat medium circuits, and the like.

**[0063]** The two first temperature sensors 31 a and 31 b (also simply referred to as first temperature sensors 31) detect the temperature of the heat medium that has flown out from the heat exchangers related to heat medium 15, that is, the temperature of the heat medium at the outlets of the heat exchangers related to heat medium 15. The first temperature sensor 31 a is provided on the heat medium pipe 5 that is on the inlet side of the pump 21 a. The first temperature sensor 31 b is provided on the heat medium pipe 5 that is on the inlet side of the pump 21 b. It is desirable that the first temperature sensors 31 be formed with, for example, a thermistor or the like.

**[0064]** The four second temperature sensors 34a to 34d (also simply referred to as second temperature sensors 34) are provided between the first heat medium channel switch units 22 and the heat medium flow control devices 25, and detect temperatures of the heat medium that flows out from the use-side heat exchangers 26. The second temperature sensors 34 are provided in accordance with the number (here, four) of the provided indoor units 2. Note that the second temperature sensors are illustrated as the second temperature sensor 34a, the second temperature sensor 34b, the second temperature sensor 34c, and the second temperature sensor 34d from the bottom of the sheet in accordance with the indoor units 2. It is desirable that the second temperature sensors 34 be formed with, for example, a thermistor or the like.

**[0065]** The four third temperature sensors 35a to 35d (also simply referred to as third temperature sensors 35) are provided on inlet sides or outlet sides of the heat exchangers related to heat medium 15 through which the heat-source side refrigerant flows, and detect the temperatures of the heat-source side refrigerant that flows into the heat exchangers related to heat medium 15 or the temperatures of the heat-source side refrigerant that flows out from the heat exchangers related to heat medium 15. The third temperature sensor 35a is provided between the heat exchanger related to heat medium 15a and the second refrigerant channel switch unit 18a. The third temperature sensor 35b is provided between the heat exchanger related to heat medium 15a and the expansion unit 16a. The third temperature sensor 35c is provided between the heat exchanger related to heat medium 15b and the second refrigerant channel switch unit 18b. The third temperature sensor 35d is provided between the heat exchanger related to heat medium 15b and the expansion unit 16b. It is desirable that the third temperature sensors 35 be formed with, for example, a thermistor or the like.

**[0066]** The pressure sensor 36 is provided between the heat exchanger related to heat medium 15b and the expansion unit 16b, similarly to the setting position of the third temperature sensor 35d, and detects the pressure applied on the heat-source side refrigerant that flows between the heat exchanger related to heat medium 15b and the expansion unit 16b.

**[0067]** Moreover, a main controller, not illustrated, is configured with a microcomputer and the like to be provided, and controls the driving frequency of the compressor 10, the rotation speed (including ON/OFF) of the air-sending device (not illustrated), switching performed by the first refrigerant channel switch unit, driving of the pumps 21, the opening degree of the expansion units 16, opening and closing of the on-off units 17, switching performed by the second refrigerant channel switch units 18, switching performed by the first heat medium channel switch units 22, switching performed by the second heat medium channel switch units 23, and the opening degree of the heat medium flow control devices 25 and the like, on the basis of the information detected by the various detection units and instructions sent from a remote controller, thereby executing each operation mode described below. Note that a controller may be provided in each unit, or may be provided in the outdoor unit 1 or in the heat medium relay unit 3.

**[0068]** The heat medium pipes 5 in which the heat medium flows include a pipe that is connected to the heat exchanger related to heat medium 15a and a pipe that is connected to the heat exchanger related to heat medium 15b. The heat medium pipes 5 is divided into channels (here, each into four channels), the number of which corresponds to the number of indoor units 2 connected to the heat medium relay unit 3. Then, the heat medium pipes 5 are connected to the first heat medium channel switch units 22 and the second heat medium channel switch units 23. Whether the heat medium from the heat exchanger related to heat medium 15a flows into the use-side heat exchangers 26 or the heat medium from the heat exchanger related to heat medium 15b flows into the use-side heat exchangers 26 is set by controlling the first heat medium channel switch units 22 and the second heat medium channel switch units 23.

**[0069]** Then, the air-conditioning apparatus 100 includes the refrigerant circuit A, which has a structure in which the compressor 10, the first refrigerant channel switch unit 11, the heat-source side heat exchanger 12, the on-off units 17, the expansion units 16, passages of the heat exchangers related to heat medium 15 for the heat-source side refrigerant, the second refrigerant channel switch units 18, and the accumulator 19 are connected with the refrigerant pipes 4. Moreover, the heat medium circulation circuit B has a structure in which passages of the heat exchangers related to heat medium 15 for the heat medium, the pumps 21, the first heat medium channel switch units 22, the heat medium flow control devices 25, the use-side heat exchangers 26, and the second heat medium channel switch units 23 are connected with the heat medium pipes 5. That is, each of the heat exchangers related to heat medium 15 is connected to a plurality of use-side heat exchangers 26 in parallel, and thus the heat medium circulation circuit B has a plurality of systems.

**[0070]** Thus, in the air-conditioning apparatus 100, the outdoor unit 1 and the heat medium relay unit 3 are connected through the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b provided in the heat medium relay unit 3, and the heat medium relay unit 3 and the indoor units 2 are connected through the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b. That is, in the air-conditioning apparatus 100, the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b exchange heat between the heat-source side refrigerant circulating in the refrigerant circuit A and the heat medium that circulates in the heat medium circulation circuit B.

**[0071]** On the basis of instructions from each of indoor units 2, this air-conditioning apparatus 100 enable to perform a cooling operation or a heating operation possible by using the indoor unit 2. That is, the air-conditioning apparatus 100 can perform the same operation in the indoor units 2 or can perform individual operation in each of the indoor units 2 differently.

**[0072]** Operation modes performed by the air-conditioning apparatus 100 contain the cooling only operation mode in which all driving indoor units 2 execute the cooling operation, the heating only operation mode in which all driving indoor units 2 execute the heating operation, the cooling main operation mode as the cooling and heating mixed operation mode with a greater cooling load, and the heating main operation mode as the cooling and heating mixed operation mode with a greater heating load. In the following, each of the operation modes will be described in terms of the flow of the heat-source side refrigerant and that of the heat medium.

[Cooling Only Operation Mode]

**[0073]** Fig. 3 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus 100 in the cooling only operation mode. In Fig. 3, the cooling only operation mode is described in an example of the case where a cooling load is generated only in the use-side heat exchanger 26a and the use-side heat exchanger 26b. Note that, in Fig. 3, pipes drawn with a thick line indicate pipes in which the refrigerant (the heat-source side refrigerant and the heat medium) flows. Moreover, in Fig. 3, the direction in which the heat-source side refrigerant flows is indicated by arrows drawn with a solid line, and the direction in which the heat medium flows is indicated by arrows drawn with a broken line.

**[0074]** In the case of the cooling only operation mode illustrated in Fig. 3, the outdoor unit 1 makes the first refrigerant channel switch unit 11 perform switching in such a manner that the heat-source side refrigerant discharged from the compressor 10 flows into the heat-source side heat exchanger 12. The heat medium relay unit 3 drives the pump 21 a and the pump 21 b, opens the heat medium flow control device 25a and the heat medium flow control device 25b, fully opens the heat medium flow control device 25c and the heat medium flow control device 25d, and circulates the heat medium between the heat exchanger related to heat medium 15a and both the use-side heat exchanger 26a and use-side heat exchanger 26b and between the second heat exchanger related to heat medium 15b and both the use-side heat exchanger 26a and second use-side heat exchanger 26b.

**[0075]** At first, the flow of the heat-source side refrigerant in the refrigerant circuit A is described.

A low-temperature low-pressure refrigerant is compressed by the compressor 10, and becomes a high-temperature high-pressure refrigerant gas, which is then discharged. The high-temperature high-pressure refrigerant gas that has been discharged from the compressor 10 flows into the heat-source side heat exchanger 12 through the first refrigerant channel switch unit 11. The heat is transferred to the outside air in the heat-source side heat exchanger 12, and consequently, the high-temperature high-pressure refrigerant gas becomes a high-pressure liquid refrigerant.

The liquid refrigerant that has flown out from the heat-source side heat exchanger 12 flows out from the outdoor unit 1 through the pipe that is provided with the check valve 13a and the high-pressure side refrigerant pipe 4a (1), and flows into the heat medium relay unit 3 through the high-pressure side refrigerant pipe 4a(2).

The high-pressure liquid refrigerant that has flown into the heat medium relay unit 3 flows through the on-off unit 17a, then is divided and flows into the expansion unit 16a and the expansion unit 16b to be expanded. As a result, a low-temperature low-pressure two-phase refrigerant is obtained. Note that the on-off unit 17b is closed.

**[0076]** The low-temperature low-pressure two-phase refrigerant flows into each of the heat exchanger related to heat medium 15a and heat exchanger related to heat medium 15b that function as an evaporator. Then, the low-temperature low-pressure two-phase refrigerant becomes a low-temperature low-pressure refrigerant gas while absorbing heat from the heat medium that circulates in the heat medium circulation circuit B, and consequently, cooling the heat medium.

The refrigerant gas that has flown out from the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b flows out from the heat medium relay unit 3 through the second refrigerant channel switch unit 18a and the second refrigerant channel switch unit 18b, and then flows again into the outdoor unit 1 through the low-pressure side refrigerant pipe 4b (2).

The refrigerant gas that has flown into the outdoor unit 1 is sucked again by the compressor 10 through the low-pressure side refrigerant pipe 4b(1), the pipe to which the check valve 13d is connected, the first refrigerant channel switch unit 11, and the accumulator 19.

**[0077]** The opening degree of the expansion unit 16a is controlled in such a manner that superheating (a degree of superheat) obtained as the difference between the temperature detected by the third temperature sensor 35a and the temperature detected by the third temperature sensor 35b is constant. Similarly, the opening degree of the expansion unit 16b is controlled in such a manner that superheating obtained as the difference between the temperature detected by the third temperature sensor 35c and the temperature detected by the third temperature sensor 35d is constant.

