



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

(43) Date of publication:
11.04.2018 Bulletin 2018/15

(51) Int Cl.:
F25B 49/02 (2006.01)

(21) Application number: **16863952.4**

(86) International application number:
PCT/JP2016/080641

(22) Date of filing: **17.10.2016**

(87) International publication number:
WO 2017/081988 (18.05.2017 Gazette 2017/20)

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

- **KOMAI, Takao**
Tokyo 100-8310 (JP)
- **MAEDA, Akira**
Tokyo 100-8310 (JP)
- **KAWASHIMA, Mitsuru**
Tokyo 100-8310 (JP)
- **TAKAGI, Masahiko**
Tokyo 100-8310 (JP)
- **TANAKA, Kenyu**
Tokyo 100-8310 (JP)
- **WATANABE, Kazuki**
Tokyo 100-8310 (JP)

(30) Priority: **09.11.2015 PCT/JP2015/081514**

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

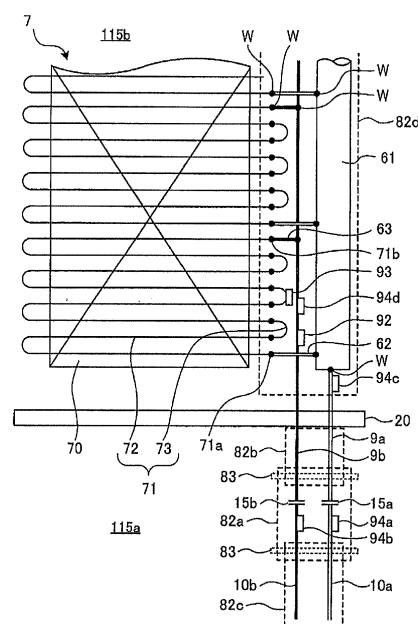
(72) Inventors:
• **SUZUKI, Yasuhiro**
Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Joachimsthaler Straße 10-12
10719 Berlin (DE)

(54) **REFRIGERATION CYCLE DEVICE AND METHOD FOR DETECTING COOLANT LEAKAGE**

(57) A refrigeration cycle apparatus includes a refrigerant circuit in which refrigerant circulates, a temperature sensor provided at a position on the refrigerant circuit, the position being adjacent to a brazed portion or adjacent to a joint portion in which refrigerant pipes are joined to each other, and a controller configured to determine whether or not the refrigerant has leaked based on a detected temperature detected by the temperature sensor. The temperature sensor is covered with a heat insulating material together with the brazed portion or the joint portion.

FIG. 5



Description

Technical Field

[0001] The present invention relates to a refrigeration cycle apparatus and a refrigerant leakage detection method.

Background Art

[0002] In Patent Literature 1, there is described an air-conditioning apparatus. The air-conditioning apparatus includes a gas sensor provided on an outer surface of an indoor unit to detect refrigerant, and a controller configured to perform control to rotate an indoor fan when the gas sensor detects refrigerant. In the air-conditioning apparatus, when refrigerant has leaked from an extension pipe, which is connected to the indoor unit, to the indoor space, or when refrigerant that has leaked inside the indoor unit flows to the outside of the indoor unit through a gap of a casing of the indoor unit, the leaking refrigerant can be detected by the gas sensor. Further, when a leakage of refrigerant is detected, by rotating the indoor fan, the indoor air is sucked from an air inlet formed in the casing of the indoor unit, and the air is blown off from an air outlet to the indoor space. Therefore, the leaking refrigerant can be diffused.

[0003] In Patent Literature 2, there is described a refrigeration apparatus. The refrigeration apparatus includes a temperature sensor configured to detect a temperature of liquid refrigerant, and a refrigerant leakage determination unit configured to determine that refrigerant has leaked when a refrigerant temperature, which is detected by the temperature sensor when a compressor is stopped, drops at a rate exceeding a predetermined rate. The temperature sensor is arranged at a position where liquid refrigerant may be accumulated in a refrigerant circuit. Specifically, the temperature sensor is arranged below a header of an indoor heat exchanger. In Patent Literature 2, it is described that a rapid leakage of refrigerant can be detected reliably by detecting a rapid drop of the temperature of the liquid refrigerant.

Citation List

Patent Literature

[0004]

Patent Literature 1: Japanese Patent No. 4599699
Patent Literature 2: Japanese Patent No. 3610812

Summary of Invention

Technical Problem

[0005] In the air-conditioning apparatus described in Patent Literature 1, a gas sensor is used as a refrigerant

detection unit. However, the detection characteristic of a gas sensor is liable to be aged, and hence there is a problem in that the air-conditioning apparatus disclosed in Patent Literature 1 may not be capable of detecting a leakage of refrigerant reliably for a long period of time.

[0006] Meanwhile, in the refrigeration apparatus described in Patent Literature 2, instead of a gas sensor, a temperature sensor having long-term reliability is used as a refrigerant detection unit. However, when the compressor is stopped, refrigerant distribution in the refrigerant circuit is not always controllable. Accordingly, variation arises in the amount of liquid refrigerant accumulated in a portion in which a temperature sensor is arranged, and hence variation also arises in the degree of drop of a refrigerant temperature due to the heat of vaporization when refrigerant leaks. Further, a leakage of refrigerant does not always occur at a place where liquid refrigerant is accumulated. When refrigerant leaks at a place other than the place where liquid refrigerant is accumulated, gas refrigerant is mainly leaked first. Accordingly, it takes time until liquid refrigerant is gasified at a place where the liquid refrigerant is accumulated and the refrigerant temperature drops. Therefore, in the refrigeration apparatus described in Patent Literature 2, there is a problem in that a leakage of refrigerant may not be detected with high responsiveness.

[0007] The present invention has been made to solve the above-mentioned problems, and it is an object of the present invention to provide a refrigeration cycle apparatus and a refrigerant leakage detection method, which are capable of detecting a leakage of refrigerant reliably with high responsiveness for a long period of time.

Solution to Problem

[0008] A refrigeration cycle apparatus according to one embodiment of the present invention includes: a refrigerant circuit in which refrigerant circulates; a temperature sensor provided at a position on the refrigerant circuit, the position being adjacent to a brazed portion or the position being adjacent to a joint portion in which refrigerant pipes are joined to each other; and a controller configured to determine whether or not the refrigerant has leaked based on a detected temperature detected by the temperature sensor. The temperature sensor is covered with a heat insulating material together with the brazed portion or the joint portion.

[0009] Further, a refrigerant leakage detection method according to one embodiment of the present invention includes: detecting a temperature of a position on a refrigerant circuit in which refrigerant circulates, the position being adjacent to a brazed portion and being covered with a heat insulating material together with the brazed portion, or the position being adjacent to a joint portion in which refrigerant pipes are joined and being covered with a heat insulating material together with the joint portion; and determining whether or not the refrigerant has leaked based on the temperature.

Advantageous Effects of Invention

[0010] According to one embodiment of the present invention, a leakage of refrigerant can be detected reliably with high responsiveness for a long period of time.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram for illustrating a schematic configuration of an air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a front view for illustrating an external appearance configuration of an indoor unit 1 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a front view for schematically illustrating an internal structure of the indoor unit 1 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a side view for schematically illustrating the internal structure of the indoor unit 1 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a front view for schematically illustrating a configuration of a load-side heat exchanger 7 and the peripheral components thereof of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a schematic diagram for illustrating a modification example of a configuration of a heat insulating material 82d illustrated in Fig. 5.

[Fig. 7] Fig. 7 is a schematic diagram for illustrating another modification example of the configuration of the heat insulating material 82d illustrated in Fig. 5.

[Fig. 8] Fig. 8 is a graph for showing exemplary temporal changes of the temperature detected by a temperature sensor 94a when refrigerant is caused to leak from a joint 15b in the indoor unit 1 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 9] Fig. 9 is a flowchart for illustrating an example of refrigerant leakage detection processing to be performed by a controller 30 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 10] Fig. 10 is a flowchart for illustrating another example of refrigerant leakage detection processing to be performed by the controller 30 of the air-conditioning apparatus according to Embodiment 1 of the present invention.

Description of Embodiments

Embodiment 1

[0012] A refrigeration cycle apparatus and a refrigerant leakage detection method according to Embodiment 1 of the present invention are described. In Embodiment 1, an air-conditioning apparatus is described as an example of a refrigeration cycle apparatus. Fig. 1 is a refrigerant circuit diagram for illustrating a schematic configuration of the air-conditioning apparatus according to Embodiment 1. In the drawings described below including Fig. 1, the dimensional relationships and the shapes of the respective constituent members may be different from actual ones.

[0013] As illustrated in Fig. 1, the air-conditioning apparatus includes a refrigerant circuit 40 in which refrigerant circulates. The refrigerant circuit 40 has a configuration in which a compressor 3, a refrigerant flow path switching device 4, a heat source-side heat exchanger 5 (for example, outdoor heat exchanger), a decompression device 6, and a load-side heat exchanger 7 (for example, indoor heat exchanger) are sequentially connected via refrigerant pipes to form a ring. The air-conditioning apparatus also includes as a heat source unit an outdoor unit 2, which is installed outside the indoor space, for example. Further, the air-conditioning apparatus also includes as a load unit an indoor unit 1, which is installed in the indoor space, for example. The indoor unit 1 and the outdoor unit 2 are connected to each other via extension pipes 10a and 10b, which are part of the refrigerant pipes.

[0014] As refrigerant circulating in the refrigerant circuit 40, slightly flammable refrigerant such as HFO-1234yf or HFO-1234ze, or highly flammable refrigerant such as R290 or R1270 may be used, for example. Such refrigerant may be used as single refrigerant, or as mixed refrigerant in which two or more types of refrigerant are mixed. Refrigerant having a slightly flammable level or higher (for example, 2 L or higher in the classification of ASHRAE34) may be hereinafter referred to as "flammable refrigerant". Further, as refrigerant circulating in the refrigerant circuit 40, it is also possible to use nonflammable refrigerant such as R22 or R410A having no flammability (for example, 1 in the classification of ASHRAE34). Those types of refrigerant have density larger than that of air under the atmospheric pressure, for example.

[0015] The compressor 3 is fluid machinery configured to compress sucked low-pressure refrigerant and discharge the resultant refrigerant as high-pressure refrigerant. The refrigerant flow path switching device 4 is configured to switch a flow direction of the refrigerant in the refrigerant circuit 40 between the cooling operation and the heating operation. As the refrigerant flow path switching device 4, a four-way valve is used, for example. The heat source-side heat exchanger 5 is a heat exchanger that functions as a radiator (for example, condenser) at

the time of cooling operation, and functions as an evaporator at the time of heating operation. In the heat source-side heat exchanger 5, heat exchange is performed between the refrigerant flowing inside and the outdoor air supplied by an outdoor fan 5f described later. The decompression device 6 is configured to decompress high-pressure refrigerant into low-pressure refrigerant. As the decompression device 6, an electronic expansion valve, in which the opening degree is adjustable, or similar valve may be used, for example. The load-side heat exchanger 7 is a heat exchanger that functions as an evaporator at the time of cooling operation, and functions as a radiator (for example, condenser) at the time of heating operation. In the load-side heat exchanger 7, heat exchange is performed between the refrigerant flowing inside and the air supplied by an indoor fan 7f described later. The cooling operation refers to an operation of supplying low-temperature and low-pressure refrigerant to the load-side heat exchanger 7, and the heating operation refers to an operation of supplying high-temperature and high-pressure refrigerant to the load-side heat exchanger 7.

