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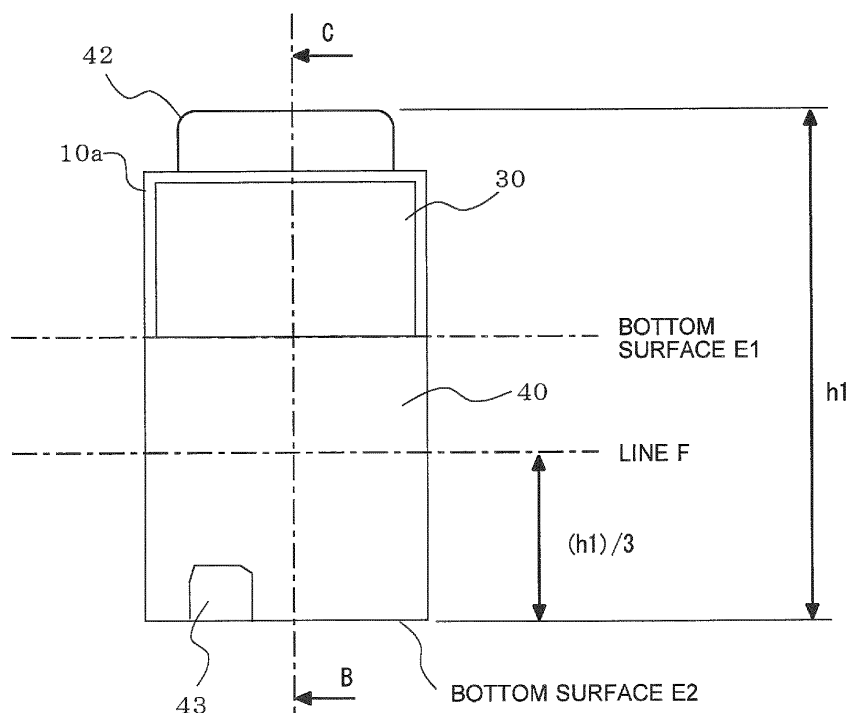
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(54) **OUTDOOR UNIT AND AIR CONDITIONING DEVICE WITH OUTDOOR UNIT**

(57) In an outdoor unit 10, an electrical component box 30 is disposed such that a bottom surface E1 of the electrical component box 30 is located at a height greater than 1/3 a height h1 of a housing 10 from a bottom surface E2 of the housing 10. A controller 50 and relays 33a

through 33d are disposed such that bottom surfaces E4 and E5 thereof are located at a height greater than 1/3 a height h2 of the electrical component box 30 from a bottom surface E3 of the electrical component box 30.

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Description

Technical Field

[0001] The present invention relates to an outdoor unit applied to, for example, a multi-air-conditioning apparatuses for buildings, and an air-conditioning apparatus provided with the outdoor unit.

Background Art

[0002] In conventional air-conditioning apparatuses such as multi-air-conditioning apparatuses for buildings, a refrigerant is circulated between an outdoor unit that is a heat source unit disposed outside the building and indoor units that are disposed in rooms of the building, for example. In such an air-conditioning apparatus, the refrigerant transfers heat to or receives heat from air, so that the thus heated or cooled air heats or cools the air-conditioned space.

[0003] In the outdoor unit of the air-conditioning apparatus, many electrical components are mounted, such as a compressor, a solenoid valve, a fan motor. Further, in order to drive these electrical components, an inverter device and a substrate are accommodated in an electrical component box and disposed in the outdoor unit. The electrical component box has slits or holes in the upper or lower surface, or has a large heat sink. The reason for this is to allow air to flow into the electrical components and thus to suppress temperature increase by the electronic parts inside the electrical component box.

[0004] In recent years, from the viewpoint of global warming, there has been a move to restrict the use of HFC-based refrigerants having high global warming potential (for example, R410A, R404A, R407C, R134a, and so on). Accordingly, air-conditioning apparatuses that use refrigerants having low global warming potential (for example, R32, HFO1234yf, HFO1234ze(E), and a mixture of these refrigerants) have been proposed. However, these refrigerants having low global warming potential are all flammable, and might enter the electrical component box when the refrigerant leaks.