**[0078]** Next, the flow of the heat medium in the heat medium circulation circuit B will be described.

In the cooling only operation mode, the cooling energy of the heat-source side refrigerant is transferred to the heat medium in both the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b, and the cooled heat medium is made to flow in the heat medium pipes 5 by the pump 21 a and pump 21b. The heat medium that has flown out by being compressed by the pump 21 a and the pump 21 b flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b through the second heat medium channel switch unit 23a and the second heat medium channel switch unit 23b. Then, the heat medium removes heat from the room air in the use-side heat exchanger 26a and the use-side heat exchanger 26b, and consequently, cooling for the room space 7 is performed.

**[0079]** Then, the heat medium flows out from the use-side heat exchanger 26a and the use-side heat exchanger 26b and flows into the heat medium flow control device 25a and the heat medium flow control device 25b. In this case, the amount of the flowing heat medium is controlled by the operation of the heat medium flow control device 25a and heat medium flow control device 25b so as to be the amount that is necessary to meet an air conditioning load that is needed in the room, and flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b.

The heat medium that has flown out from the heat medium flow control device 25a flows into the heat exchanger related to heat medium 15a and the second heat exchanger related to heat medium 15b through the first heat medium channel switch unit 22a, and is sucked again by the pump 21 a and the pump 21 b.

**[0080]** Note that, in the heat medium pipes 5 of the use-side heat exchangers 26, the heat medium flows in the direction from the second heat medium channel switch units 23 to the first heat medium channel switch units 22 via the heat medium flow control devices 25. Moreover, the air conditioning load can meet an amount needed in the room space 7 by performing control in such a manner that the differences between the temperature detected by the first temperature sensor 31 a and the temperatures detected by the second temperature sensors 34 or the differences between the temperature detected by the first temperature sensor 31 b and the temperatures detected by the second temperature sensors 34 are to have a target value. As an output temperature of the heat exchangers related to heat medium 15, either the temperature detected by the first temperature sensor 31 a or that detected by the first temperature sensor 31 b may be used, or the average of these temperatures may be used. In this case, the first heat medium channel switch units 22 and the second heat medium channel switch units 23 have an intermediate opening degree in such a manner that the heat medium flows in both channels for the heat exchanger related to heat medium 15a and channels for the heat exchanger related to heat medium 15b.

**[0081]** In the case where the cooling only operation mode is performed, since no heat medium need to flow into the use-side heat exchangers 26 that have no heating load (thermostat off is included), the heat medium flow control devices 25 close the channels so that the heat medium does not flow into the use-side heat exchangers 26. In Fig. 3, since the use-side heat exchanger 26a and the use-side heat exchanger 26b have a heating load, the heat medium flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b, while the use-side heat exchanger 26c and the use-side heat exchanger 26d have no heating load, and the corresponding heat medium flow control device 25c and the corresponding heat medium flow control device 25d are fully closed. In the case where a heating load is generated in the use-side heat exchanger 26c, the heat medium flow control device 25c is to be opened so as to circulate the heat medium. In the case where a heating load is generated in the use-side heat exchanger 26d, the heat medium flow control device 25d is to be opened so as to circulate the heat medium.
Note that this operation may be similarly applied in other operation modes.

[Heating Only Operation Mode]

**[0082]** Fig. 4 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus 100 in the heating only operation mode. In Fig. 4, the heating only operation mode is described in an example of the case where a heating load is generated only in the use-side heat exchanger 26a and the use-side heat exchanger 26b. Note that, in Fig. 4, pipes drawn with a thick line indicate pipes in which the refrigerant (the heat-source side refrigerant and the heat medium) flows. Moreover, in Fig. 4, the direction in which the heat-source side refrigerant flows is indicated by arrows drawn with a solid line, and the direction in which the heat medium flows is indicated by arrows drawn with a broken line.

**[0083]** In the case of the heating only operation mode illustrated in Fig. 4, the outdoor unit 1 makes the first refrigerant channel switch unit 11 perform switching in such a manner that the heat-source side refrigerant discharged from the compressor 10 flows into the heat medium relay unit 3 without flowing through the heat-source side heat exchanger 12. The heat medium relay unit 3 drives the pump 21 a and the pump 21 b, opens the heat medium flow control device 25a and the heat medium flow control device 25b, fully closes the heat medium flow control device 25c and the heat medium flow control device 25d, and circulates the heat medium between the heat exchanger related to heat medium 15a and both the use-side heat exchanger 26a and use-side heat exchanger 26b and between the heat exchanger related to heat medium 15b and both the use-side heat exchanger 26a and use-side heat exchanger 26b.

**[0084]** At first, the flow of the heat-source side refrigerant in the refrigerant circuit A is described.
A low-temperature low-pressure refrigerant is compressed by the compressor 10, and becomes a high-temperature high-pressure refrigerant gas, which is then discharged. The high-temperature high-pressure refrigerant gas that has been discharged from the compressor 10 flows out from the outdoor unit 1 through the first refrigerant channel switch unit 11, the first connection pipe 42a, and the high-pressure side refrigerant pipe 4a(1). The high-temperature high-pressure refrigerant gas that has flown out from the outdoor unit 1 flows into the heat medium relay unit 3 through the high-pressure side refrigerant pipe 4a(2). The high-temperature high-pressure refrigerant gas that has flown into the heat medium relay unit 3 is divided and flows into the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b through the second refrigerant channel switch unit 18a and the second refrigerant channel switch unit 18b.

**[0085]** The high-temperature high-pressure refrigerant that has flown into the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b becomes a high-pressure refrigerant whose temperature has decreased while transferring heat to the heat medium that circulates in the heat medium circulation circuit B. The liquid refrigerant that has flown out from the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b is expanded by the expansion unit 16a and the expansion unit 16b, and becomes a low-temperature low-pressure two-phase refrigerant. The low-temperature low-pressure two-phase refrigerant flows out from the heat medium relay unit 3 through the on-off unit 17b and flows again into the outdoor unit 1 through the low-pressure side refrigerant pipe 4b(2). Note that the on-off unit 17a is closed and the on-off unit 17b is opened.

**[0086]** The refrigerant that has flown into the outdoor unit 1 flows into the heat-source side heat exchanger 12, which operates as an evaporator, through the low-pressure side refrigerant pipe 4b(1) and the second connection pipe 42b. Then, the refrigerant that has flown into the heat-source side heat exchanger 12 removes heat from the outside air in the heat-source side heat exchanger 12, and becomes a low-temperature low-pressure refrigerant gas. The low-temperature low-pressure refrigerant gas that has flown out from the heat-source side heat exchanger 12 is sucked again by the compressor 10 through the first refrigerant channel switch unit 11 and the accumulator 19.

Note that the refrigerant that has flown into the low-pressure side refrigerant pipe 4b(1) flows into the second connection pipe 42b (the check valve 13c) but does not flow into the check valve 13d. This is because the refrigerant that flows at a point P1 illustrated in Fig. 4 is a higher pressure refrigerant than the refrigerant that flows at a point P3, and thus the check valve 13d closes.

The refrigerant that has flown into the second connection pipe 42b flows into the heat-source side heat exchanger 12 but does not flow into the check valve 13a. This is because the refrigerant that flows at a point P4 illustrated in Fig. 4 is a higher-pressure refrigerant than the refrigerant that flows at a point P2, and thus the check valve 13a closes.

**[0087]** The opening degree of the expansion unit 16a is controlled in such a manner that subcooling (a degree of subcooling) obtained as the difference between a saturation temperature, into which the pressure detected by the pressure sensor 36 is converted, and the temperature detected by the third temperature sensor 35b is constant. Similarly, the opening degree of the expansion unit 16b is controlled in such a manner that subcooling obtained as the difference between the saturation temperature, into which the pressure detected by the pressure sensor 36 is converted, and the temperature detected by the third temperature sensor 35d is constant. Note that, in the case where the temperature at a middle position of the heat exchangers related to heat medium 15 is measured, the temperature at the middle position may be used instead of using the pressure sensor 36, thereby reducing the cost of the system.

**[0088]** Next, the flow of the heat medium in the heat medium circulation circuit B will be described.

In the heating only operation mode, the heating energy of the heat-source side refrigerant is transferred to the heat medium in both the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b, and the heated heat medium is made to flow in the heat medium pipes 5 by the pump 21 a and pump 21b. The heat medium that has flown out by being compressed by the pump 21 a and the pump 21 b flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b through the second heat medium channel switch unit 23a and the second heat medium channel switch unit 23b. Then, the heat medium transfers heat to the room air in the use-side heat exchanger 26a and the use-side heat exchanger 26b, and consequently, heating for the room space 7 is performed.

**[0089]** Then, the heat medium flows out from the use-side heat exchanger 26a and the use-side heat exchanger 26b and flows into the heat medium flow control device 25a and the heat medium flow control device 25b. In this case, the amount of the flowing heat medium is controlled by the operation of the heat medium flow control device 25a and heat medium flow control device 25b so as to be the amount that is necessary to meet an air conditioning load that is needed in the room, and flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b. The heat medium that has flown out from the heat medium flow control device 25a and the heat medium flow control device 25b flows into the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b through the first heat medium channel switch unit 22a and the first heat medium channel switch unit 22b, and is sucked again by the pump 21 a and the pump 21 b.

**[0090]** Note that, in the heat medium pipes 5 of the use-side heat exchangers 26, the heat medium flows in the direction from the second heat medium channel switch units 23 to the first heat medium channel switch units 22 via the heat medium flow control devices 25. Moreover, the air conditioning load can meet an amount needed in the room space 7 by performing control in such a manner that the differences between the temperature detected by the first temperature sensor 31 a and the temperatures detected by the second temperature sensors 34 or the differences between the temperature detected by the first temperature sensor 31 b and the temperatures detected by the second temperature sensors 34 are to have a target value. As a temperature at the outlets of the heat exchangers related to heat medium 15, either the temperature detected by the first temperature sensor 31 a or that detected by the first temperature sensor 31 b may be used, or the average of these temperatures may be used.