[0016] In the outdoor unit 2, the compressor 3, the refrigerant flow path switching device 4, the heat source-side heat exchanger 5, and the decompression device 6 are accommodated. The outdoor fan 5f configured to supply outdoor air to the heat source-side heat exchanger 5 is also accommodated in the outdoor unit 2. The outdoor fan 5f is arranged to face the heat source-side heat exchanger 5. When the outdoor fan 5f is rotated, an air flow passing through the heat source-side heat exchanger 5 is generated. As the outdoor fan 5f, a propeller fan is used, for example. The outdoor fan 5f is arranged downstream of the heat source-side heat exchanger 5, for example, in the air flow generated by the outdoor fan 5f.

[0017] In the outdoor unit 2, as refrigerant pipes, there are arranged a refrigerant pipe connecting an extension pipe connection valve 13a that is on the gas side at the time of cooling operation and the refrigerant flow path switching device 4, a suction pipe 11 connected to the suction side of the compressor 3, a discharge pipe 12 connected to the discharge side of the compressor 3, a refrigerant pipe connecting the refrigerant flow path switching device 4 and the heat source-side heat exchanger 5, a refrigerant pipe connecting the heat source-side heat exchanger 5 and the decompression device 6, and a refrigerant pipe connecting an extension pipe connection valve 13b that is on the liquid side at the time of cooling operation and the decompression device 6. The extension pipe connection valve 13a is a two-way valve that can be switched to be opened or closed, and one end thereof has a joint 16a (for example, flare joint) mounted thereto. Further, the extension pipe connection valve 13b is constructed of a three-way valve that can be switched to be opened or closed. One end of the extension pipe connection valve 13b has mounted thereto a service port 14a to be used for vacuum drawing that is a prior work of filling the refrigerant circuit 40 with refrigerant,

and the other end thereof has a joint 16b (for example, flare joint) mounted thereto.

[0018] In the discharge pipe 12, high-temperature and high-pressure gas refrigerant compressed by the compressor 3 flows both at the time of cooling operation and at the time of heating operation. In the suction pipe 11, low-temperature and low-pressure gas refrigerant after evaporation or two phase refrigerant flows both at the time of cooling operation and at the time of heating operation. The suction pipe 11 is connected to a service port 14b with a flare joint of the low-pressure side, and the discharge pipe 12 is connected to a service port 14c with a flare joint of the high-pressure side. The service ports 14b and 14c are used for measuring the operation pressure with a pressure gauge connected thereto, when a trial operation is performed at the time of installing or repairing the air-conditioning apparatus.

[0019] The indoor unit 1 accommodates the load-side heat exchanger 7. The indoor unit 1 also accommodates the indoor fan 7f configured to supply air to the load-side heat exchanger 7. When the indoor fan 7f is rotated, an air flow passing through the load-side heat exchanger 7 is generated. As the indoor fan 7f, a centrifugal fan (for example, sirocco fan or turbo fan), a cross flow fan, a mixed flow fan, an axial fan (for example, propeller fan), or other fan may be used depending on the form of the indoor unit 1. While the indoor fan 7f of Embodiment 1 is arranged upstream of the load-side heat exchanger 7 in the air flow generated by the indoor fan 7f, the indoor fan 7f may be arranged downstream of the load-side heat exchanger 7.

[0020] In an indoor pipe 9a on the gas side among the refrigerant pipes of the indoor unit 1, a connecting portion to the extension pipe 10a of the gas side has mounted thereto a joint 15a (for example, flare joint) for connecting the extension pipe 10a to the connecting portion. Further, in an indoor pipe 9b on the liquid side of the refrigerant pipes of the indoor unit 1, a connecting portion to the extension pipe 10b on the liquid side has mounted thereto a joint 15b (for example, flare joint) for connecting the extension pipe 10b to the connecting portion.

[0021] The indoor unit 1 also includes an intake air temperature sensor 91 configured to detect a temperature of the indoor air sucked from the indoor space, a heat exchanger liquid pipe temperature sensor 92 configured to detect a temperature of liquid refrigerant at an inlet port at the time of cooling operation (outlet port at the time of heating operation) of the load-side heat exchanger 7, a heat exchanger two-phase pipe temperature sensor 93 configured to detect a temperature of the two-phase refrigerant (evaporating temperature or condensing temperature) of the load-side heat exchanger 7, and other sensors. The indoor unit 1 also includes temperature sensors 94a, 94b, 94c, and 94d (not shown in Fig. 1) for detecting a refrigerant leakage described below. Those temperature sensors 91, 92, 93, 94a, 94b, 94c, and 94d output detection signals to the controller 30 configured to control the indoor unit 1 or the entire air-con-

ditioning apparatus.

[0022] The controller 30 includes a microcomputer including a CPU, a ROM, a RAM, an I/O port, a timer, and other components. The controller 30 is configured to perform data communication to/from an operation unit 26 (see Fig. 2). The operation unit 26 receives an operation by a user and output an operation signal, which is based on the operation, to the controller 30. The controller 30 of Embodiment 1 controls an operation of the indoor unit 1 or the entire air-conditioning apparatus including an operation of the indoor fan 7f based on the operation signal from the operation unit 26, detection signals from the sensors, and other signals. The controller 30 may be provided in the casing of the indoor unit 1 or in the casing of the outdoor unit 2. Further, the controller 30 may be constructed of an outdoor unit control unit provided in the outdoor unit 2, and an indoor unit control unit provided in the indoor unit 1 and capable of performing data communication to/from the outdoor unit control unit.

[0023] Next, an operation of the refrigerant circuit 40 of the air-conditioning apparatus is described. First, an operation at the time of cooling operation is described. In Fig. 1, the arrow of the solid line indicates a flow direction of refrigerant at the time of cooling operation. In the cooling operation, the refrigerant flow path is switched to that indicated by the solid line by the refrigerant flow path switching device 4, and the refrigerant circuit 40 is configured such that low-temperature and low-pressure refrigerant flows to the load-side heat exchanger 7.

[0024] The high-temperature and high-pressure gas refrigerant discharged from the compressor 3 first flows into the heat source-side heat exchanger 5 via the refrigerant flow path switching device 4. In the cooling operation, the heat source-side heat exchanger 5 functions as a condenser. Specifically, in the heat source-side heat exchanger 5, heat exchange is performed between the refrigerant flowing inside and the outdoor air supplied by the outdoor fan 5f, and the heat of condensation of the refrigerant is radiated to the outdoor air. In this way, the refrigerant flowing into the heat source-side heat exchanger 5 is condensed to be high-pressure liquid refrigerant. The high-pressure liquid refrigerant flows into the decompression device 6, and is decompressed to be low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows into the load-side heat exchanger 7 of the indoor unit 1 via the extension pipe 10b. In the cooling operation, the load-side heat exchanger 7 functions as an evaporator. Specifically, in the load-side heat exchanger 7, heat exchange is performed between the refrigerant flowing inside and the air supplied by the indoor fan 7f (for example, indoor air), and the heat of evaporation of the refrigerant is removed from the air. In this way, the refrigerant flowing into the load-side heat exchanger 7 evaporates to be low-pressure gas refrigerant or two-phase refrigerant. Further, the air supplied by the indoor fan 7f is cooled by heat removal action of the refrigerant. The low-pressure gas refrigerant or the two-phase refrigerant evaporated in the load-side heat ex-

changer 7 is sucked by the compressor 3 via the extension pipe 10a and the refrigerant flow path switching device 4. The refrigerant sucked by the compressor 3 is compressed to be high-temperature and high-pressure gas refrigerant. In the cooling operation, the cycle described above is repeated.

[0025] Next, an operation at the time of heating operation is described. In Fig. 1, the arrow of the dotted line indicates a flow direction of refrigerant at the time of heating operation. In the heating operation, a refrigerant flow path is switched to that indicated by the dotted line by the refrigerant flow path switching device 4, and the refrigerant circuit 40 is configured such that high-temperature and high-pressure refrigerant flows to the load-side heat exchanger 7. In the heating operation, the refrigerant flows in a direction opposite to that in the cooling operation, and the load-side heat exchanger 7 functions as a condenser. Specifically, in the load-side heat exchanger 7, heat exchange is performed between the refrigerant flowing inside and the air supplied by the indoor fan 7f, and the heat of condensation of the refrigerant is radiated to the air. In this way, the air supplied by the indoor fan 7f is heated by the heat radiation action of the refrigerant.

[0026] Fig. 2 is a front view for illustrating an external appearance configuration of the indoor unit 1 of the air-conditioning apparatus according to Embodiment 1. Fig. 3 is a front view for schematically illustrating an internal structure of the indoor unit 1. Fig. 4 is a side view for schematically illustrating the internal structure of the indoor unit 1. The left side of Fig. 4 is a front side (indoor space side) of the indoor unit 1. In Embodiment 1, as the indoor unit 1, the indoor unit 1 of the floor type, which is to be installed on the floor of an indoor space that is an air-conditioned space, is illustrated exemplarily. The positional relation (for example, up and down relation) between the respective constituent members in the following description is that when the indoor unit 1 is installed in a usable state, in principle.

[0027] As illustrated in Fig. 2 to Fig. 4, the indoor unit 1 includes a casing 111 having a vertically long rectangular parallelepiped shape. A lower portion of the front surface of the casing 111 has formed therein an air inlet 112 for sucking the air of the indoor space. The air inlet 112 of Embodiment 1 is provided at a position below a center portion in the vertical direction of the casing 111 and in the vicinity of the floor. An upper portion of the front surface of the casing 111, that is, a position higher than the height of the air inlet 112 (for example, above the center portion in the vertical direction of the casing 111), has formed therein an air outlet 113 for blowing off the air sucked from the air inlet 112 to the indoor space. On the front surface of the casing 111, the operation unit 26 is provided above the air inlet 112 and below the air outlet 113. The operation unit 26 is connected to the controller 30 via a communication line, and is capable of performing data communication to/from the controller 30. In the operation unit 26, a start operation and a stop op-

eration of the air-conditioning apparatus, switching of operation mode, setting of set temperature and set air flow amount, and other operations are performed by a user's operation. In the operation unit 26, a display unit, a sound output unit, and other units are provided as informing units configured to inform the user of information.

[0028] The casing 111 is a hollow box. The front surface of the casing 111 has formed therein a front open part. The casing 111 includes a first front panel 114a, a second front panel 114b, and a third front panel 114c that are mounted attachably/detachably to the front open part. Each of the first front panel 114a, the second front panel 114b, and the third front panel 114c has a substantially rectangular flat plate outer shape. The first front panel 114a is mounted attachably/detachably to the lower portion of the front open part of the casing 111. In the first front panel 114a, the air inlet 112 is formed. The second front panel 114b is arranged adjacently above the first front panel 114a, and is mounted attachably/detachably to the center portion in the vertical direction of the front open part of the casing 111. On the second front panel 114b, the operation unit 26 is provided. The third front panel 114c is arranged adjacently above the second front panel 114b, and is mounted attachably/detachably with respect to the upper portion of the front open part of the casing 111. In the third front panel 114c, the air outlet 113 is formed.

[0029] The internal space of the casing 111 is roughly divided into a lower space 115a serving as an air sending unit, and an upper space 115b located above the lower space 115a and serving as a heat exchange unit. The lower space 115a and the upper space 115b are partitioned by a partition 20. The partition 20 has a flat plate shape, for example, and is arranged almost horizontally. The partition 20 at least includes an air passage opening port 20a serving as an air passage between the lower space 115a and the upper space 115b. The lower space 115a is exposed to the front surface side when the first front panel 114a is removed from the casing 111. The upper space 115b is exposed to the front surface side when the second front panel 114b and the third front panel 114c are removed from the casing 111. That is, the height where the partition 20 is arranged almost matches the height of the top end of the first front panel 114a or the bottom end of the second front panel 114b. The partition 20 may be integrally formed with a fan casing 108 described later, may be integrally formed with a drain pan described later, or may be formed separately of the fan casing 108 and the drain pan.