[0005] In view of such an issue, there has been disclosed a technique in which a non-contact switch is used in an electrical component, and in which a film that passes only gas is provided on an electrical component box (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 6-101913 (paragraphs [0030] - [0033], [0045], and so on)

Summary of Invention

Technical Problem

[0007] However, if a non-contact switch is provided or a film that passes only gas is used as in the technique disclosed in Patent Literature 1, costs are significantly increased. Moreover, since the film severely degrades over time, it is difficult to ensure long-term reliability. Therefore, the film needs to be replaced periodically, making maintenance of the system very troublesome and expensive.

[0008] The present invention has been made to solve the above problems, and aims to provide an outdoor unit with significantly improved safety while reducing cost increase, and an air-conditioning apparatus provided with the outdoor unit. Solution to Problem

[0009] An outdoor unit according to the present invention constitutes part of an air-conditioning apparatus using a flammable refrigerant. The outdoor unit includes a housing; a compressor disposed inside the housing and configured to compress a refrigerant; a heat-source-side heat exchanger disposed along a part of an inner wall of the housing, and into which the refrigerant discharged from the compressor or the refrigerant that is to be suctioned into the compressor flows; an outdoor air-sending device disposed on a top of the housing and configured to form an air flow inside the housing; a controller configured to control the compressor and the outdoor air-sending device; and an electrical component disposed in the housing and configured to accommodate at least the controller and an electrical component used for controlling a drive unit including in the air-conditioning apparatus. The electrical component box is disposed such that a bottom surface of the electrical component box is located at a height greater than 1/3 a height of the housing from a bottom surface of the housing. The controller and the electrical component are disposed such that bottom surfaces thereof are located at a height greater than 1/3 a height of the electrical component box from the bottom surface of the electrical component box. Advantageous Effects of Invention

[0010] The outdoor unit according to the present invention, the installation position of the electrical component box and the installation positions of the controller and relays accommodated in the electrical component box are specified. Therefore, even if a flammable refrigerant leaks, it is possible to significantly suppress entry of the leaked refrigerant into the electrical component box. Further, even if the leaked refrigerant enters the electrical component box, the controller and the relays are not exposed to the refrigerant. Therefore, according to the outdoor unit of the present invention, the safety is significantly improved while reducing cost increase.

Brief Description of Drawings

[0011]

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

[Fig. 2] Fig. 2 is a refrigerant circuit diagram illustrating the flow of a refrigerant when the air-conditioning apparatus is in a cooling operation mode according to Embodiment of the present invention.

[Fig. 3] Fig. 3 is a refrigerant circuit diagram illustrating the flow of a refrigerant when the air-conditioning apparatus is in a heating operation mode according to Embodiment of the present invention.

[Fig. 4] Fig. 4 is a circuit diagram schematically illustrating an electrical connection state of the air-conditioning apparatus according to Embodiment of the present invention.

[Fig. 5] Fig. 5 is a schematic perspective view illustrating the external view of an outdoor unit according to Embodiment of the present invention.

[Fig. 6] Fig. 6 is a schematic side view of the outdoor unit as viewed from a direction A (the front) of Fig. 5 according to Embodiment of the present invention.

[Fig. 7] Fig. 7 is a diagram illustrating a cross section B-C of the outdoor unit of Fig. 6 according to Embodiment of the present invention.

[Fig. 8] Fig. 8 is a schematic diagram schematically illustrating the layout of electrical components in an electrical component box mounted in the outdoor unit according to Embodiment of the present invention.

[Fig. 9] Fig. 9 is a schematic diagram schematically illustrating an installation example of a wide bandgap semiconductor that constitutes at least a part of devices of a controller mounted in the outdoor unit according to Embodiment of the present invention.

Description of Embodiments

[0012] Hereinafter, Embodiment of the present invention will be described with reference to the drawings.

[0013] Fig. 1 is a schematic circuit diagram illustrating an exemplary circuit configuration of an air-conditioning apparatus 100 according to Embodiment of the present invention. The circuit configuration of the air-conditioning apparatus 100 will be described in detail with reference to Fig. 1. Fig. 1 illustrates an exemplary case in which four indoor units 20 are connected. Note that the dimensional relationship between the components in Fig. 1 and the subsequent drawings may be different from the actual one. Further, components denoted by the same reference numerals in Fig. 1 and the subsequent drawings have the same or corresponding functions. This applies throughout the specification. Furthermore, embodiments of the components that will be described in the specification are only examples, and the present invention is not limited to these examples.