**[0091]** In this case, the first heat medium channel switch units 22 and the second heat medium channel switch units 23 have an intermediate opening degree in such a manner that the heat medium flows in both the channels for the heat exchanger related to heat medium 15a and the heat exchanger related to heat medium 15b. Moreover, it is primarily desirable that the use-side heat exchanger 26a is controlled by the difference between the temperature at the inlet and the temperature at the outlet thereof; however, the temperatures of the heat medium on the inlet sides of the use-side heat exchangers 26 are almost the same as the temperature detected by the first temperature sensor 31 b. The number of temperature sensors may be reduced by using the first temperature sensor 31 b, thereby reducing the cost of the system.

[Cooling Main Operation Mode]

**[0092]** Fig. 5 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus 100 in the cooling main operation mode. In Fig. 5, the cooling main operation mode is described in an example of the case where a cooling load is generated in the use-side heat exchanger 26a and a heating load is generated in the use-side heat exchanger 26b. Note that, in Fig. 5, pipes drawn with a thick line indicate pipes in which the refrigerant (the heat-source side refrigerant and the heat medium) flows. Moreover, in Fig. 5, the direction in which the heat-source side refrigerant flows is indicated by arrows drawn with a solid line, and the direction in which the heat medium flows is indicated by arrows drawn with a broken line.

**[0093]** In the case of the cooling main operation mode illustrated in Fig. 5, the outdoor unit 1 makes the first refrigerant channel switch unit 11 perform switching in such a manner that the heat-source side refrigerant discharged from the compressor 10 flows into the heat-source side heat exchanger 12. The heat medium relay unit 3 drives the pump 21 a and the pump 21 b, opens the heat medium flow control device 25a and the heat medium flow control device 25b, fully closes the heat medium flow control device 25c and the heat medium flow control device 25d, and circulates the heat medium between the heat exchanger related to heat medium 15a and the use-side heat exchanger 26a and between the heat exchanger related to heat medium 15b and the use-side heat exchanger 26b.

**[0094]** At first, the flow of the heat-source side refrigerant in the refrigerant circuit A is described.

A low-temperature low-pressure refrigerant is compressed by the compressor 10, and becomes a high-temperature high-pressure refrigerant gas, which is then discharged. The high-temperature high-pressure refrigerant gas that has been discharged from the compressor 10 flows into the heat-source side heat exchanger 12 through the first refrigerant channel switch unit 11. The high-temperature high-pressure refrigerant gas becomes a liquid refrigerant while transferring heat to the outside air in the heat-source side heat exchanger 12.

The high-pressure liquid refrigerant that has flown out from the heat-source side heat exchanger 12 flows out from the outdoor unit 1 through the pipe that is provided with the check valve 13a and the high-pressure side refrigerant pipe 4a(1), and flows into the heat medium relay unit 3 through the high-pressure side refrigerant pipe 4a (2). The high-pressure liquid refrigerant that has flown into the heat medium relay unit 3 flows through the second refrigerant channel switch unit 18b and flows into the heat exchanger related to heat medium 15b, which functions as a condenser. Note that the on-off units 17 are closed.

**[0095]** The refrigerant that has flown into the heat exchanger related to heat medium 15b becomes a further low-temperature refrigerant while transferring heat to the heat medium that circulates in the heat medium circulation circuit B. The refrigerant that has flown out from the heat exchanger related to heat medium 15b is expanded by the expansion unit 16b and becomes a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows into the heat exchanger related to heat medium 15a, which functions as an evaporator, through the expansion unit 16a. The low-pressure two-phase refrigerant that has flown into the heat exchanger related to heat medium 15a becomes a low-pressure refrigerant gas while cooling the heat medium that circulates in the heat medium circulation circuit B by absorbing heat from the heat medium. The refrigerant gas that has flown out from the heat exchanger related to heat medium 15a flows out from the heat medium relay unit 3 through the second refrigerant channel switch unit 18a, and flows again into the outdoor unit 1 through the low-pressure side refrigerant pipe 4b(2). The refrigerant that has flown into the outdoor unit 1 is sucked again by the compressor 10 through the low-pressure side refrigerant pipe 4b(1); the pipe that is provided with the check valve 13d; the first refrigerant channel switch unit 11; and the accumulator 19.

**[0096]** The opening degree of the expansion unit 16b is controlled in such a manner that superheating obtained as the difference between the temperature detected by the third temperature sensor 35a and the temperature detected by the third temperature sensor 35b is constant. Here, the expansion unit 16a is fully opened, the on-off unit 17a and the on-off unit 17b are closed. Note that the opening degree of the expansion unit 16b may be controlled in such a manner that subcooling obtained as the difference between a saturation temperature, into which the pressure detected by the pressure sensor 36 is converted, and the temperature detected by the third temperature sensor 35d is constant. Moreover, the expansion unit 16b may be fully opened, and superheating or subcooling may be controlled by the expansion unit 16a.

**[0097]** Next, the flow of the heat medium in the heat medium circulation circuit B will be described.

In the cooling main operation mode, the heating energy of the heat-source side refrigerant is transferred to the heat medium in the heat exchanger related to heat medium 15b, and the heated heat medium is made to flow in the heat medium pipes 5 by the pump 21 b. Moreover, in the cooling main operation mode, the cooling energy of the heat-source side refrigerant is transferred to the heat medium in the heat exchanger related to heat medium 15a, and the cooled heat medium is made to flow in the heat medium pipes 5 by the pump 21 a. The heat medium that has flown out by being compressed by the pump 21 a and the pump 21 b flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b through the second heat medium channel switch unit

23a and the second heat medium channel switch unit 23b.

**[0098]** The heat medium transfers heat to the room air in the use-side heat exchanger 26b, and consequently, heating for the room space 7 is performed. Moreover, the heat medium removes heat from the room air in the use-side heat exchanger 26a, and consequently, cooling for the room space 7 is performed. In this case, the amount of the flowing heat medium is controlled by the operation of the heat medium flow control device 25a and heat medium flow control device 25b so as to be the amount that is necessary to meet an air conditioning load that is needed in the room, and flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b. The heat medium that has flown through the use-side heat exchanger 26b and whose temperature has slightly decreased flows into the heat exchanger related to heat medium 15b through the heat medium flow control device 25b and the first heat medium channel switch unit 22b, and is sucked again by the pump 21 b. The heat medium that has flown through the use-side heat exchanger 26a and the whose temperature has slightly increased flows into the heat exchanger related to heat medium 15a through the heat medium flow control device 25a and the first heat medium channel switch unit 22a, and is sucked again by the pump 21 a.

**[0099]** During this time, the warm heat medium is not mixed with the cold heat medium by the operation of the first heat medium channel switch units 22 and second heat medium channel switch units 23. The warm heat medium is guided to the use-side heat exchanger 26 that has a heating load, and the cold heat medium is guided to the use-side heat exchanger 26 that has a cooling load. Note that, in the heat medium pipes 5 of the use-side heat exchangers 26, the heat medium flows in the direction from the second heat medium channel switch units 23 to the first heat medium channel switch units 22 via the heat medium flow control devices 25 on both heating and cooling sides. Moreover, the air conditioning load can meet an amount needed in the room space 7 by performing control in such a manner that the differences between the temperature detected by the first temperature sensor 31 b and the temperatures detected by the second temperature sensors 34 on the heating side and the differences between the temperatures detected by the second temperature sensors 34 and the temperature detected by the first temperature sensor 31 a on the cooling side are kept as a target value.

[Heating Main Operation Mode]

**[0100]** Fig. 6 is a diagram of a refrigerant circuit illustrating a flow of the refrigerant in the air-conditioning apparatus 100 in the heating main operation mode. In Fig. 6, the heating main operation mode is described in an example of the case where a heating load is generated in the use-side heat exchanger 26a and a cooling load is generated in the use-side heat exchanger 26b. Note that, in Fig. 6, pipes drawn with a thick line indicate pipes in which the refrigerant (the heat-source side refrigerant and the heat medium) flows. Moreover, in Fig. 6, the direction in which the heat-source side refrigerant flows is indicated by arrows drawn with a solid line, and the direction in which the heat medium flows is indicated by arrows drawn with a broken line.

**[0101]** In the case of the heating main operation mode illustrated in Fig. 6, the outdoor unit 1 makes the first refrigerant channel switch unit 11 perform switching in such a manner that the heat-source side refrigerant discharged from the compressor 10 flows into the heat medium relay unit 3 without flowing through the heat-source side heat exchanger 12. The heat medium relay unit 3 drives the pump 21 a and the pump 21 b, opens the heat medium flow control device 25a and the heat medium flow control device 25b, fully closes the heat medium flow control device 25c and the heat medium flow control device 25d, and circulates the heat medium between the heat exchanger related to heat medium 15a and the use-side heat exchanger 26b and between the heat exchanger related to heat medium 15b and the use-side heat exchanger 26a.

**[0102]** At first, the flow of the heat-source side refrigerant in the refrigerant circuit A is described.

A low-temperature low-pressure refrigerant is compressed by the compressor 10, and becomes a high-temperature high-pressure refrigerant gas, which is then discharged. The high-temperature high-pressure refrigerant gas that has been discharged from the compressor 10 flows out from the outdoor unit 1 through the first refrigerant channel switch unit 11, the first connection pipe 42a, and the high-pressure side refrigerant pipe 4a(1). The high-temperature high-pressure refrigerant gas that has flown out from the outdoor unit 1 flows into the heat medium relay unit 3 through the high-pressure side refrigerant pipe 4a(2). The high-temperature high-pressure refrigerant gas that has flown into the heat medium relay unit 3 flows into the heat exchanger related to heat medium 15b, which functions as a condenser, through the second refrigerant channel switch unit 18b. Note that the on-off units 17 are closed.