[0030] In the lower space 115a, the indoor fan 7f is arranged. The indoor fan 7f generates an air flow from the air inlet 112 to the air outlet 113 in an air passage 81 in the casing 111. The indoor fan 7f of Embodiment 1 is a sirocco fan including a motor (not shown), and an impeller 107 that is connected to the output shaft of the motor and in which a plurality of vanes are circumferentially arranged with equal intervals, for example. The rotating shaft of the impeller 107 is arranged to be in almost

parallel with the depth direction of the casing 111. As the motor of the indoor fan 7f, a non-brush type motor (for example, induction motor or DC brushless motor) is used. Accordingly, no sparking is caused when the indoor fan 7f rotates.

[0031] The impeller 107 of the indoor fan 7f is covered with the spiral shaped fan casing 108. The fan casing 108 is formed separately of the casing 111, for example. Near the center of the spiral of the fan casing 108, a suction opening port 108b for sucking the indoor air into the fan casing 108 via the air inlet 112 is formed. The suction opening port 108b is arranged to face the air inlet 112. Further, in the tangential direction of the spiral of the fan casing 108, an air outlet opening port 108a from which sending air is blown off is formed. The air outlet opening port 108a is arranged to face upward and is connected to the upper space 115b via the air passage opening port 20a of the partition 20. In other words, the air outlet opening port 108a communicates to the upper space 115b via the air passage opening port 20a. An opening end of the air outlet opening port 108a and an opening end of the air passage opening port 20a may be connected directly to each other, or may be connected indirectly to each other via a duct member, for example.

[0032] Further, the lower space 115a has an electrical component box 25 in which a microcomputer constructing the controller 30, various electrical components, a substrate, and other components are stored, for example.

[0033] The upper space 115b is located downstream of the lower space 115a in the flow of air caused by the indoor fan 7f. On the air passage 81 in the upper space 115b, the load-side heat exchanger 7 is arranged. Below the load-side heat exchanger 7, a drain pan (not shown) for receiving condensed water condensed on the surface of the load-side heat exchanger 7 is provided. The drain pan may be formed as a part of the partition 20, or may be formed separately of the partition 20 and arranged on the partition 20.

[0034] When the indoor fan 7f is driven, the indoor air is sucked from the air inlet 112. The sucked indoor air passes through the load-side heat exchanger 7 to be conditioned air, and is blown off from the air outlet 113 to the indoor space.

[0035] Fig. 5 is a front view for schematically illustrating the configuration of the load-side heat exchanger 7 and the peripheral components thereof of the air-conditioning apparatus according to Embodiment 1. As illustrated in Fig. 5, the load-side heat exchanger 7 of Embodiment 1 is a plate fin tube type heat exchanger including a plurality of fins 70 arranged in parallel with predetermined intervals, and a plurality of heat transfer tubes 71 penetrating the plurality of fins 70 and allowing the refrigerant to flow through the inside thereof. The heat transfer tube 71 is constructed of a plurality of hair-pin pipes 72 having long straight pipes penetrating the plurality of fins 70 and a plurality of U bent pipes 73 allowing the adjacent hair-pin pipes 72 to communicate to each other. The hair-pin pipe

72 and the U bent pipe 73 are joined by a brazed portion W. In Fig. 5, the brazed portion W is indicated by a black dot. The number of heat transfer tubes 71 may be one or plural. Further, the number of hair-pin pipes 72 constructing one heat transfer tube 71 may be one or plural. The heat exchanger two-phase pipe temperature sensor 93 is provided on the U bent pipe 73 located in the middle of the refrigerant channel in the heat transfer tube 71.

[0036] The indoor pipe 9a of the gas side is connected to a cylindrical header main pipe 61. To the header main pipe 61, a plurality of header branch pipes 62 are connected in a branched manner. Each of the header branch pipes 62 is connected to one end portion 71a of the heat transfer tube 71. To the indoor pipe 9b of the liquid side, a plurality of indoor refrigerant branch pipes 63 are connected in a branched manner. Each of the indoor refrigerant branch pipes 63 is connected to an other end portion 71b of the heat transfer tube 71. The heat exchanger liquid pipe temperature sensor 92 is provided on the indoor pipe 9b.

[0037] The indoor pipe 9a and the header main pipe 61, the header main pipe 61 and the header branch pipe 62, the header branch pipe 62 and the heat transfer tube 71, the indoor pipe 9b and the indoor refrigerant branch pipe 63, and the indoor refrigerant branch pipe 63 and the heat transfer tube 71 are each joined by the brazed portions W.

[0038] In Embodiment 1, the brazed portions W of the load-side heat exchanger 7 (in Embodiment 1, including the brazed portions W of the peripheral components of the indoor pipe 9a, the header main pipe 61, the header branch pipe 62, the indoor refrigerant branch pipe 63, the indoor pipe 9b, and other pipes) are arranged in the upper space 115b. The indoor pipes 9a and 9b penetrate the partition 20 and are drawn downward from the upper space 115b to the lower space 115a. The joint 15a connecting the indoor pipe 9a and the extension pipe 10a and the joint 15b connecting the indoor pipe 9b and the extension pipe 10b are arranged in the lower space 115a.

[0039] To the indoor pipes 9a and 9b in the upper space 115b, the temperature sensors 94c and 94d for detecting a refrigerant leakage are provided separately from the heat exchanger liquid pipe temperature sensor 92 and the heat exchanger two-phase pipe temperature sensor 93, which are used for operation control of the refrigerant circuit 40. The temperature sensor 94c is provided at a position adjacent to the brazed portion W of the load-side heat exchanger 7 of the indoor pipe 9a to be in contact with the outer peripheral surface of the indoor pipe 9a. The temperature sensor 94c is provided below the lowermost brazed portion W and in the vicinity of the same brazed portion W, for example. The temperature sensor 94d is provided at a position adjacent to the brazed portion W of the load-side heat exchanger 7 of the indoor pipe 9b to be in contact with the outer peripheral surface of the indoor pipe 9b. The temperature sensor 94d is provided below the lowermost brazed portion W among at least the brazed portions W of the indoor pipe 9b in

the vicinity of the same brazed portion W.

[0040] Below the indoor pipe 9a, the header main pipe 61, the header branch pipe 62, the indoor refrigerant branch pipe 63, and the indoor pipe 9b, the partition 20, that is, a drain pan, is provided. Accordingly, in the upper space 115b, there is originally no particular need to provide a heat insulating material around the indoor pipe 9a, the header main pipe 61, the header branch pipe 62, the indoor refrigerant branch pipe 63, and the indoor pipe 9b. However, in Embodiment 1, the indoor pipe 9a, the header main pipe 61, the header branch pipe 62, the indoor refrigerant branch pipe 63, and the indoor pipe 9b (at least the brazed portions W where those pipes are joined) located above (for example, immediately above) the drain pan are integrally covered with a unit of heat insulating material 82d (for example, one heat insulating member or a pair of insulating members closely attached to each other via mating surfaces). As described later with use of Fig. 6 and Fig. 7, the heat insulating material 82d may be constructed of a plurality of heat insulating members connected integrally. The heat insulating material 82d is closely attached to the refrigerant pipes, and hence only a minute gap is formed between the outer peripheral surface of each refrigerant pipe and the heat insulating material 82d. The heat insulating material 82d is mounted in the manufacturing step of the indoor unit 1 by an air-conditioning apparatus manufacturer.

[0041] The temperature sensors 94c and 94d are covered with the heat insulating material 82d, together with the brazed portions W of the load-side heat exchanger 7, the indoor pipes 9a and 9b, and other pipes. Specifically, the temperature sensor 94c is provided on the internal side of the heat insulating material 82d, and detects a temperature of the portion covered with the heat insulating material 82d in the indoor pipe 9a. The temperature sensor 94d is provided on the internal side of the heat insulating material 82d, and detects a temperature of the portion covered with the heat insulating material 82d in the indoor pipe 9b. Further, in Embodiment 1, the heat exchanger liquid pipe temperature sensor 92 and the heat exchanger two-phase pipe temperature sensor 93 are also covered with the heat insulating material 82d.

[0042] The indoor pipes 9a and 9b in the lower space 115a are covered with a heat insulating material 82b for preventing dew condensation, except for the portions near the joints 15a and 15b. In Embodiment 1, two indoor pipes 9a and 9b are collectively covered with one heat insulating material 82b. However, the indoor pipes 9a and 9b may be covered with different heat insulating materials. The heat insulating material 82b is mounted in the manufacturing step of the indoor unit 1 by the air-conditioning apparatus manufacturer.

[0043] In the lower space 115a, the temperature sensors 94a and 94b for detecting a refrigerant leakage are provided, besides the intake air temperature sensor 91. The temperature sensor 94a is provided at a position adjacent to the joint 15a of the extension pipe 10a to be in contact with the outer peripheral surface of the exten-

sion pipe 10a. The temperature sensor 94a is provided below the joint 15a in the vicinity of the joint 15a, for example. The temperature sensor 94b is provided at a position adjacent to the joint 15b of the extension pipe 10b to be in contact with the outer peripheral surface of the extension pipe 10b. The temperature sensor 94b is provided below the joint 15b in the vicinity of the joint 15b, for example. In Embodiment 1, while the temperature sensors 94a and 94b are provided at positions adjacent to the joints 15a and 15b to which the extension pipes 10a and 10b and the indoor pipes 9a and 9b are connected, the temperature sensors 94a and 94b may be provided at positions adjacent to joint portions in which refrigerant pipes (for example, the extension pipe 10a and the indoor pipe 9a, or the extension pipe 10b and the indoor pipe 9b, and other pipes) are joined to each other by brazing, welding, or the like, instead of the positions adjacent to the joints 15a and 15b.

[0044] The extension pipes 10a and 10b are covered with a heat insulating material 82c for preventing dew condensation except for the vicinity of the joints 15a and 15b (in Embodiment 1, including the positions where the temperature sensors 94a and 94b are provided). In Embodiment 1, the two extension pipes 10a and 10b are collectively covered with one heat insulating material 82c. However, the extension pipes 10a and 10b may be covered with different heat insulating materials. In general, the extension pipes 10a and 10b are arranged by an installation provider who installs the air-conditioning apparatus. The heat insulating material 82c may be mounted before the extension pipes 10a and 10b are purchased, or the installation provider may arrange the extension pipes 10a and 10b and the heat insulating material 82c separately, and mount the insulating material 82c on the extension pipes 10a and 10b when installing the air-conditioning apparatus. In Embodiment 1, the temperature sensors 94a and 94b are mounted on the extension pipes 10a and 10b by the installation provider.

[0045] The vicinity of the joints 15a and 15b of the indoor pipes 9a and 9b, the vicinity of the joints 15a and 15b of the extension pipes 10a and 10b, and the joints 15a and 15b are covered with another heat insulating material 82a that is different from the heat insulating materials 82b and 82c to prevent dew condensation. The heat insulating material 82a is mounted by an installation provider at the time of installing the air-conditioning apparatus after the extension pipes 10a and 10b and the indoor pipes 9a and 9b are connected to each other, respectively, and then the temperature sensors 94a and 94b are mounted on the extension pipes 10a and 10b, respectively. The heat insulating material 82a is often packed together with the indoor unit 1 in a shipping state. The heat insulating material 82a has a cylindrical shape divided by a plane containing a cylinder axis, for example. The heat insulating material 82a is wound to cover respective end portions of the heat insulating materials 82b and 82c from the outside and is mounted thereon with use of a band 83. The heat insulating material 82a is

closely attached to the refrigerant pipes, and hence only a minute gap is formed between the outer peripheral surface of each refrigerant pipe and the inner peripheral surface of the heat insulating material 82a.

[0046] In the indoor unit 1, portions having the possibility of a refrigerant leakage are the brazed portions W of the load-side heat exchanger 7 and joint portions in which refrigerant pipes are joined to each other (in Embodiment 1, joints 15a and 15b). In general, the refrigerant leaked from the refrigerant circuit 40 under the atmospheric pressure is adiabatically expanded to be gasified, and is diffused to the air. When the refrigerant is adiabatically expanded and gasified, the refrigerant removes heat from the surrounding air and the like.

[0047] Meanwhile, in Embodiment 1, the brazed portions W and the joints 15a and 15b having a possibility of a refrigerant leakage are covered with the heat insulating materials 82d and 82a. Accordingly, the refrigerant that is adiabatically expanded and gasified cannot remove heat from the air outside the heat insulating materials 82d and 82a. Further, the heat capacity of the heat insulating materials 82d and 82a is small, and hence the refrigerant hardly removes heat from the heat insulating materials 82d and 82a. Thus, the refrigerant mainly removes heat from refrigerant pipes. On the other hand, the refrigerant pipe itself is thermally insulated from the outside air by the heat insulating materials. Accordingly, when the heat of the refrigerant pipe is removed by the refrigerant, the temperature of the refrigerant pipe drops in accordance with the removed heat amount, and the dropped temperature of the refrigerant pipe is maintained. In this way, the temperature of the refrigerant pipe near the leakage portion drops to an extremely-low temperature of about boiling point (for example, in the case of HFO-1234yf, about -29 degrees C) of the refrigerant, and the temperature of the refrigerant pipe away from the leakage portion also drops sequentially.

[0048] Further, the adiabatically expanded and gasified refrigerant is hardly diffused to the air outside the heat insulating materials 82d and 82a, and remains in a minute gap between the refrigerant pipe and the heat insulating materials 82d and 82a. Then, when the temperature of the refrigerant pipe drops to the boiling point of the refrigerant, the gas refrigerant remaining in the minute gap is recondensed on the outer peripheral surface of the refrigerant pipe. The leaking refrigerant that is liquified by recondensation runs through the outer peripheral surface of the refrigerant pipe or the inner peripheral surface of the heat insulating material and flows downward in the minute gap between the refrigerant pipe and the heat insulating material.

[0049] At this time, in the temperature sensors 94a, 94b, 94c, and 94d, the temperature of extremely-low liquid refrigerant flowing downward in the minute gap or the temperature of the refrigerant pipe that is dropped to the extremely-low temperature is detected.

[0050] It is desirable that the heat insulating materials 82a, 82b, 82c, and 82d be made of closed cell foamed

resin (e.g., foamed polyethylene). With this configuration, it is possible to prevent leaking refrigerant existing in the minute gap between the refrigerant pipe and the heat insulating material from leaking to the outside air by passing through the heat insulating material. Further, the heat capacity of a heat insulating material is also decreased.

[0051] Fig. 6 is a schematic diagram for illustrating a modification example of a configuration of the heat insulating material 82d illustrated in Fig. 5. In Fig. 6, as the brazed portions W, there are illustrated a brazed portion W1 between the indoor pipe 9a and the header main pipe 61, a brazed portion W2 between the header main pipe 61 and a header branch pipe 62-1, a brazed portion W3 between the header main pipe 61 and a header branch pipe 62-2, a brazed portion W4 between the header main pipe 61 and a header branch pipe 62-3, a brazed portion W5 between the indoor pipe 9b and an indoor refrigerant branch pipe 63-1, and a brazed portion W6 between the indoor pipe 9b and an indoor refrigerant branch pipe 63-2. Further, in Fig. 6, among the brazed portions W illustrated in Fig. 5, the brazed portion W between the header branch pipe 62 and the heat transfer tube 71, the brazed portion W between the indoor refrigerant branch pipe 63 and the heat transfer tube 71, and the brazed portion W between the hair-pin pipe 72 and the U bent pipe 73 are not shown.

[0052] As illustrated in Fig. 6, the heat insulating material 82d is constructed of at least four heat insulating members 82d1, 82d2, 82d3, and 82d4 that are linked integrally. That is, substantially a unit of heat insulating material 82d is formed of the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4. Each of the heat insulating members 82d1, 82d2, 82d3, and 82d4 may be a pair of heat insulating members closely attached to each other via mating surfaces. In this case, when it is assumed that a pair of heat insulating members forms a set, the heat insulating material 82d is constructed of at least four sets of heat insulating members 82d1, 82d2, 82d3, and 82d4.

[0053] Among the heat insulating members 82d1, 82d2, 82d3, and 82d4, two adjacent heat insulating members are arranged such that end portions thereof (for example, an end portion 82d1a of the heat insulating member 82d1 and an end portion 82d2a of the heat insulating member 82d2) are closely attached to each other over the entire circumference. In this way, the heat insulating members 82d1, 82d2, 82d3, and 82d4 are integrated with no gap as the unit of heat insulating material 82d.

[0054] For example, the temperature sensor 94c is covered with the heat insulating member 82d1. On the other hand, the brazed portions W1, W2, W3, W4, W5, and W6 are covered with any of the heat insulating members 82d2, 82d3, and 82d4 rather than the heat insulating member 82d1. However, the heat insulating members 82d1, 82d2, 82d3, and 82d4 are integrated as the unit of heat insulating material 82d, and hence, when refrigerant leaks at any of the brazed portions W1, W2, W3, and W4, the temperature of extremely-low temperature liquid re-

frigerant flowing downward in the minute gap along the refrigerant pipe or the temperature of the refrigerant pipe that is lowered to extremely-low temperature is detected by the temperature sensor 94c. Further, when refrigerant leaks in any one of the brazed portions W5 and W6, the leaking refrigerant moves within the range of the unit of heat insulating material 82d along the minute gap between the mating surfaces of the respective heat insulating members 82d1, 82d2, 82d3, and 82d4 or a minute gap between two adjacent heat insulating members among the heat insulating members 82d1, 82d2, 82d3, and 82d4. Accordingly, even in the case where refrigerant leaks in any one of the brazed portions W5 and W6, the temperature of the extremely-low temperature liquid refrigerant flowing downward in the minute gap or the temperature of the refrigerant pipe in which the temperature is decreased to extremely-low temperature is detected by the temperature sensor 94c.

[0055] That is, in the example illustrated in Fig. 6, the temperature sensor 94c and the brazed portions W1, W2, W3, W4, W5, and W6 are integrally covered with the unit of heat insulating material 82d constructed of the heat insulating members 82d1, 82d2, 82d3, and 82d4. Accordingly, extremely-low temperature caused by a leakage of refrigerant in any of the brazed portions W1, W2, W3, W4, W5, and W6 can be detected by the temperature sensor 94c.

[0056] Similarly, in the example illustrated in Fig. 6, the temperature sensor 94d and the brazed portions W1, W2, W3, W4, W5, and W6 are integrally covered with the unit of heat insulating material 82d constructed of the heat insulating members 82d1, 82d2, 82d3, and 82d4. Accordingly, extremely-low temperature caused by a leakage of refrigerant in any of the brazed portions W1, W2, W3, W4, W5, and W6 can also be detected by the temperature sensor 94d.

[0057] Fig. 7 is a schematic diagram for illustrating another modification example of the configuration of the heat insulating material 82d illustrated in Fig. 5. In the example illustrated in Fig. 7, among the heat insulating members 82d1, 82d2, 82d3, and 82d4, two adjacent heat insulating members are arranged such that end surfaces thereof (for example, an end surface 82d1b of the heat insulating member 82d1 and an end surface 82d2b of the heat insulating member 82d2) are closely attached to each other over the entire circumference. Even with the configuration illustrated in Fig. 7, extremely-low temperature caused by a leakage of refrigerant in any of the brazed portions W1, W2, W3, W4, W5, and W6 can be detected by the temperature sensors 94c and 94d.

[0058] As illustrated in Fig. 6 and Fig. 7, the heat insulating material 82d is not necessarily constructed of one heat insulating member or a pair of heat insulating members but may be constructed of a plurality of heat insulating members or a plurality of sets of heat insulating members that are linked integrally. With such a configuration, the size of each of the heat insulating members 82d1, 82d2, 82d3, and 82d4 can be decreased to an

easily mountable level, and hence the workability of manufacturing the indoor unit 1 can be improved. Further, heat insulating members having the same shape can be used as the heat insulating members 82d1, 82d2, 82d3, and 82d4. Therefore, the heat insulating members can be standardized, that is, manufacturing cost can be reduced.

[0059] Fig. 8 is a graph for showing exemplary temporal changes of the temperature detected by the temperature sensor 94b when refrigerant is caused to leak from the joint 15b in the indoor unit 1 of the air-conditioning apparatus according to Embodiment 1. In the graph, the horizontal axis represents the elapsed time (seconds) from the start of leakage, and the vertical axis represents the temperature (degrees C). In Fig. 8, a temporal change of the temperature when the leakage speed is 1 kg/h and a temporal change of the temperature when the leakage speed is 10 kg/h are shown together. As refrigerant, HFO-1234yf is used.

[0060] As shown in Fig. 8, when the leaking refrigerant is adiabatically expanded and gasified, the detected temperature detected by the temperature sensor 94b begins to decrease immediately after the start of leakage. When liquifaction due to recondensation of refrigerant begins after several seconds to over ten seconds elapsed from the start of leakage, the detected temperature detected by the temperature sensor 94b suddenly drops to about -29 degrees C, which is the boiling point of HFO-1234yf. Then, the detected temperature detected by the temperature sensor 94b is maintained at about -29 degrees C.

[0061] As described above, because the refrigerant leakage portion is covered with a heat insulating material, it is possible to detect a temperature drop due to a refrigerant leakage without time delay. Further, because a refrigerant leakage portion is covered with a heat insulating material, even in the case where the leakage speed is 1 kg/h, which is relatively low, it is possible to detect a temperature drop due to a refrigerant leakage with high responsiveness.

[0062] Fig. 9 is a flowchart for illustrating an example of refrigerant leakage detection processing to be performed by the controller 30 of the air-conditioning apparatus of Embodiment 1. The refrigerant leakage detection processing is performed repeatedly with predetermined time intervals only when power is supplied to the air-conditioning apparatus (that is, a breaker for supplying power to the air-conditioning apparatus is on) and the indoor fan 7f is stopped, for example. During an operation of the indoor fan 7f, the air in the indoor space is stirred. Thus, even if refrigerant has leaked, the refrigerant concentration does not become high locally. Accordingly, in Embodiment 1, the refrigerant leakage detection processing is performed only when the indoor fan 7f is stopped. In Embodiment 1, the temperature sensor for detecting a refrigerant leakage is accommodated in the casing 111 of the indoor unit 1 along with the indoor fan 7f, but even in the case where the temperature sensor for detecting a refrigerant leakage is not accommodated in the casing

111 of the indoor unit 1, the refrigerant leakage detection processing may be performed only when the indoor fan 7f is stopped. In this way, it is possible to prevent the refrigerant concentration in the indoor space from becoming high locally more reliably. In the case where a battery or an uninterruptible power source device capable of supplying power to the indoor unit 1 is mounted, the refrigerant leakage detection processing may be performed even when the breaker is off.

[0063] In Embodiment 1, the refrigerant leakage detection processing procedures using the respective temperature sensors 94a, 94b, 94c, and 94d are performed in parallel. In the following description, only the refrigerant leakage detection processing using the temperature sensor 94b is described as an example.

[0064] In Step S1 of Fig. 9, the controller 30 acquires information of a detected temperature detected by the temperature sensor 94b.