**[0103]** The refrigerant gas that has flown into the heat exchanger related to heat medium 15b becomes a low-temperature refrigerant in a supercritical state while the refrigerant gas transfers heat to the heat medium that circulates in the heat medium circulation circuit B. The refrigerant that has flown out from the heat exchanger related to heat medium 15b is expanded by the expansion unit 16b and becomes a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows into the heat exchanger related to heat medium 15a, which functions as an evaporator, through the expansion unit 16a. The low-pressure two-phase refrigerant that has flown into the heat exchanger related to heat medium 15a evaporates by absorbing heat from the heat medium that circulates in the heat medium circulation circuit B, and consequently, cools the heat medium. The low-pressure two-phase refrigerant flows out from the heat exchanger related to heat medium 15a, flows out from the heat medium relay unit 3 through the second refrigerant channel switch unit 18a, and flows again into the outdoor unit 1 through the low-pressure side refrigerant pipe 4b (2).

**[0104]** The refrigerant that has flown into the outdoor unit 1 flows into the heat-source side heat exchanger 12, which functions as an evaporator, through the low-pressure side refrigerant pipe 4b(1) and the second connection pipe 42b. The refrigerant that has flown into the heat-source side heat exchanger 12 removes heat from the outside air in the heat-source side heat exchanger 12, and consequently, becomes a low-temperature low-pressure refrigerant gas. The low-temperature low-pressure refrigerant gas that has flown out from the heat-source side heat exchanger 12 is sucked again by the compressor 10 through the first refrigerant channel switch unit 11 and the accumulator 19.

**[0105]** The opening degree of the expansion unit 16b is controlled in such a manner that subcooling obtained as the difference between a saturation temperature, into which the pressure detected by the pressure sensor 36 is converted, and the temperature detected by the third temperature sensor 35b is constant. Here, the expansion unit 16a is fully opened, and the on-off unit 17b is closed. Note that the expansion unit 16b may be fully opened and subcooling may be controlled by the expansion unit 16a.

**[0106]** Next, the flow of the heat medium in the heat medium circulation circuit B will be described.
In the heating main operation mode, the heating energy of the heat-source side refrigerant is transferred to the heat medium in the heat exchanger related to heat medium 15b, and the heated heat medium is made to flow in the heat medium pipes 5 by the pump 21 b. Moreover, in the heating main operation mode, the cooling energy of the heat-source side refrigerant is transferred to the heat medium in the heat exchanger related to heat medium 15a, and the cooled heat medium is made to flow in the heat medium pipes 5 by the pump 21 a. The heat medium that has flown out by being compressed by the pump 21 a and the pump 21 b flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b through the second heat medium channel switch unit 23a and the second heat medium channel switch unit 23b.

**[0107]** The heat medium removes heat from the room air in the use-side heat exchanger 26b, and consequently, cooling for the room space 7 is performed. Moreover, the heat medium transfers heat to the room air in the use-side heat exchanger 26a, and consequently, heating for the room space 7 is performed. In this case, the amount of the heat medium that flows is controlled by the operation of the heat medium flow control device 25a and heat medium flow control device 25b so as to be the amount that is necessary to meet an air conditioning load that is needed in the room, and flows into the use-side heat exchanger 26a and the use-side heat exchanger 26b. The heat medium that has flown through the use-side heat exchanger 26b and the whose temperature has slightly increased flows into the heat exchanger related to heat medium 15a through the heat medium flow control device 25b and the first heat medium channel switch unit 22b, and is sucked again by the pump 21a. The heat medium that has flown through the use-side heat exchanger 26a and the whose temperature has slightly decreased flows into the heat exchanger related to heat medium 15b through the heat medium flow control device 25a and the first heat medium channel switch unit 22a, and is sucked again by the pump 21 b.

**[0108]** During this time, the warm heat medium is not mixed with the cold heat medium by the operation of the first heat medium channel switch units 22 and second heat medium channel switch units 23. The warm heat medium is guided to the use-side heat exchanger 26 that has a heating load, and the cold heat medium is guided to the use-side heat exchanger 26 that has a cooling load. Note that, in the heat medium pipes 5 of the use-side heat exchangers 26, the heat medium flows in the direction from the second heat medium channel switch units 23 to the first heat medium channel switch units 22 via the heat medium flow control devices 25 on both heating and cooling sides. Moreover, the air conditioning load can meet an amount needed in the room space 7 by performing control in such a manner that the differences between the temperature detected by the first temperature sensor 31 b and the temperatures detected by the second temperature sensors 34 on the heating side and the differences between the temperatures detected by the second temperature sensors 34 and the temperature detected by the first temperature sensor 31 a on the cooling side are kept as a target value.

[Refrigerant Pipes 4]

**[0109]** As described above, the air-conditioning apparatus 100 according to Embodiment is provided with some operation modes. In these operation modes, the heat-source side refrigerant flows in the refrigerant pipes 4 that connect the outdoor unit 1 and the heat medium relay unit 3.

[Heat Medium Pipes 5]

**[0110]** In some of the operation modes performed by the air-conditioning apparatus 100 according to Embodiment, a heat medium such as water and an antifreezing solution flows in the heat medium pipes 5 that connect the heat medium relay unit 3 and the indoor units 2.

[Heat-Source Side Refrigerant]

**[0111]** In the air-conditioning apparatus 100 according to Embodiment, a refrigerant that has a small global warming potential is used as the heat-source side refrigerant. Examples of such a refrigerant include HFO1234yf, refrigerant mixture using HFO1234yf, HFO1234ze, other tetrafluoropropene-based refrigerants, R32, HC, carbon dioxide, a refrigerant mixture containing at least one of the above-described refrigerants as a component, and the like.

[Heat Medium]

**[0112]** As the heat medium, for example, brine (an antifreezing solution), water, a mixed solution of brine and water, a mixed solution in which water and an additive that has a high anti-corrosive effect are mixed, and the like may be used. Thus, in the air-conditioning apparatus 100, even in the case where the heat medium leaks into the room space 7 through the indoor unit 2, since the heat medium with a high degree of safety is used, the degree of safety is improved.

**[0113]** The air-conditioning apparatus 100 which employs the above-described structure makes it possible to detect leaking of the refrigerant from the refrigerant circuit (the refrigerant circuit A), and consequently, the degree of safety is greatly improved. Moreover, by using a refrigerant that can transition into a supercritical state, the air-conditioning apparatus 100 can reduce the environmental load.

**[0114]** The air-conditioning apparatus 100 has been described as an air-conditioning apparatus that can perform the cooling and heating mixed operation; however, the air-conditioning apparatus 100 is not limited thereto. For example, the present invention may be applied to air-conditioning apparatuses that have a structure in which one heat exchanger related to heat medium 15 and one expansion unit 16 are included and a plurality of use-side heat exchangers 26 and a plurality of heat medium flow control devices 25 are connected to the heat exchanger related to heat medium 15 and the expansion unit 16 in parallel and that may only perform either the cooling operation or the heating operation.

**[0115]** Moreover, the present invention may be applied to the case in which one use-side heat exchanger 26 and one heat medium flow control device 25 are connected. Furthermore, it is clear that, a plurality of units that function the same as the heat exchangers related to heat medium 15 and the expansion units 16 may be provided. Furthermore, the example in which the heat medium flow control devices 25 are built in the heat medium relay unit 3 has been described; however, the structure is not limited thereto and the heat medium flow control devices 25 may be built in the indoor units 2. The heat medium relay unit 3 and the indoor units 2 may also be separately provided.

**[0116]** Moreover, in general, the heat-source side heat exchanger 12 and the use-side heat exchangers 26 are equipped with an air-sending device to accelerate condensation and evaporation by blowing air; however, the structure is not limited thereto. For example, something like a panel heater that utilizes eradiation may also be used as the use-side heat exchangers 26 or water-cooled type heat exchangers in which heat is transferred by using water or an antifreezing solution may also be used as the heat-source side heat exchanger 12. That is, a structure that can transfer or remove heat, regardless of the kind of units, may be used as the heat-source side heat exchanger 12 and the use-side heat exchangers 26.

**[0117]** In the air-conditioning apparatus 100 according to Embodiment, the examples in which four use-side heat exchangers 26 are used has been described; however the number of the use-side heat exchangers 26 is not limited thereto. Moreover, the examples in which two heat exchangers related to heat medium 15 are used has been described; however, as a matter of course, the number of the heat exchangers related to heat medium 15 is not limited thereto. If the air-conditioning apparatus 100 is configured to be able to cool or/and heat the heat medium, the number of the heat exchangers related to heat medium 15 does not matter. Furthermore, the number of the pump 21 a and that of the pump 21 b do not have to be one, and a plurality of pumps, each of which has a small capacity, may be arranged and connected in parallel.

**[0118]** Fig. 8 is a diagram illustrating an example of the structure of another refrigerant circuit of the air-conditioning apparatus 100 according to Embodiment of the present invention. A difference between Fig. 8 and Figs. 2 to 6 is that a direct expansion type air-conditioning apparatus that does not have the heat medium circulation circuit B is used. Furthermore, four expansion units 14a to 14d are provided. Even in the air-conditioning apparatus 100 having this structure, the effects similar in the cases of Figs. 2 to 6 are obtained by the operation of the concentration detection unit 39, the concentration calculation unit 41, the first cutoff unit 37, the second cutoff unit 38 and the cutoff control unit 40.