[0065] Next, in Step S2, it is determined whether or not the detected temperature detected by the temperature sensor 94b is lower than a preset threshold temperature (for example, -10 degrees C). The threshold temperature may be set to a lower limit (for example, 3 degrees C; the detail is described later) of the evaporating temperature of the load-side heat exchanger 7 at the time of cooling operation, for example. When it is determined that the detected temperature is lower than the threshold temperature, the processing proceeds to Step S3. When it is determined that the detected temperature is equal to or higher than the threshold temperature, the processing ends.

[0066] In Step S3, it is determined that refrigerant has leaked. When determining that refrigerant has leaked, the controller 30 may operate the indoor fan 7f. In this way, the air in the indoor space is stirred, and the leaking refrigerant can be diffused. Thus, it is possible to prevent the refrigerant concentration from becoming high locally. Accordingly, even in the case where flammable refrigerant is used as refrigerant, it is possible to prevent a region in which a refrigerant concentration is at a flammable level from being formed.

[0067] Further, when determining that refrigerant has leaked, the controller 30 may set the system state of the air-conditioning apparatus to "abnormal" to not allow operations of those components other than the indoor fan 7f.

[0068] Further, when determining that refrigerant has leaked, the controller 30 may inform the user of abnormality by using an informing unit (display unit or sound output unit) provided on the operation unit 26. For example, the controller 30 displays, on the display unit provided on the operation unit 26, an instruction such as "gas leakage occurs, open the window". In this way, it is possible to immediately allow the user to recognize that refrigerant has leaked and that an action such as ventilation is required to be taken. Accordingly, it is possible to prevent the refrigerant concentration from becoming high locally more reliably.

[0069] Fig. 10 is a flowchart for illustrating another ex-

ample of the refrigerant leakage detection processing to be performed by the controller 30 of the air-conditioning apparatus according to Embodiment 1. In Step S11 of Fig. 10, the controller 30 acquires information of a detected temperature detected by the temperature sensor 94b.

[0070] In Step S12, the controller 30 calculates a temporal change of the detected temperature detected by the temperature sensor 94b. For example, in the case where the detected temperature detected by the temperature sensor 94b is acquired every one minute, a value obtained by subtracting the detected temperature that was acquired one minute before from the currently acquired detected temperature may be used as a temporal change of the detected temperature. When the detected temperature is decreasing, the temporal change of the detected temperature takes a negative value. Accordingly, when the detected temperature is decreasing, the temporal change of the detected temperature decreases as the detected temperature changes more drastically.

[0071] In Step S13, it is determined whether or not the detected temperature detected by the temperature sensor 94b is lower than a threshold value (for example, -20 degrees C/minute). When it is determined that the temporal change of the detected temperature is lower than the threshold value, the processing proceeds to Step S14. When it is determined that the temporal change of the detected temperature is equal to or larger than the threshold value, the processing ends.

[0072] In Step S14, it is determined that refrigerant has leaked, and the same processing as that of Step S3 of Fig. 9 is performed.

[0073] Next, still another example of the refrigerant leakage detection processing is described. As each temperature sensor, a thermistor in which electric resistance is changed in accordance with a change of the temperature is used. The electric resistance of a thermistor decreases when the temperature increases, while the electric resistance increases when the temperature decreases. On the substrate, a fixed resistor connected in series to the thermistor is mounted. The thermistor and the fixed resistor are applied with a voltage of DC 5 V, for example. The electric resistance of the thermistor is changed in accordance with the temperature, and hence the voltage (divided voltage) applied to the thermistor is changed in accordance with the temperature. The controller 30 converts a value of the voltage applied to the thermistor into the temperature, to thereby acquire the detected temperature detected by each temperature sensor.

[0074] The range of resistance values of a thermistor is set based on the range of temperature that is to be detected. When the voltage applied to the thermistor is out of the voltage range corresponding to the detected temperature range, an error indicating that the temperature is out of the detected temperature range may be detected by the controller 30 in some cases.

[0075] Meanwhile, in the configuration illustrated in Fig. 3 to Fig. 5 and other figures, temperature sensors

configured to detect a refrigerant temperature of the load-side heat exchanger 7 (for example, the heat exchanger liquid pipe temperature sensor 92 and the heat exchanger two-phase pipe temperature sensor 93) and the temperature sensors 94a, 94b, 94c, and 94d for detecting a refrigerant leakage are provided independently. However, for example, the heat exchanger liquid pipe temperature sensor 92 may also serve as the temperature sensor 94d for detecting a refrigerant leakage. The heat exchanger liquid pipe temperature sensor 92 is covered with the heat insulating material 82d, which is the same as the heat insulating material 82d covering the brazed portion W, and is provided at a position thermally connected to the brazed portion W via a refrigerant pipe. Accordingly, it is possible to detect an extremely-low temperature phenomenon near the brazed portion W.

[0076] The detected temperature range of the temperature sensor configured to detect a refrigerant temperature of the load-side heat exchanger 7 is set based on the temperature range of the load-side heat exchanger 7 at the time of normal operation. For example, the refrigerant circuit 40 is controlled such that the evaporating temperature at the time of cooling operation does not decrease to 3 degrees C or lower, by cryoprotection of the load-side heat exchanger 7. Further, the refrigerant circuit 40 is controlled such that the condensing temperature at the time of heating operation does not increase to 60 degrees C or higher, by condensing temperature (condensing pressure) excessive rise prevention protection for preventing failure of the compressor 3, for example. In this case, the temperature range of the load-side heat exchanger 7 at the time of normal operation is from 3 degrees C to 60 degrees C.

[0077] As described above, when a refrigerant leakage occurs in Embodiment 1, the temperature sensor near the leakage portion detects an extremely-low temperature that is greatly different from the temperature range of the load-side heat exchanger 7. In this case, when an error indicating that the temperature is out of the detected temperature range of the temperature sensor is detected, the controller 30 may determine that an extremely-low temperature is detected by the temperature sensor to determine that refrigerant has leaked.

[0078] With this configuration, similar to the configuration illustrated in Fig. 3 to Fig. 5 and other figures, a leakage of refrigerant can be detected reliably with high responsiveness for a long period of time. Further, with this configuration, the number of temperature sensors can be reduced, and thus the manufacturing cost of the air-conditioning apparatus can be reduced.

[0079] Next, a modification example of the refrigeration cycle apparatus according to Embodiment 1 is described. In the configuration illustrated in Fig. 3 to Fig. 5 and other figures, while the temperature sensors 94a, 94b, 94c, and 94d are provided below the brazed portions W or joint portions (for example, joints 15a and 15b), the temperature sensors 94a, 94b, 94c, and 94d may be provided above or beside the brazed portions W or joint portions.

For example, the temperature sensors 94a and 94b may be provided at positions above or beside the joints 15a and 15b of the indoor pipes 9a and 9b in the lower space 115a illustrated in Fig. 5, and where the temperature sensors 94a and 94b are covered with the heat insulating material 82b (for example, positions where the temperature sensors 94a and 94b are further covered with the heat insulating material 82a). With this configuration, the temperature sensors 94a and 94b can be mounted on the indoor pipe 9a and 9b by the air-conditioning apparatus manufacturer. Accordingly, the need to mount the temperature sensors 94a and 94b at the time of installing the air-conditioning apparatus is eliminated, and hence the installation workability can be improved.

[0080] The gaps between the outer peripheral surfaces of the indoor pipes 9a and 9b and the inner peripheral surfaces of the heat insulating materials 82a and 82b are minute, and hence the extremely-low temperature refrigerant liquified by recondensation in the vicinity of the joints 15a and 15b moves not only downward but also upward and sideward by the capillary phenomenon. Accordingly, even when the temperature sensors 94a and 94b are provided above or beside the joints 15a and 15b, a temperature of the extremely-low temperature refrigerant can be detected.

[0081] Further, the heat exchanger two-phase pipe temperature sensor 93 may also serve as the temperature sensor 94d for detecting a refrigerant leakage, for example.

[0082] For example, when a refrigerant leakage occurs at one brazed portion W, extremely-low temperature refrigerant, which is liquified by recondensation, moves within the range of the heat insulating material 82d along a minute gap between the heat insulating material 82d and the refrigerant pipe or a minute gap between the mating surfaces of the heat insulating material 82d, by the capillary phenomenon. The heat exchanger two-phase pipe temperature sensor 93 is integrally covered with the heat insulating material 82d, which is the same as the heat insulating material covering the brazed portions W of the U bent pipe 73 to which the heat exchanger two-phase pipe temperature sensor 93 is provided, other U bent pipes 73, the indoor pipes 9a and 9b, the header main pipe 61, and other pipes. Accordingly, the heat exchanger two-phase pipe temperature sensor 93 is capable of detecting a temperature of the extremely-low temperature refrigerant that has leaked at each brazed portion W covered with the heat insulating material 82d.

[0083] As described above, the refrigeration cycle apparatus according to Embodiment 1 includes: the refrigerant circuit 40 in which refrigerant circulates, the temperature sensors 94a, 94b, 94c, and 94d provided at positions on the refrigerant circuit 40, the positions being adjacent to brazed portions (for example, the brazed portions W of the load-side heat exchanger 7) or the position being adjacent to joint portions (for example, the joints 15a and 15b) in which refrigerant pipes are joined to each other; and the controller 30 configured to determine

whether or not the refrigerant has leaked based on a detected temperature detected by the temperature sensors 94a, 94b, 94c, and 94d. The temperature sensors 94a, 94b, 94c, and 94d are covered with the heat insulating materials 82a, 82b, and 82d together with the brazed portions or the joint portions.

[0084] With this configuration, the temperature sensors 94a, 94b, 94c, and 94d can be used as refrigerant detection units. Therefore, a leakage of refrigerant can be detected reliably for a long period of time. Further, with this configuration, the temperature sensors 94a, 94b, 94c, and 94d are covered with the heat insulating materials 82a, 82b, and 82d together with the brazed portions or the joint portions. Therefore, it is possible to detect a temperature drop due to a refrigerant leakage in the brazed portions or the joint portions without time delay. Accordingly, a leakage of refrigerant can be detected with high responsiveness.

[0085] Further, in the refrigeration cycle apparatus according to Embodiment 1, the controller 30 may be configured to determine that the refrigerant has leaked when the detected temperature is lower than the threshold temperature.

[0086] Further, in the refrigeration cycle apparatus according to Embodiment 1, the controller 30 may be configured to determine that the refrigerant has leaked when a temporal change of the detected temperature is lower than the threshold value.

[0087] Further, the refrigeration cycle apparatus according to Embodiment 1 may further include the fan (for example, indoor fan 7f), and the controller 30 may be configured to determine whether or not the refrigerant has leaked only when the fan is stopped.

[0088] Further, the refrigeration cycle apparatus according to Embodiment 1 may further include the fan (for example, the indoor fan 7f) and the casing (for example, the casing 111) configured to accommodate the fan. The temperature sensors (for example, temperature sensors 94a, 94b, 94c, and 94d) may be accommodated in the casing, and the controller 30 may be configured to determine whether or not the refrigerant has leaked only when the fan is stopped.

[0089] Further, in the refrigeration cycle apparatus according to Embodiment 1, the temperature sensors 94a, 94b, 94c, and 94d may be provided below the brazed portions or the joint portions.

[0090] Further, in the refrigeration cycle apparatus according to Embodiment 1, the temperature sensors 94a, 94b, 94c, and 94d may be provided above or beside the brazed portions or the joint portions.

[0091] Further, in the refrigeration cycle apparatus according to Embodiment 1, the temperature sensors 94a, 94b, 94c, and 94d may be covered with the heat insulating materials 82a, 82b, and 82d that are the same as the heat insulating materials 82a, 82b, and 82d covering the brazed portions or the joint portions.

[0092] Further, in the refrigeration cycle apparatus according to Embodiment 1, the heat insulating material

82d may be constructed of the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4.

[0093] Further, in the refrigeration cycle apparatus according to Embodiment 1, two adjacent heat insulating members among the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4 may be arranged such that end portions thereof (for example, the end portion 82d1a of the heat insulating member 82d1 and the end portion 82d2a of the heat insulating member 82d2) overlap with each other.

[0094] Further, in the refrigeration cycle apparatus according to Embodiment 1, two adjacent heat insulating members among the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4 may be arranged such that end surfaces thereof (for example, the end surface 82d1b of the heat insulating member 82d1 and the end surface 82d2b of the heat insulating member 82d2) are in contact with each other.

[0095] Further, in the refrigeration cycle apparatus according to Embodiment 1, the brazed portions or the joint portions may be covered with first heat insulating members 82d2, 82d3, and 82d4 among the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4, and the temperature sensor 94c may be covered with a second heat insulating member 82d1 among the plurality of heat insulating members 82d1, 82d2, 82d3, and 82d4.

[0096] Further, in the refrigeration cycle apparatus according to Embodiment 1, the temperature sensors configured to detect the refrigerant temperature (for example, liquid pipe temperature or two-phase pipe temperature) of the heat exchanger may also serve as the temperature sensors 94a, 94b, 94c, and 94d.

[0097] Further, a refrigerant leakage detection method according to Embodiment 1 includes: detecting a temperature of a position on the refrigerant circuit 40 in which refrigerant circulates, the position being adjacent to brazed portions (for example, the brazed portions W of load-side heat exchanger 7) and being covered with the heat insulating material 82d together with the brazed portions, or the position being adjacent to joint portions in which refrigerant pipes are joined to each other (for example, the joints 15a and 15b) and being covered with the heat insulating materials 82a and 82b together with the joint portions; and determining whether or not the refrigerant has leaked based on the temperature. With this configuration, it is possible to detect a leakage of refrigerant reliably with high responsiveness for a long period of time.

Other Embodiments

[0098] The present invention can be modified in various manners without being limited to Embodiment 1.

[0099] For example, while a floor type indoor unit is exemplarily described as the indoor unit 1 in Embodiment 1, the present invention is applicable to indoor units of other types such as a ceiling cassette type, a ceiling concealed type, a ceiling suspended type, and a wall type.

[0100] Further, while Embodiment 1 exemplarily describes a configuration in which a temperature sensor for detecting a refrigerant leakage is provided in the indoor unit 1, a temperature sensor for detecting a refrigerant leakage may be provided in the outdoor unit 2 (for example, in the casing of the outdoor unit 2). In this case, the temperature sensor for detecting a refrigerant leakage is provided at a position adjacent to a brazed portion of the heat source-side heat exchanger 5, for example, and is covered with a heat insulating material together with the brazed portion. Alternatively, the temperature sensor for detecting a refrigerant leakage is provided at a position in the outdoor unit 2, which is adjacent to a joint portion in which refrigerant pipes are joined to each other, and is covered with a heat insulating material together with the joint portion. The controller 30 determines whether or not the refrigerant has leaked based on the detected temperature detected by the temperature sensor for detecting a refrigerant leakage. With this configuration, it is possible to detect a leakage of refrigerant in the outdoor unit 2 reliably with high responsiveness for a long period of time. During an operation of the outdoor fan 5f, the air around the outdoor unit 2 is stirred. Accordingly, even if refrigerant has leaked in the outdoor unit 2, the refrigerant concentration does not increase locally around the outdoor unit 2. Therefore, in the case where the outdoor fan 5f and the temperature sensor are accommodated in the casing of the outdoor unit 2, for example, determination of whether or not the refrigerant has leaked with use of the temperature sensor may be performed only when the outdoor fan 5f is stopped.

[0101] As brazed portions of the refrigerant circuit 40, while Embodiment 1 mainly describes the brazed portions W in the load-side heat exchanger 7 and brazed portions in the heat source-side heat exchanger 5 as examples, the present invention is not limited thereto. The brazed portions of the refrigerant circuit 40 exist at other positions such as between the indoor pipes 9a and 9b and the joints 15a and 15b in the indoor unit 1, between the suction pipe 11 and the compressor 3 in the outdoor unit 2, and between the discharge pipe 12 and the compressor 3 in the outdoor unit 2, besides those in the load-side heat exchanger 7 and the heat source-side heat exchanger 5. Accordingly, a temperature sensor for detecting a refrigerant leakage may be provided at a position on the refrigerant circuit 40, which is adjacent to a brazed portion other than those in the load-side heat exchanger 7 and the heat source-side heat exchanger 5, and may be covered with a heat insulating material together with the brazed portion. Even with this configuration, a leakage of refrigerant in the refrigerant circuit 40 can be detected reliably with high responsiveness for a long period of time.

[0102] Further, while Embodiment 1 mainly describes the joints 15a and 15b of the indoor unit 1 as examples of joint portions of the refrigerant circuit 40, the present invention is not limited thereto. The joint portions of the refrigerant circuit 40 also include the joints 16a and 16b

and other joints of the outdoor unit 2. Accordingly, the temperature sensor for detecting a refrigerant leakage may be provided adjacent to a joint portion other than the joints 15a and 15b (for example, the joints 16a and 16b) on the refrigerant circuit 40, and may be covered with a heat insulating material together with the joint portion. Even with this configuration, a leakage of refrigerant in the refrigerant circuit 40 can be detected reliably with high responsiveness for a long period of time.

[0103] Further, while Embodiment 1 describes an air-conditioning apparatus as an example of a refrigeration cycle apparatus, the present invention is applicable to other refrigeration cycle apparatuses such as a heat pump water heater, a chiller, and a showcase.

[0104] Further, the above-mentioned embodiments and modification examples can be carried out in combination with each other.

Reference Signs List

[0105] 1 indoor unit 2 outdoor unit 3 compressor 4 refrigerant flow path switching device 5 heat source-side heat exchanger 5f outdoor fan 6 decompression device 7 load-side heat exchanger 7f indoor fan 9a, 9b indoor pipe 10a, 10b extension pipe 11 suction pipe 12 discharge pipe 13a, 13b extension pipe connection valve 14a, 14b, 14c service port 15a, 15b, 16a, 16b joint 20 partition 20a air passage opening port 25 electrical component box 26 operation unit 30 controller 40 refrigerant circuit 61 header main pipe 62, 62-1, 62-2, 62-3 header branch pipe 63, 63-1, 63-2 indoor refrigerant branch pipe 70 fin 71 heat transfer tube 71a, 71b end portion 72 hair-pin pipe 73 U bent pipe 81 air passage 82a, 82b, 82c, 82d heat insulating material 82d1, 82d2, 82d3, 82d4 heat insulating member 82d1a, 82d2a end portion 82d1b, 82d2b end surface 83 band 91 intake air temperature sensor 92 heat exchanger liquid pipe temperature sensor 93 heat exchanger two-phase pipe temperature sensor 94a, 94b, 94c, 94d temperature sensor 107 impeller 108 fan casing 108a air outlet opening port 108b suction opening port 111 casing 112 air inlet 113 air outlet 114a first front panel 114b second front panel 114c third front panel 115a lower space 115b upper space W, W1, W2, W3, W4, W5, W6 brazed portion

Claims

1. A refrigeration cycle apparatus, comprising:

a refrigerant circuit in which refrigerant circulates;
a temperature sensor provided at a position on the refrigerant circuit, the position being adjacent to a brazed portion or the position being adjacent to a joint portion in which refrigerant pipes are joined to each other; and
a controller configured to determine whether or

not the refrigerant has leaked based on a detected temperature detected by the temperature sensor,

wherein the temperature sensor is covered with a heat insulating material together with the brazed portion or the joint portion.

2. The refrigeration cycle apparatus of claim 1, wherein the controller is configured to determine that the refrigerant has leaked when the detected temperature is lower than a threshold temperature.

3. The refrigeration cycle apparatus of claim 1, wherein the controller is configured to determine that the refrigerant has leaked when a temporal change of the detected temperature is lower than a threshold value.

4. The refrigeration cycle apparatus of any one of claims 1 to 3, further comprising a fan, wherein the controller is configured to determine whether or not the refrigerant has leaked only when the fan is stopped.

5. The refrigeration cycle apparatus of any one of claims 1 to 4, wherein the temperature sensor is provided below the brazed portion or the joint portion.

6. The refrigeration cycle apparatus of any one of claims 1 to 4, wherein the temperature sensor is provided above or beside the brazed portion or the joint portion.

7. The refrigeration cycle apparatus of any one of claims 1 to 6, wherein the temperature sensor is covered with a heat insulating material that is same as the heat insulating material covering the brazed portion or the joint portion.

8. The refrigeration cycle apparatus of any one of claims 1 to 7, wherein the heat insulating material comprises a plurality of heat insulating members.

9. The refrigeration cycle apparatus of claim 8, wherein, among the plurality of the heat insulating members, two heat insulating members that are adjacent to each other are arranged such that end portions of the two heat insulating members overlap with each other.

10. The refrigeration cycle apparatus of claim 8, wherein, among the plurality of the heat insulating members, two heat insulating members that are adjacent to each other are arranged such that end surfaces of the two heat insulating members are in contact with each other.

11. The refrigeration cycle apparatus of any one of

claims 8 to 10,
wherein the brazed portion or the joint portion is covered with a first heat insulating member among the plurality of the heat insulating members, and
wherein the temperature sensor is covered with a second heat insulating member among the plurality of the heat insulating members.

12. The refrigeration cycle apparatus of any one of claims 1 to 11, wherein the temperature sensor also serves as a temperature sensor configured to detect a refrigerant temperature of a heat exchanger.

13. A refrigerant leakage detection method, comprising:
detecting a temperature of a position on a refrigerant circuit in which refrigerant circulates, the position being adjacent to a brazed portion and being covered with a heat insulating material together with the brazed portion, or the position being adjacent to a joint portion in which refrigerant pipes are joined to each other and being covered with a heat insulating material together with the joint portion; and
determining whether or not the refrigerant has leaked based on the temperature.