Note that the examples in which the concentration detection unit 39 is arranged in or near the outdoor unit 1 (a heat source unit) have been described; however, the concentration detection unit 39 may be arranged in or near the indoor units 2. As a result, leaking of the refrigerant from the indoor units 2 may also be handled. Reference Signs List

**[0119]** 1 outdoor unit, 2 indoor unit, 2a to 2d indoor unit, 3 heat medium relay unit, 4 refrigerant pipe, 4a(1), 4a(2) high-pressure side refrigerant pipe, 4b(1), 4b(2) low-pressure side refrigerant pipe, 5 heat medium pipe, 6 outdoor space, 7 room space, 8 space, 9 building, 10 compressor, 11 first refrigerant channel switch unit, 12 heat-source side heat exchanger, 13a to 13d check valve, 15 heat exchanger related to heat medium, 14a to 14d expansion unit, 15a, 15b heat exchanger related to heat medium, 16 expansion unit, 16a, 16b expansion unit, 17 on-off unit, 17a, 17b on-off unit, 18 second refrigerant channel switch unit, 18a, 18b second refrigerant channel switch unit, 19 accumulator, 21 pump, 21 a, 21 b pump, 22 first heat medium channel switch unit, 22a to 22d first heat medium channel switch unit, 23 second heat medium channel switch unit, 23a to 23d second heat medium channel switch unit, 25 heat medium flow control device, 25a to 25d heat medium flow control device, 26 use-side heat exchanger, 26a to 26d use-side heat exchanger, 31 first temperature sensor, 31 a, 31 b first temperature sensor, 34 second temperature sensor, 34a to 34d second temperature sensor, 35 third temperature sensor, 35a to 35d third temperature sensor, 36 pressure sensor, 37 first cutoff unit, 38 second cutoff unit, 39 concentration detection unit, 40 cutoff control unit, 41 concentration calculation unit, 42a first connection pipe, 42b second connection pipe, 100 air-conditioning apparatus, A refrigerant circuit, B heat medium circulation circuit

## Claims

1. An air-conditioning apparatus that includes a refrigeration cycle in which a compressor, a heat-source side heat exchanger, an expansion unit, and a load-side heat exchanger are included and are connected with refrigerant pipes, the air-conditioning apparatus comprising:

   a cutoff unit capable of flowing or cutting off a refrigerant circulating in the refrigeration cycle;
   a detection unit detecting leaking of the refrigerant on the basis of a resistance that changes with densities of plural kinds of leaked refrigerants;
   a concentration calculation unit calculating a concentration of the refrigerant that has leaked, on the basis of the resistance of the detection unit;
   a concentration detection unit outputting a calculation result of the concentration calculation unit in order that the calculation result is used for controlling the cutoff unit; and
   a cutoff control unit controlling the cutoff unit on the basis of an output of the concentration detection unit.

2. The air-conditioning apparatus of claim 1,
   wherein the detection unit is formed using a stannic oxide semiconductor ($SnO_2$).

3. The air-conditioning apparatus of claim 1 or 2,
   wherein at least R410A, R407C, R32, R404A, HFO1234yf, HFO1234ze, a refrigerant mixture including R32 and HFO1234yf, and all refrigerant mixtures including at least one of these refrigerants as a component are detectable by the single detection unit.

4. The air-conditioning apparatus of claim 3,
   wherein the concentration calculation unit
   is capable of calculating the concentration of the refrigerant that has leaked, by using a single relational expression regarding changes in the resistance and in concentration, for R410A, R407C, R32, HFO1234yf, HFO1234ze, a refrigerant mixture including R32 and HFO1234yf, and all refrigerant mixtures including at least one of these refrigerants as a component.

5. The air-conditioning apparatus of any one of claims 1 to 4,
   wherein the concentration detection unit outputs a predetermined signal that makes the cutoff unit cut off circulation of the refrigerant to the cutoff control unit
   in a case where a calculation result regarding the concentration of the refrigerant from the concentration calculation unit is greater than or equal to a predetermined value.

6. The air-conditioning apparatus of claim 5,
   wherein the predetermined signal is within 1 (V) to 24 (V).

7. The air-conditioning apparatus of any one of claims 1 to 6, further comprising
   an outdoor unit including the compressor and the heat-source side heat exchanger,
   wherein the cutoff unit
   is provided in the outdoor unit or near the outdoor unit.

8. The air-conditioning apparatus of any one of claims 1 to 7,
   wherein the cutoff control unit is a non-contact relay formed with a semiconductor element.

9. The air-conditioning apparatus of any one of claims 1 to 8,
   wherein the cutoff unit is in an open state when energized and in a closed state when not energized.

10. The air-conditioning apparatus of any one of claims 7 to 9,
   wherein the cutoff unit
   is one of a plurality of cutoff units and at least one cutoff unit is provided at each of an outlet out of which the refrigerant flows from the outdoor unit and an inlet into which the refrigerant flows toward the outdoor unit.

11. The air-conditioning apparatus of any one of claims 1 to 10,
   wherein the cutoff unit is a two-way valve including a valve body, a sealing material that seals the valve body, and a coil that opens and closes the valve body by electromagnetic force.

12. The air-conditioning apparatus of any one of claim 11,

wherein the sealing material is composed of rubber or PTFE (polytetrafluoroethylene).

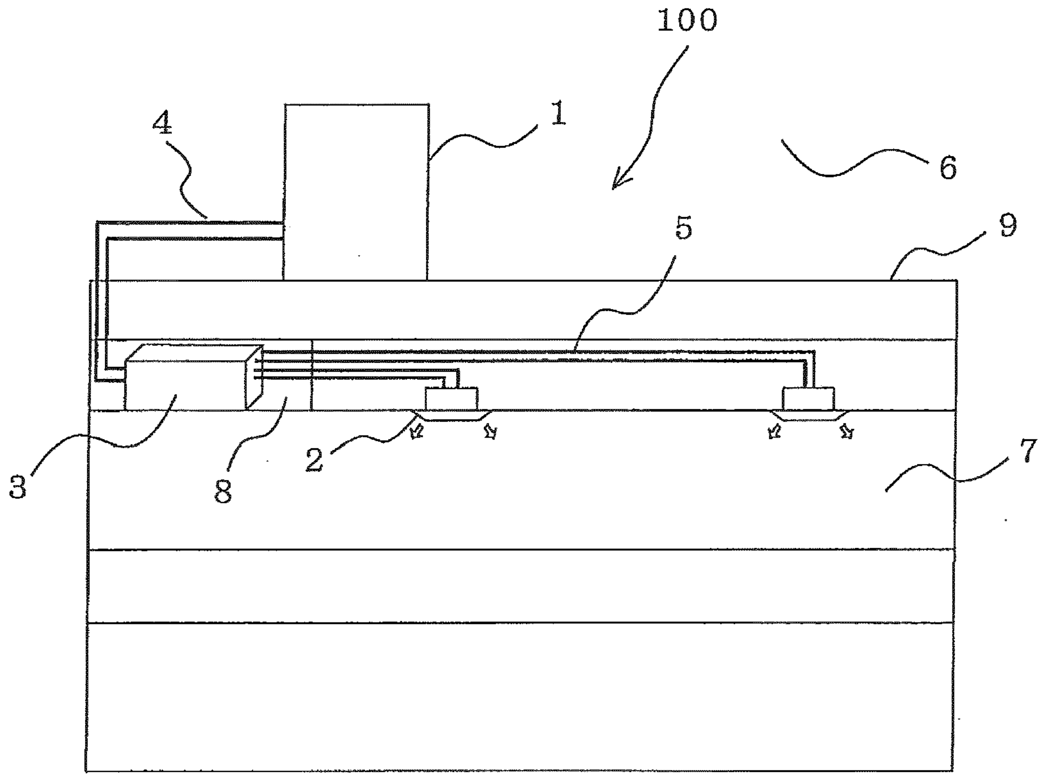
**13.** The air-conditioning apparatus of any one of claims 1 to 12,
wherein the cutoff unit
is designed to accept leakage of $1.0 \times 10^{-6}$ ($m^3$/sec) or smaller for the heat-source side refrigerant in a closed state.

**14.** The air-conditioning apparatus of any one of claims 1 to 13,
wherein assuming that a discharge side of the compressor is an upstream,
a value of a flow coefficient Cv is set to 1 or higher for a cutoff unit provided on a downstream side of the heat exchanger related to heat medium, among the cutoff units, and
a value of the flow coefficient Cv is set to 5 or higher for a cutoff unit provided on an upstream side of the heat exchanger related to heat medium, among the cutoff units.

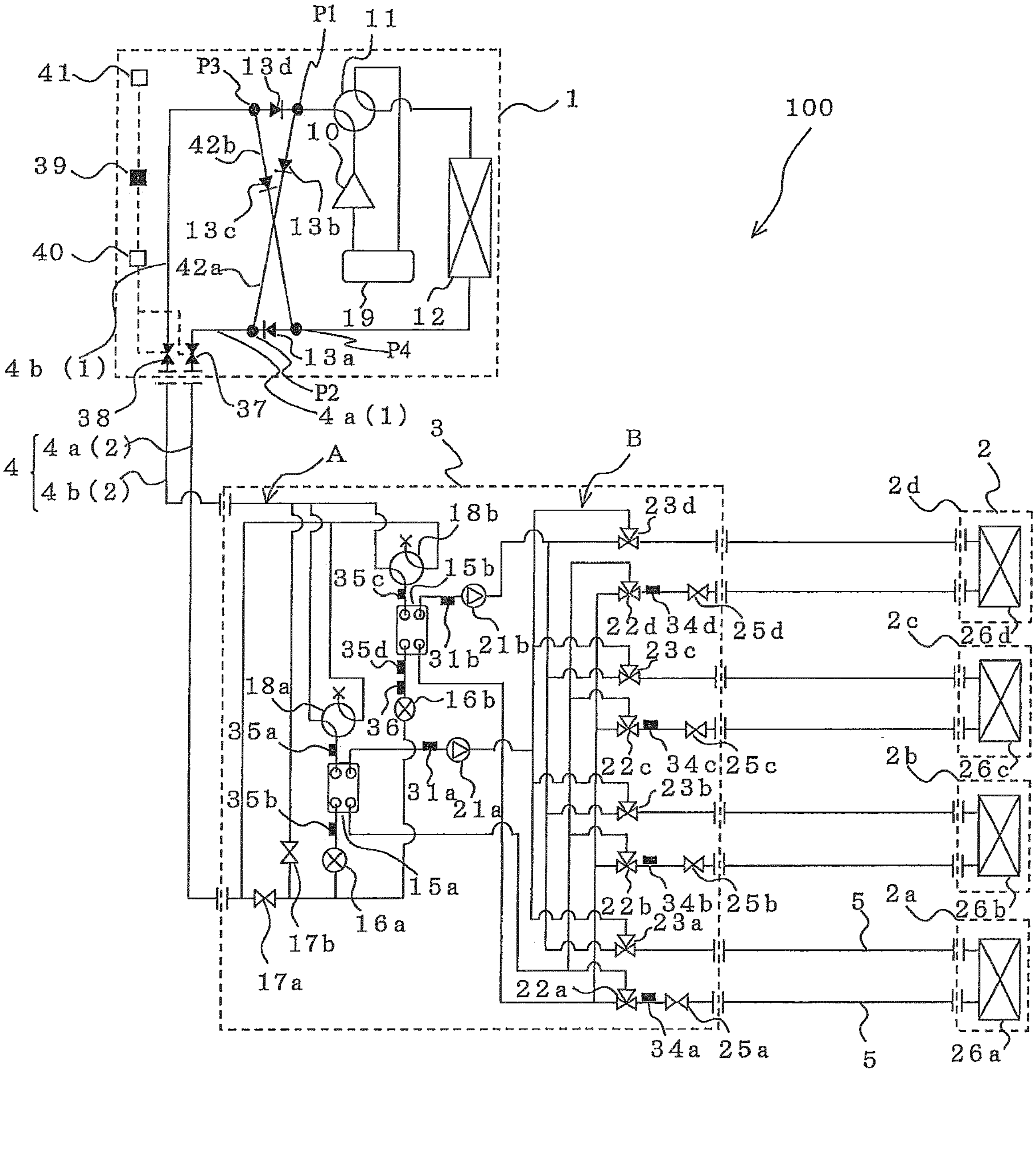
**15.** The air-conditioning apparatus of any one of claims 11 to 14,
wherein a direct-current voltage is applied to the coil.

**16.** The air-conditioning apparatus of claim 15,
wherein the direct-current voltage applied to the coil is within 12 (V) to 24 (V).

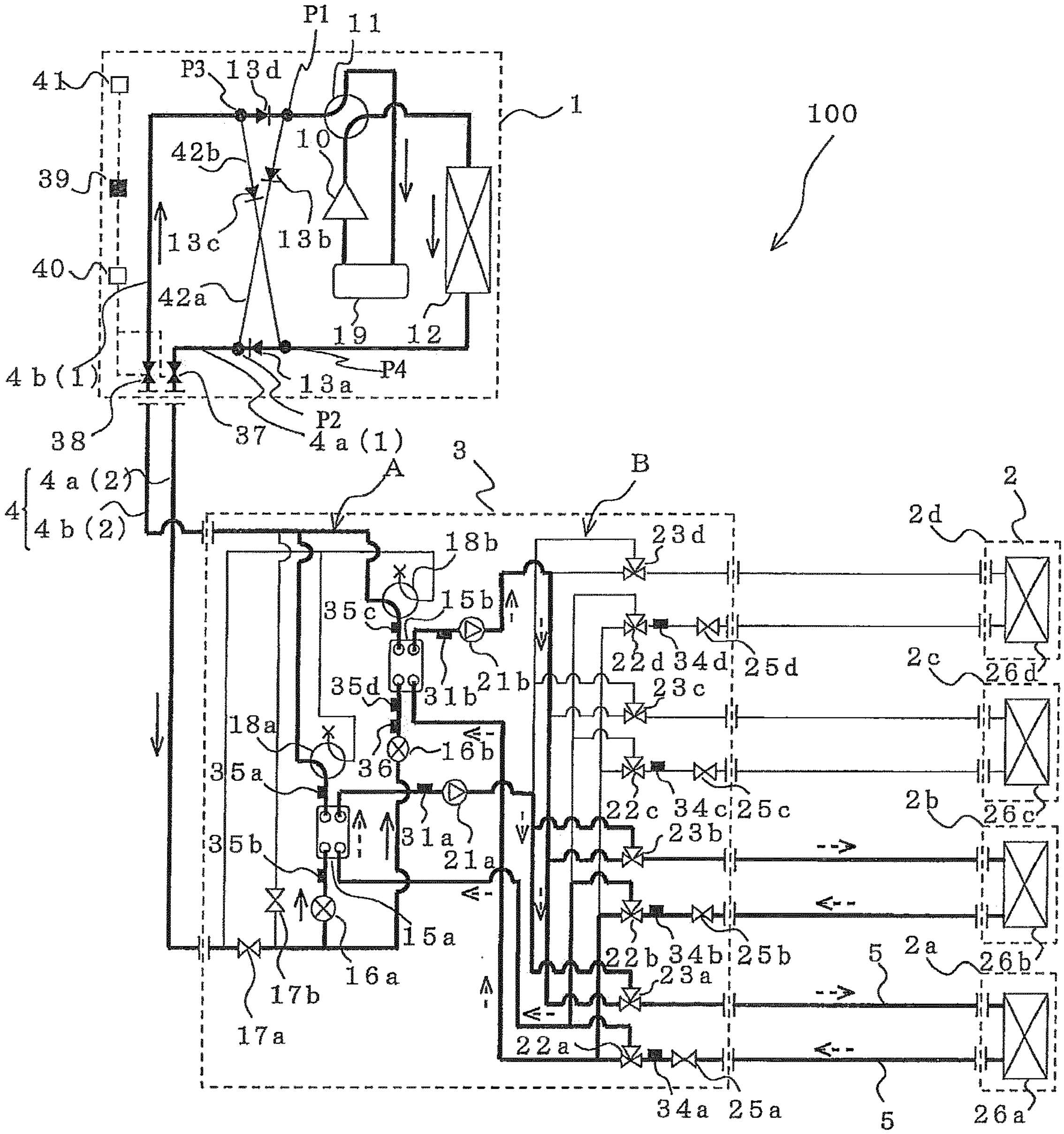
F I G. 1



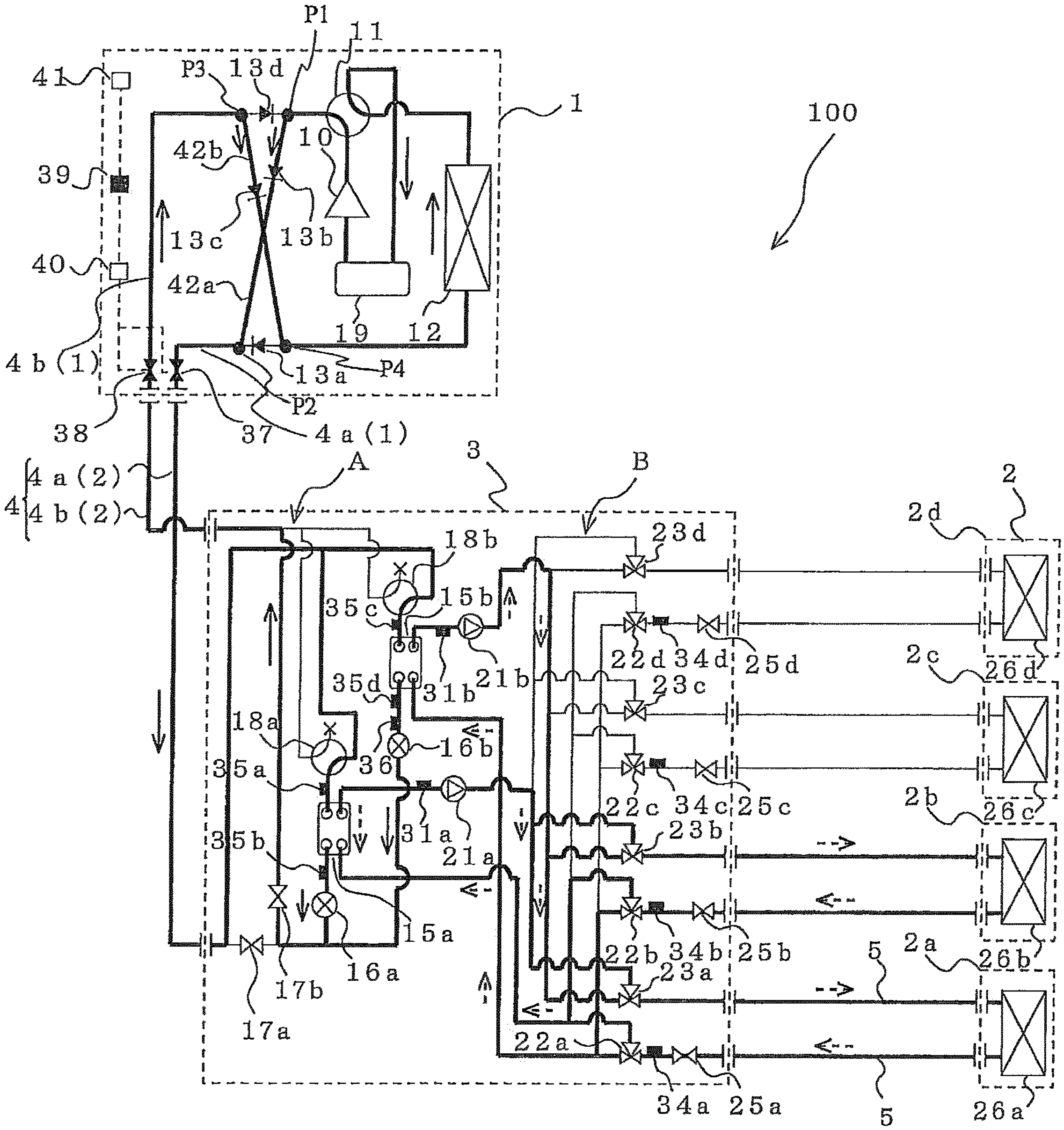
F I G. 2


100
1
41
39
40
P3
13d
P1
11
10
42b
13c
13b
42a
19
12
4b (1)
13a
P4
P2
38
37
4a(1)
4
4a(2)
4b(2)
3
A
B
2
2d
2c
2b
2a
18b
15b
35c
21b
31b
35d
23d
22d
34d
25d
26d
23c
22c
34c
25c
26c
18a
16b
36
35a
31a
21a
35b
15a
16a
17b
17a
23b
22b
34b
25b
26b
23a
22a
34a
25a
26a
5