30

35

40

45

50

55

FIG. 1

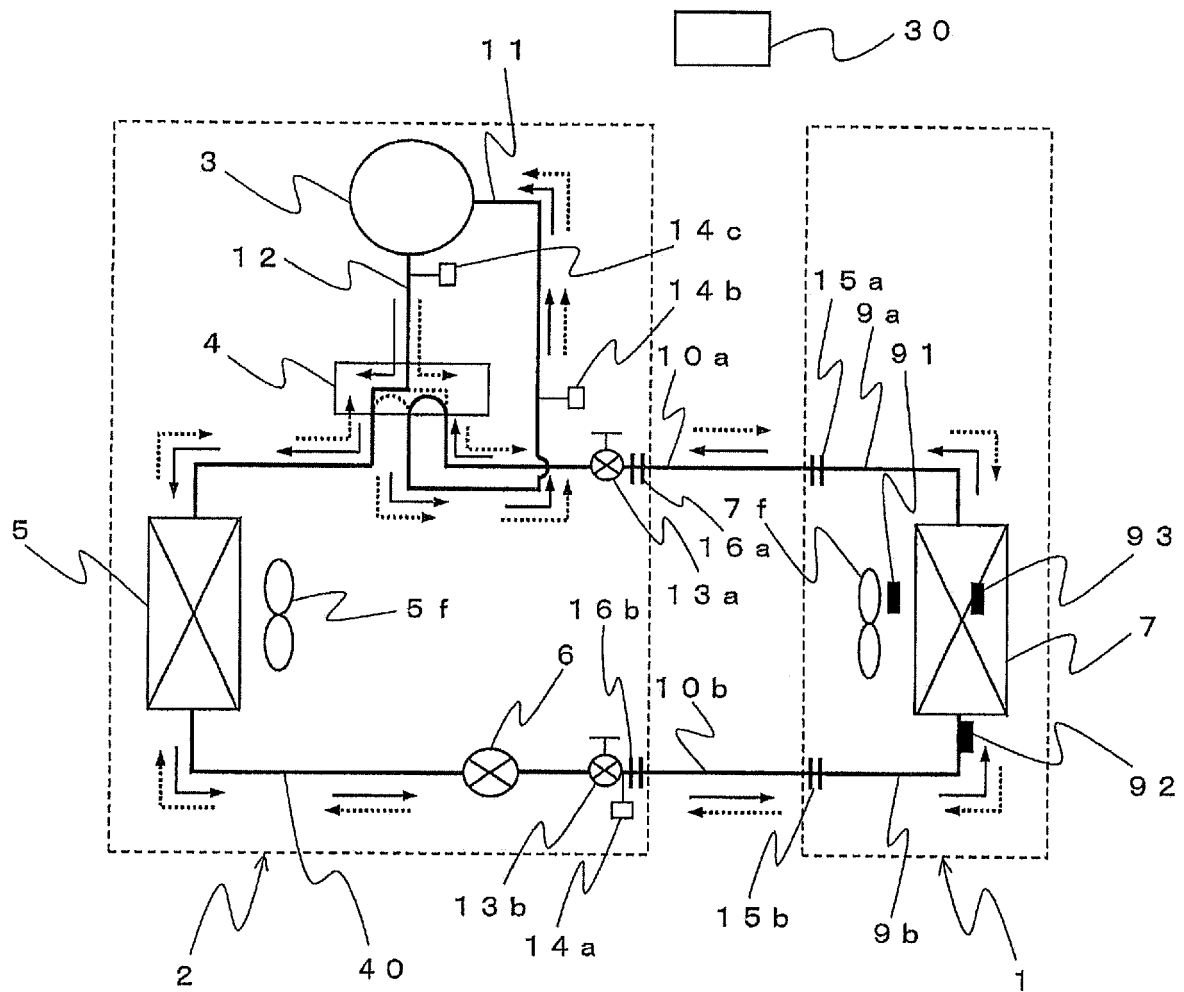


FIG. 2

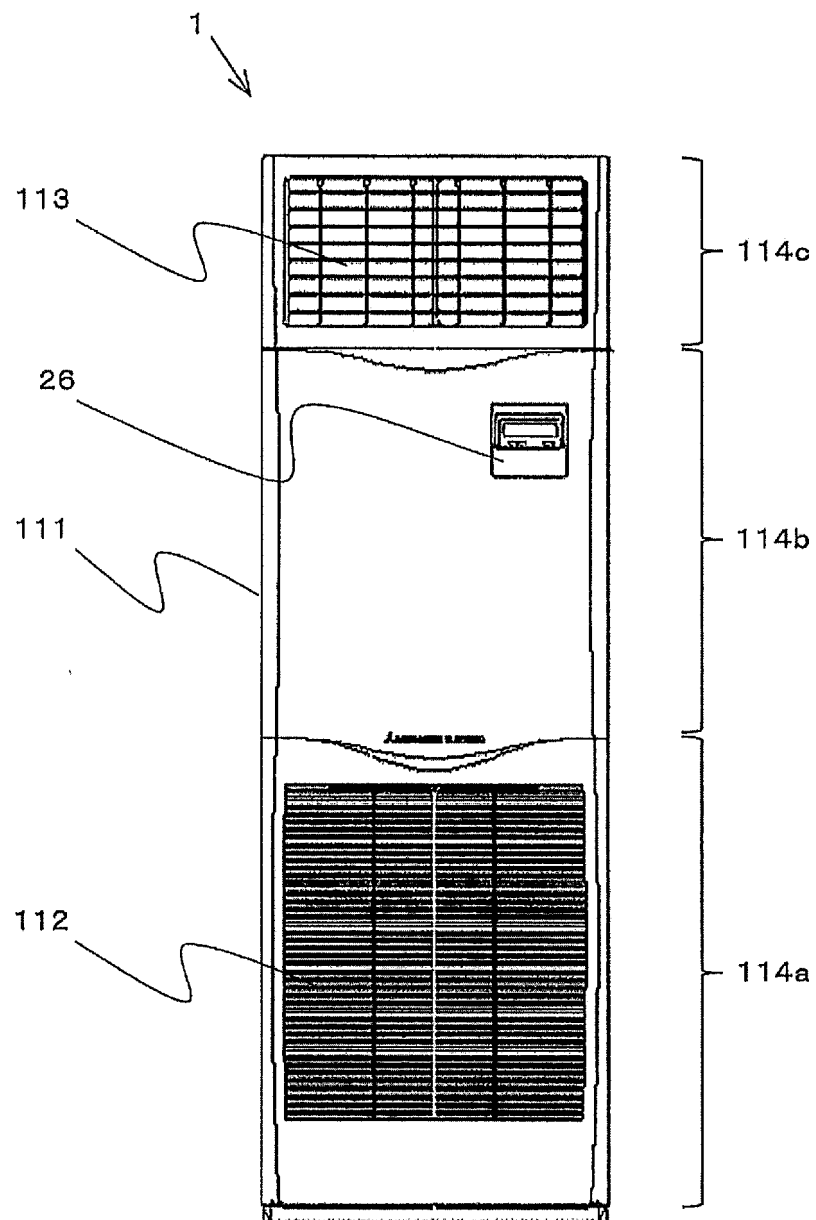


FIG. 3

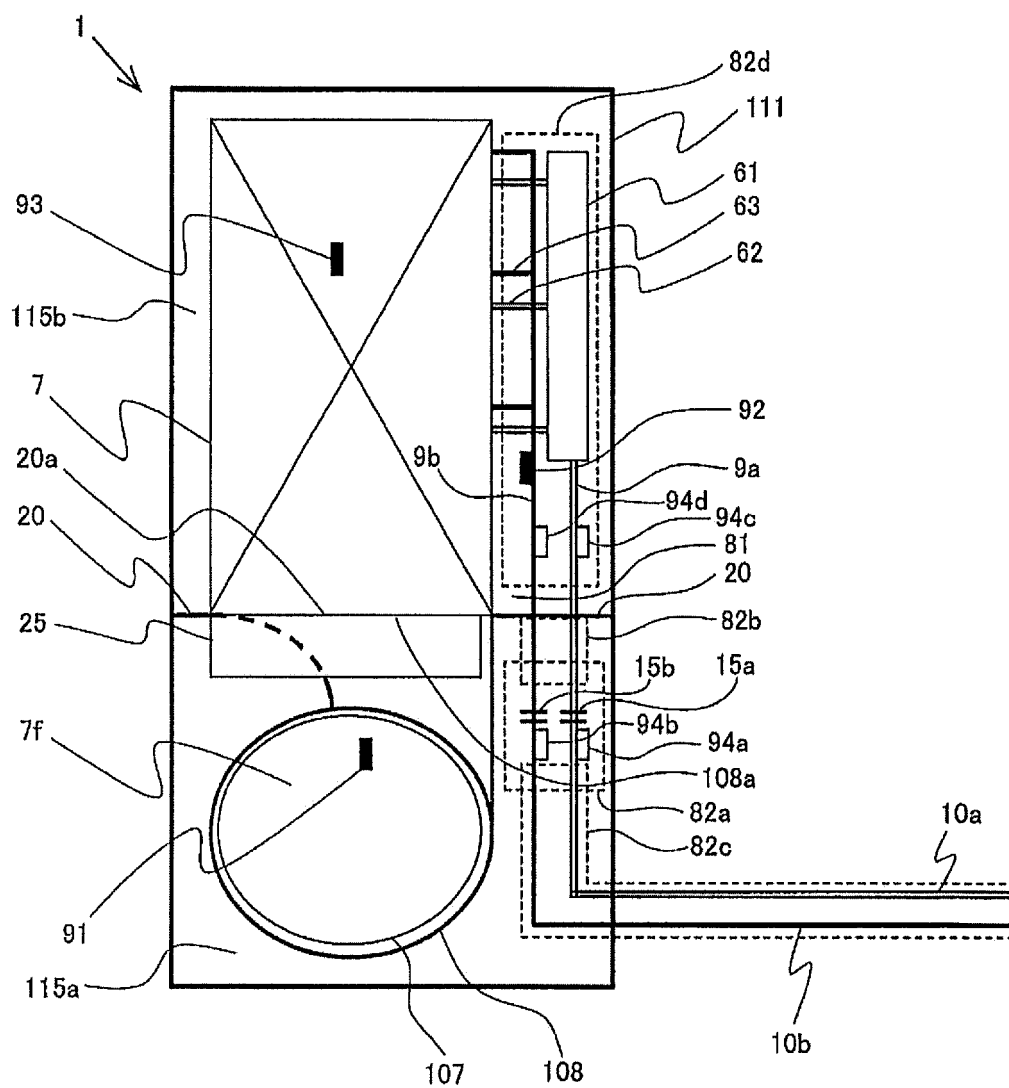


FIG. 4

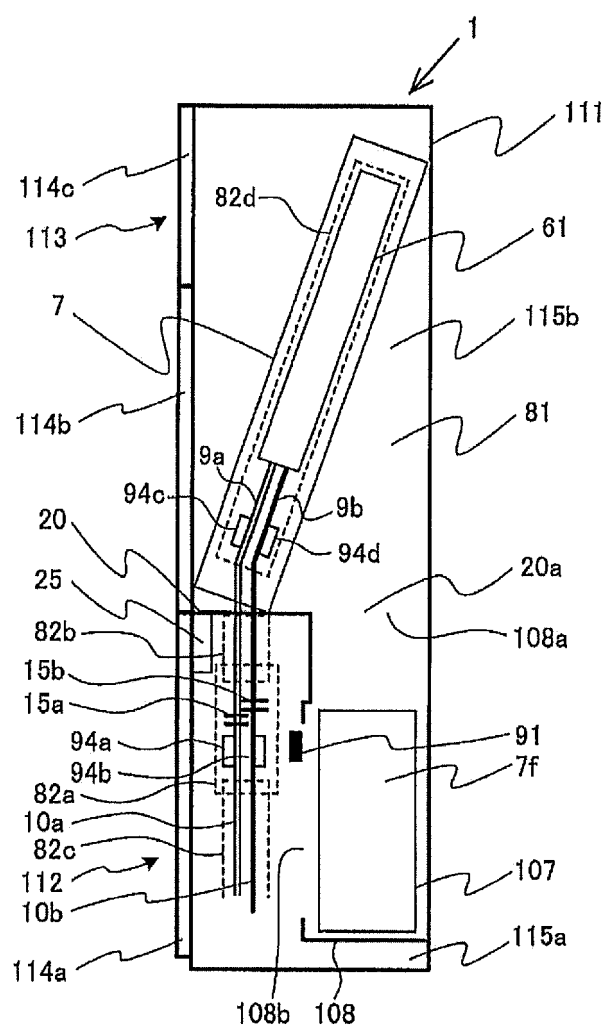


FIG. 5

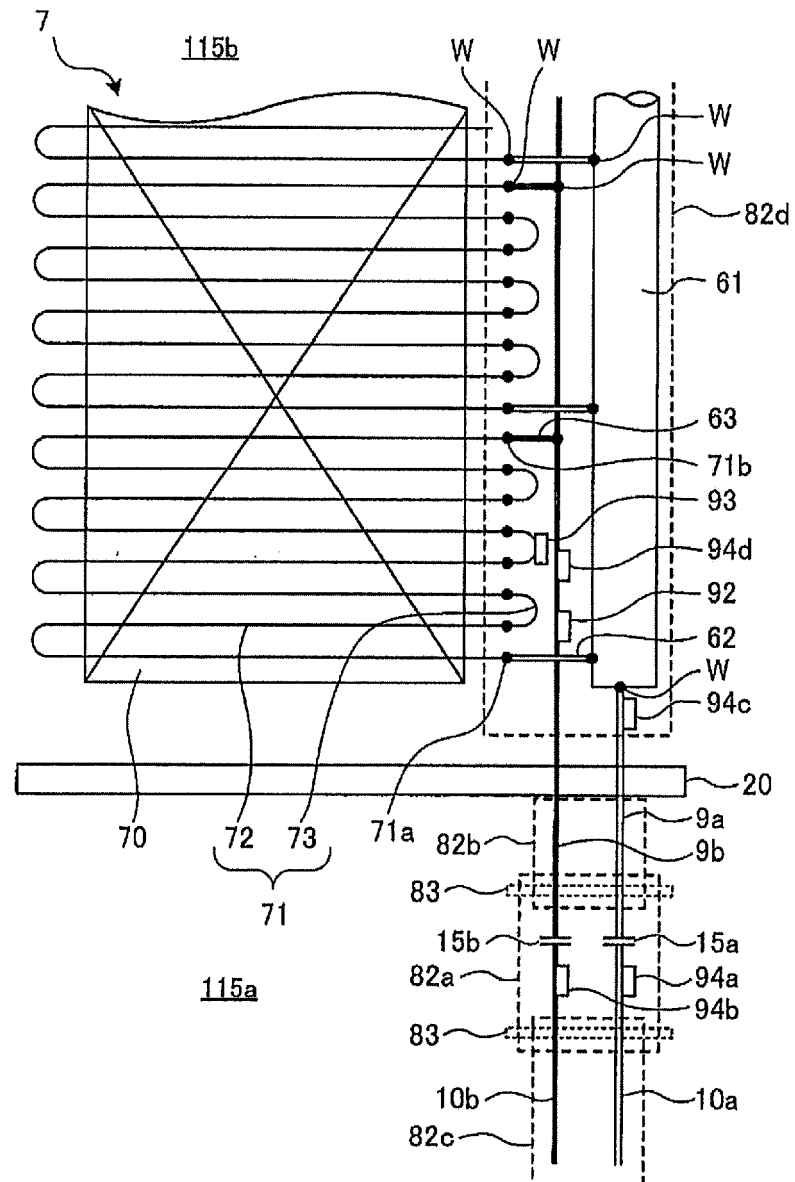


FIG. 6

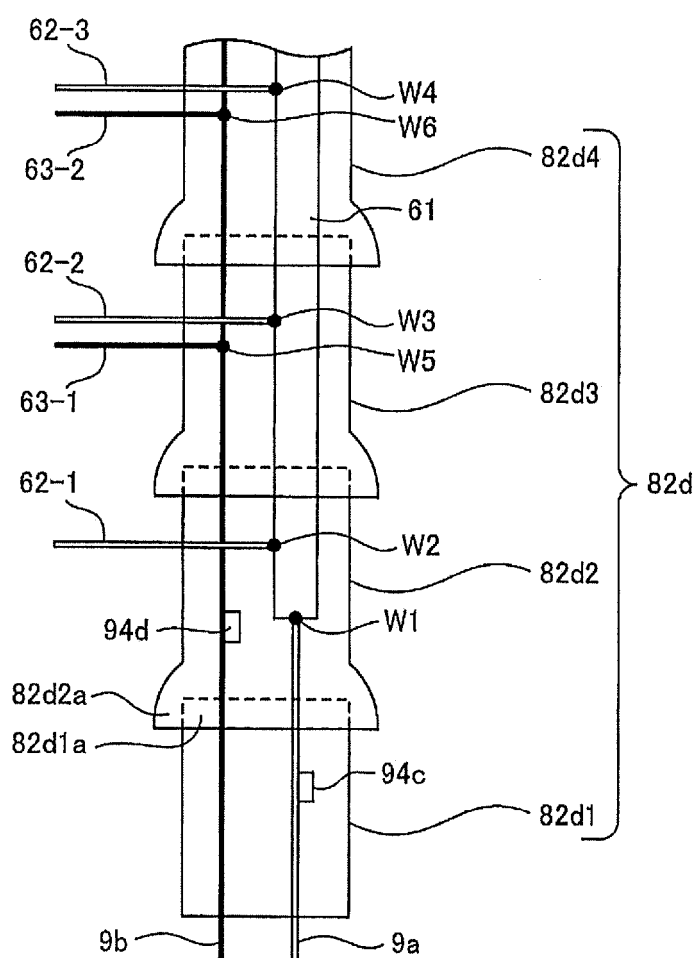


FIG. 7

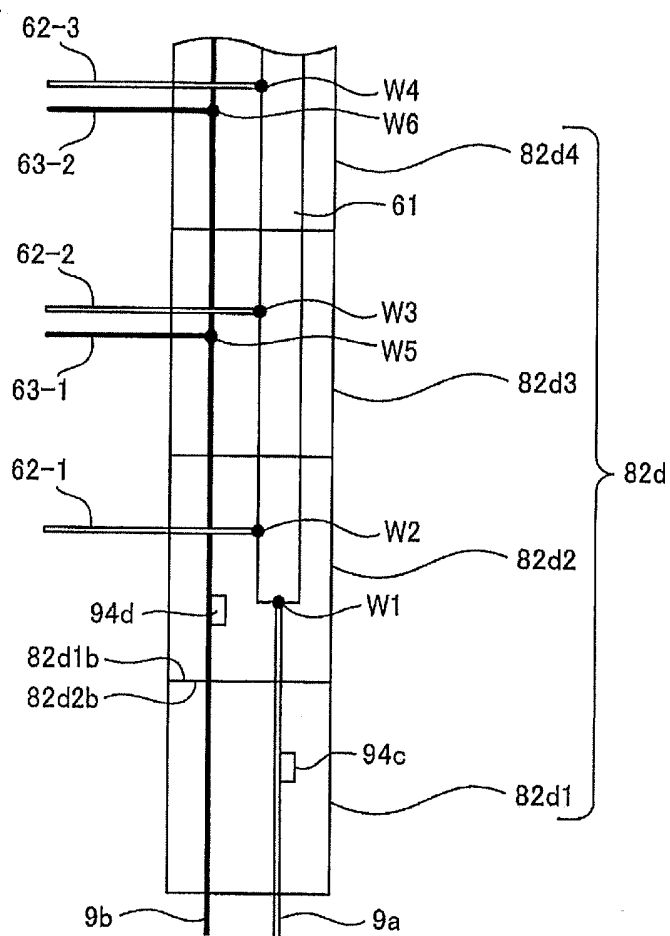


FIG. 8

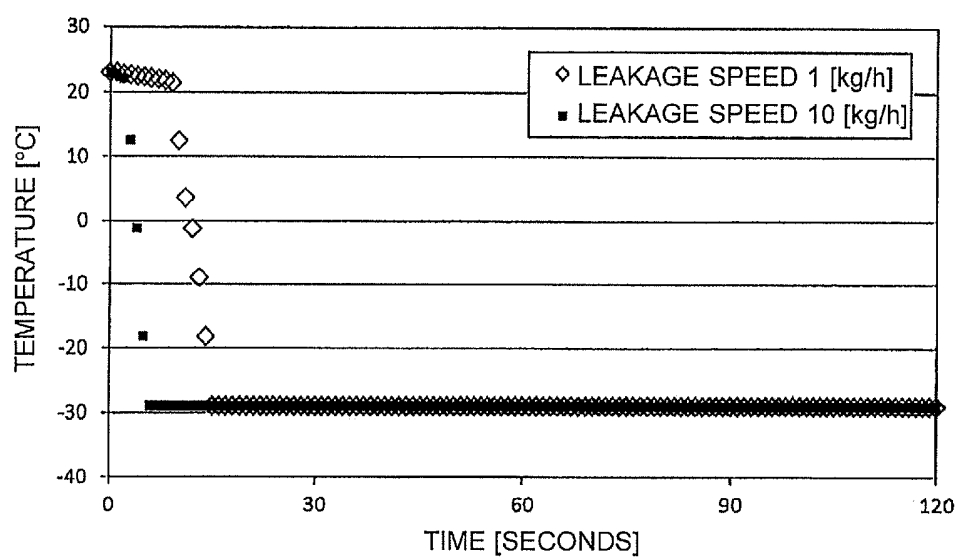


FIG. 9

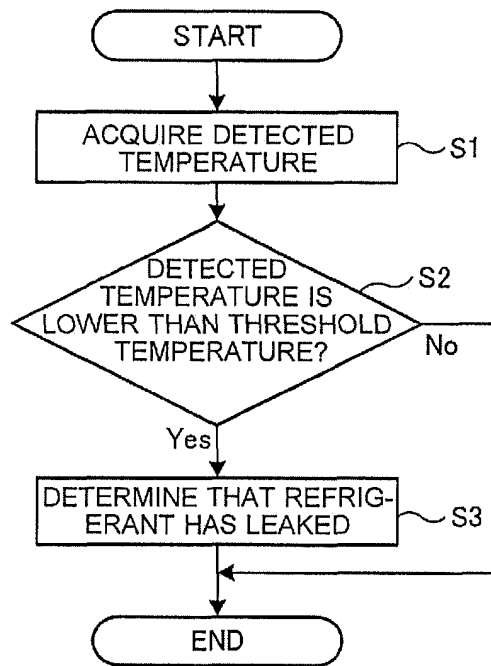
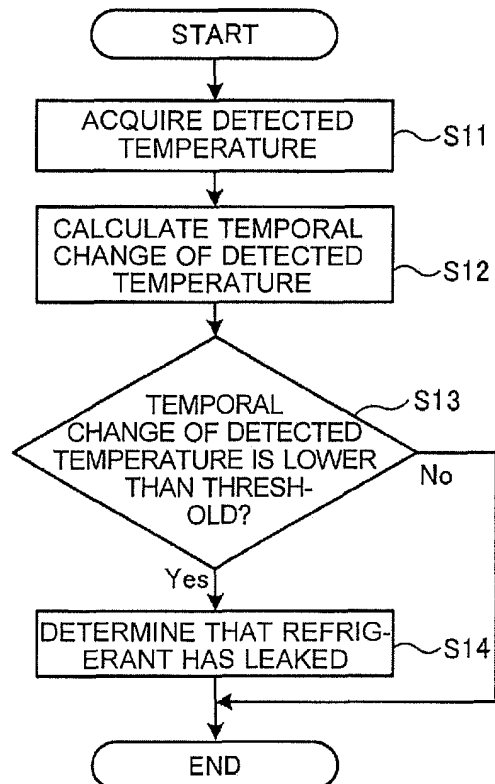


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/080641

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 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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.
A	JP 2009-68772 A (Nissan Motor Co., Ltd.), 02 April 2009 (02.04.2009), paragraph [0024]; fig. 1 (Family: none)	1-13
A	JP 2000-230761 A (Zexel Corp.), 22 August 2000 (22.08.2000), fig. 2 to 3 (Family: none)	1-13
A	JP 2000-146375 A (Hitachi, Ltd.), 26 May 2000 (26.05.2000), fig. 3 (Family: none)	1-13

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
13 December 2016 (13.12.16)Date of mailing of the international search report
27 December 2016 (27.12.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/080641

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	JP 2016-125694 A (Daikin Industries, Ltd.), 11 July 2016 (11.07.2016), paragraphs [0029] to [0037]; fig. 4 to 5 (Family: none)	1-13

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

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 4599699 B [0004]
- JP 3610812 B [0004]