F I G. 3


P1
11
41
P3
13d
1
100
10
42b
39
13b
13c
40
42a
19
12
4b(1)
13a
P4
38
37
P2
4a(1)
3
B
2
A
4a(2)
4
4b(2)
2d
23d
18b
15b
35c
22d
34d
25d
21b
2c
26d
35d
31b
23c
18a
36
16b
35a
22c
34c
25c
2b
26c
31a
23b
35b
21a
15a
22b
34b
25b
2a
26b
17b
16a
23a
5
17a
22a
34a
25a
5
26a

F I G. 4


P1
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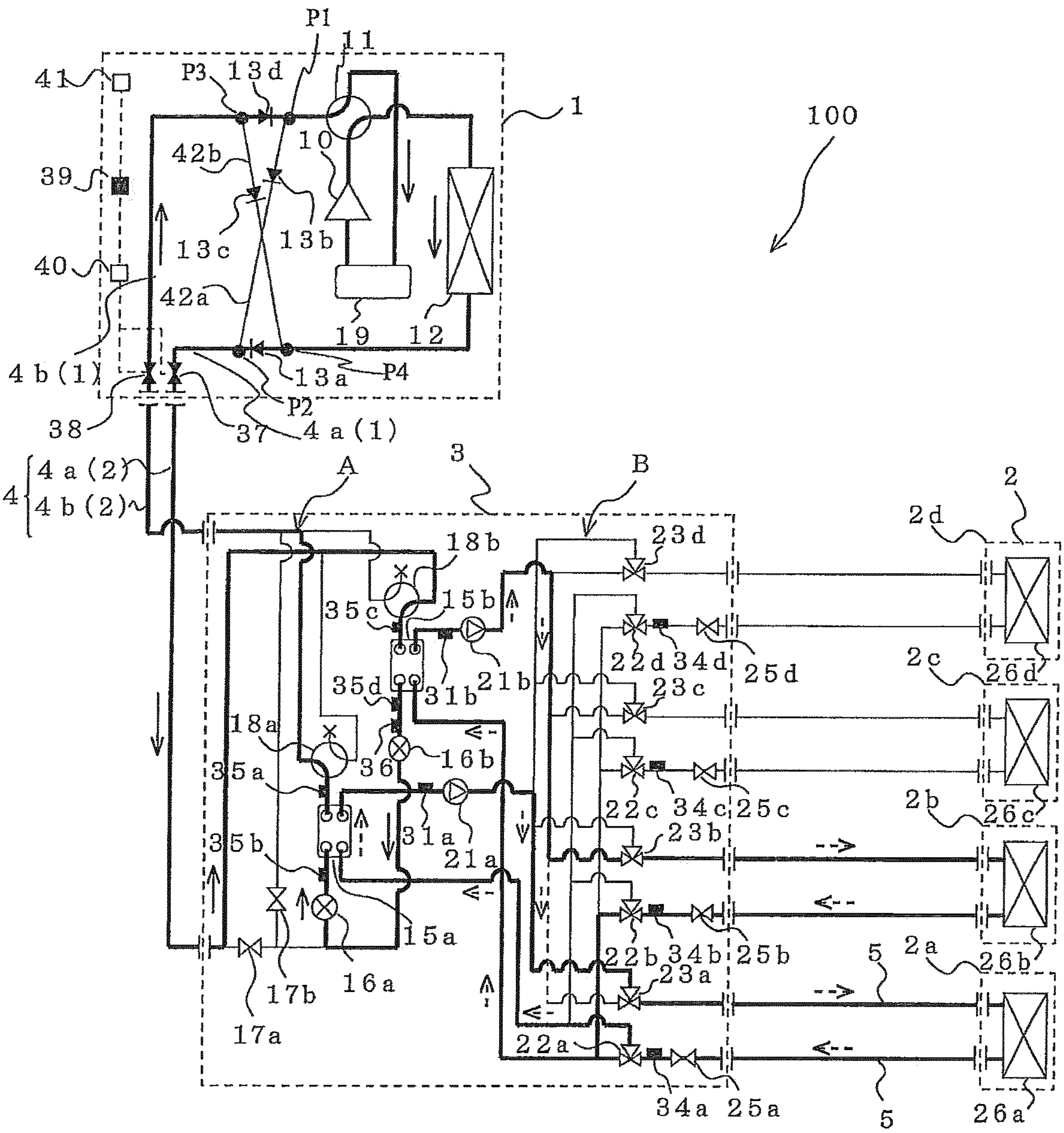
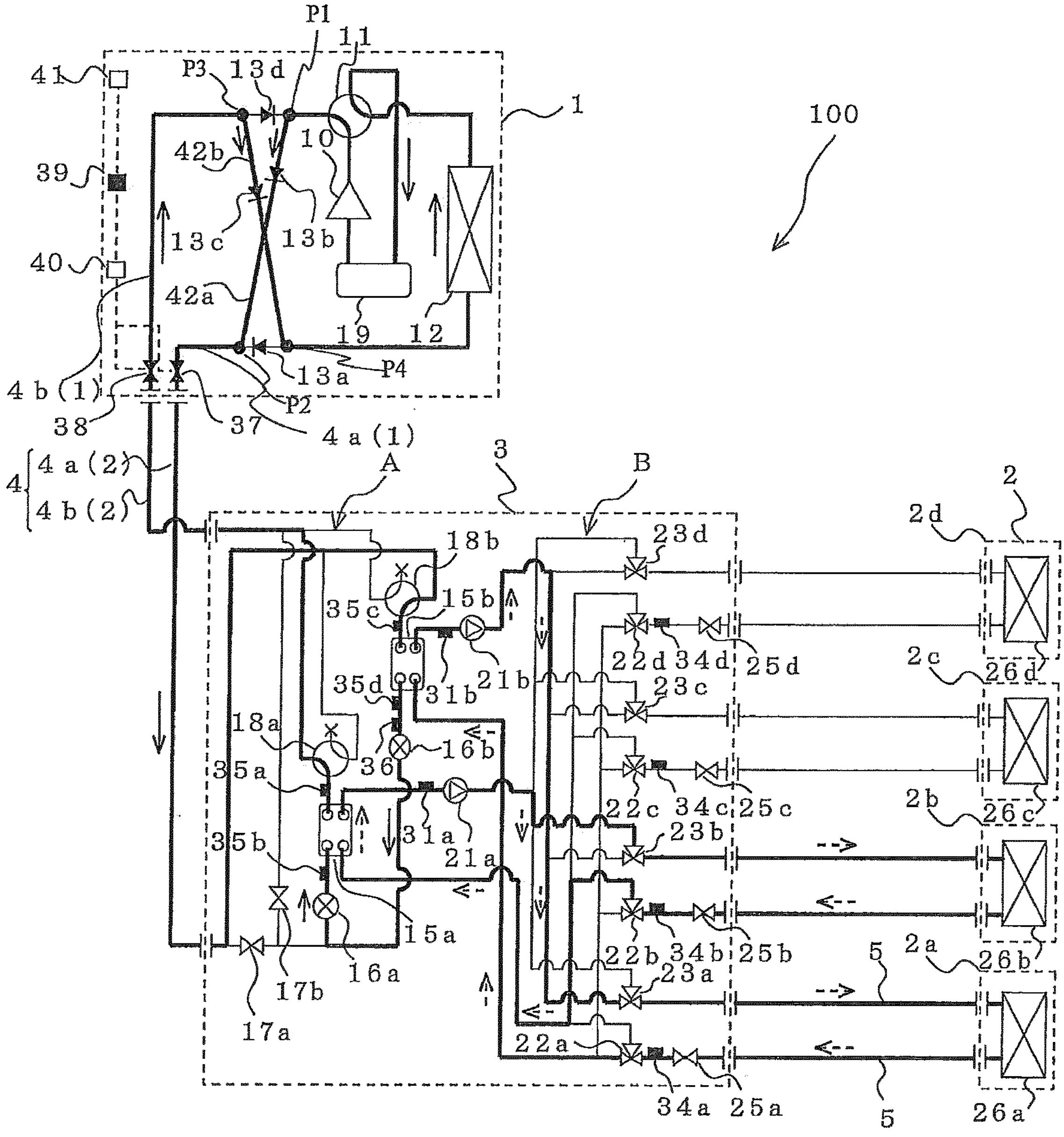
41
P3
13d
1
100
10
42b
39
13b
13c
40
42a
19
12
4b(1)
13a
P4
P2
38
37
4a(1)
4a(2)
4
4b(2)
A
3
B
2
2d
18b
23d
35c
15b
21b
22d
34d
25d
2c
26d
35d
31b
23c
18a
16b
36
35a
22c
34c
25c
2b
26c
31a
21a
23b
35b
15a
22b
34b
25b
5
2a
26b
17b
16a
23a
17a
22a
34a
25a
5
26a

F I G. 5



P1
11
P3
13d
1
100
41
10
42b
39
13b
13c
40
42a
19
12
4b(1)
13a
P4
P2
38
37
4a(1)
4
4a(2)
4b(2)
A
3
B
2
2d
23d
18b
15b
35c
22d
34d
25d
21b
26d
35d
31b
2c
23c
18a
16b
36
35a
22c
34c
25c
2b
26c
31a
23b
21a
35b
15a
22b
34b
25b
5
2a
26b
23a
17b
16a
17a
22a
34a
25a
5
26a

FIG. 6


P1
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P3
13d
1
41
100
42b
10
39
13c
13b
40
42a
19
12
4b(1)
13a
P4
38
37
P2
4a(1)
4
4a(2)
4b(2)
A
3
B
2
2d
23d
18b
35c
15b
22d
34d
25d
2c
31b
21b
26d
35d
23c
18a
16b
36
35a
22c
34c
25c
2b
26c
31a
23b
21a
35b
15a
22b
34b
25b
5
2a
26b
16a
23a
17b
17a
22a
34a
25a
5
26a

FIG. 7

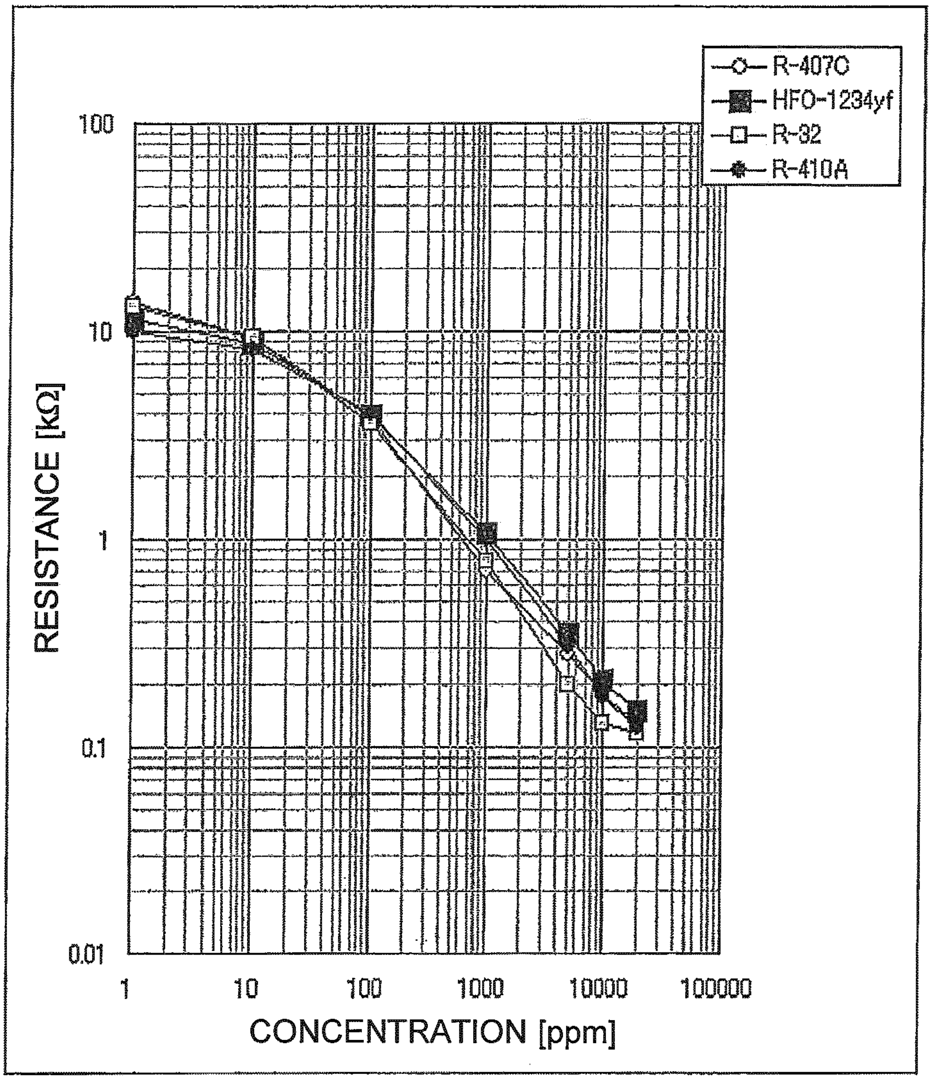
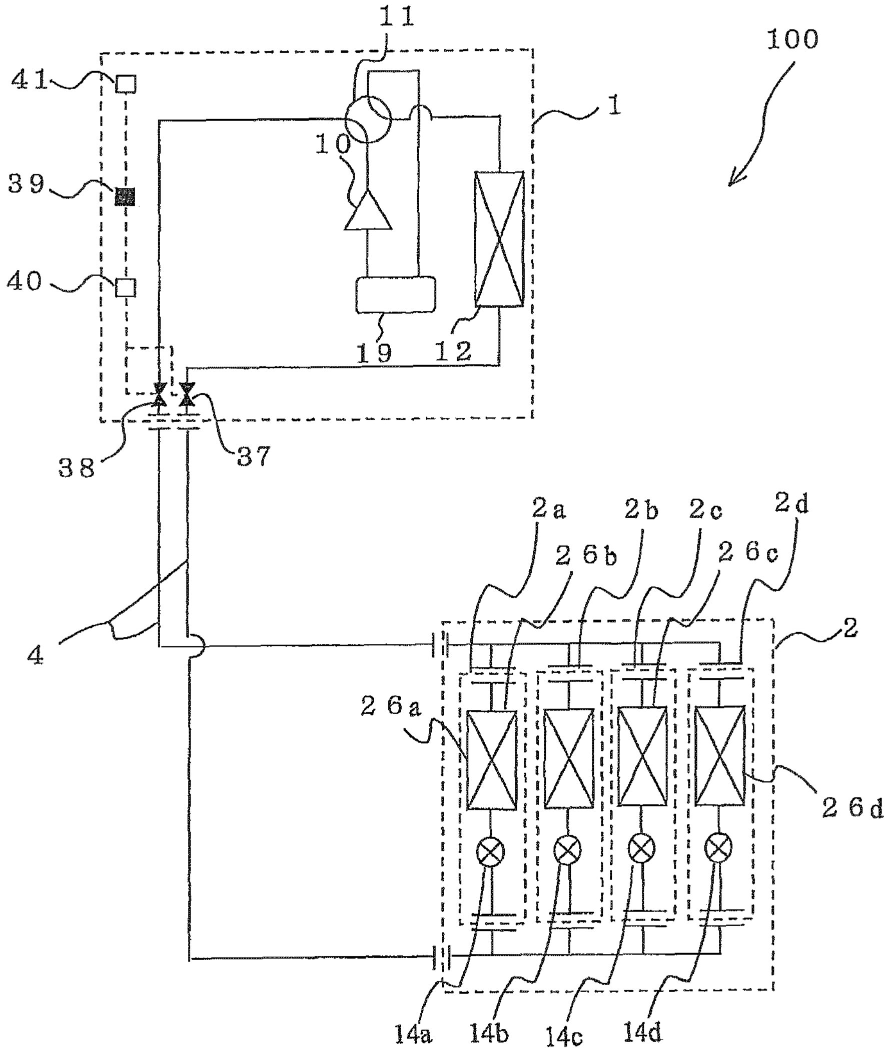

R-407C
HFO-1234yf
R-32
R-410A
100
10
1
0.1
0.01
RESISTANCE [kΩ]
1
10
100
1000
10000
100000
CONCENTRATION [ppm]

FIG. 8


11
100
41
1
10
39
40
19
12
38
37
2a
2b
2c
2d
26b
26c
4
2
26a
26d
14a
14b
14c
14d

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/000411

A. CLASSIFICATION OF SUBJECT MATTER
*F25B49/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B49/02

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

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2011 |
| Kokai Jitsuyo Shinan Koho | 1971-2011 | Toroku Jitsuyo Shinan Koho | 1994-2011 |

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | JP 5-118720 A (Hitachi, Ltd.), 14 May 1993 (14.05.1993), paragraphs [0015] to [0017]; fig. 1 to 2 (Family: none) | 1-16 |
| Y | JP 2002-195718 A (Nakano Refrigerators Co., Ltd.), 10 July 2002 (10.07.2002), paragraph [0013] (Family: none) | 1-16 |

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

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- "&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 21 April, 2011 (21.04.11) | 10 May, 2011 (10.05.11) |

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

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2011/000411

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 169332/1985(Laid-open No. 77769/1987) (Daikin Industries, Ltd.), 18 May 1987 (18.05.1987), page 4, lines 9 to 18; fig. 1 (Family: none) | 1-16 |
| Y | WO 2010/050007 A1 (Mitsubishi Electric Corp.), 06 May 2010 (06.05.2010), paragraphs [0012], [0110] (Family: none) | 1-16 |
| Y | CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 92249/1992(Laid-open No. 51657/1994) (Horiba, Ltd.), 15 July 1994 (15.07.1994), paragraph [0002] (Family: none) | 6,11,12,15, 16 |
| Y | JP 7-55267 A (Matsushita Electric Industrial Co., Ltd.), 03 March 1995 (03.03.1995), paragraphs [0005] to [0011] (Family: none) | 8 |
| Y | JP 2005-291679 A (TGK Co., Ltd.), 20 October 2005 (20.10.2005), paragraph [0013] & US 2005/0217313 A1 & EP 1584506 A1 & DE 602005001879 D | 9 |
| Y | JP 8-35746 A (Kabushiki Kaisha Fuji Koki Seisakusho), 06 February 1996 (06.02.1996), paragraphs [0020] to [0024] (Family: none) | 11,12,15,16 |
| Y | JP 2008-249234 A (Mitsubishi Electric Corp.), 16 October 2008 (16.10.2008), paragraphs [0125] to [0127] (Family: none) | 14 |

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## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description

- JP 2000320936 A **[0004]**