[0014] As illustrated in Fig. 1, the air-conditioning apparatus 100 includes an outdoor unit (heat source unit) 10 and indoor units 20 (indoor units 20a through 20d),

which are connected to and communicate with each other through pipes. That is, in the air-conditioning apparatus 100, a plurality of indoor units 20 are connected in parallel to the outdoor unit 10.

[0015] Further, in the air-conditioning apparatus 100, a refrigerant such as R32, HFO1234yf, HFO1234ze(E), a mixture of R32 and HFO1234yf, and a mixture of R32 and HFO1234ze(E), is charged. As for HFO1234yf, there are two geometric isomers. One is a trans type in which F and CF₃ are located at symmetric positions with respect to a double bond, and the other is a cis type in which F and CF₃ are located on the same side. HFO1234ze(E) in Embodiment is a trans type. According to the IUPAC nomenclature, the name is trans-1,3,3,3-tetrafluoro-1-propene.

(Outdoor Unit 10)

[0016] The outdoor unit 10 has a function that provides heating or cooling to the indoor units 20. The outdoor unit 10 includes a compressor 1, an oil separator 2 that separates a refrigerant and a refrigerating machine oil from each other, a flow switching device 3 such as a four-way valve, a heat-source-side heat exchanger 4, a supercooling heat exchanger 6 that increases the degree of supercooling during cooling operation so as to improve the performance, an expansion device 7, an accumulator 5, and an oil return circuit 8 connecting the oil separator 2 to a downstream pipe of the accumulator 5, which are connected through pipes. Further, in the outdoor unit 10, an opening and closing valve 9 is provided in a high-pressure pipe, and an opening and closing valve 11 is provided in a low-pressure pipe. The opening and closing valves 9 and 11 are used by an operator or the like during a service operation. Note that the opening and closing valves 9 and 11 may be solenoid valves and be turned on/off by relays 33 (described below).

[0017] The compressor 1 suctions the refrigerant, compresses the refrigerant into a high-temperature and high-pressure state, and transports the refrigerant to a refrigerant circuit. The compressor 1 may preferably be, for example, a capacity-controllable inverter compressor or the like. The oil separator 2 is disposed at the discharge side of the compressor 1, and is configured to separate a refrigerating machine oil that is discharged together with the refrigerant from the compressor 1, from the refrigerant. The refrigerating machine oil separated by the oil separator 2 is guided to the downstream side of the accumulator 5, that is, the suction side of the compressor 1, through the oil return circuit 8. The flow switching device 3 is disposed at the downstream side of the oil separator 2, and is configured to switch between the refrigerant flow in the heating operation mode and the refrigerant flow in the cooling operation mode.

[0018] The heat-source-side heat exchanger (outdoor-side heat exchanger) 4 serves as an evaporator during heating operation and serves as a radiator (or a condenser) during cooling operation. The heat-source-side heat

exchanger 4 exchanges heat between air supplied from an outdoor air-sending device (an outdoor air-sending device 44 of Fig. 7), such as a fan, and the refrigerant. The accumulator 5 is disposed at the suction side of the compressor 1, and is configured to store excess refrigerant due to the difference in the heating operation mode and the cooling operation mode, and excess refrigerant for a transient change in operation (change in the number of operating indoor units 20, for example).

[0019] The supercooling heat exchanger 6 exchanges heat between the refrigerant (hereinafter also referred to as a main refrigerant) flowing between the heat-source-side heat exchanger 4 and the opening and closing valve 9 and the refrigerant (hereinafter also referred to as a bypass refrigerant) that has been branched at a position between the heat-source-side heat exchanger 4 and the opening and closing valve 9 and decompressed by the expansion device 7 so as to increase the degree of supercooling during cooling operation. That is, the supercooling heat exchanger 6 exchanges heat between refrigerants. Note that the bypass refrigerant is a refrigerant that flows through a bypass 12 branching off from a position between the heat-source-side heat exchanger 4 and the opening and closing valve 9 and extending through the expansion device 7 and the bypass refrigerant side of the supercooling heat exchanger 6 to the upstream side of the accumulator 5. The supercooling heat exchanger 6 may be disposed at any position where the supercooling heat exchanger 6 can exchange heat between the refrigerants.

[0020] The expansion device 7 is disposed in the bypass 12 at the upstream side of the supercooling heat exchanger 6 through which the bypass refrigerant flows. The expansion device 7 decompresses the refrigerant flowing through the bypass 12 and adjusts the flow rate of the bypass refrigerant that flows into the supercooling heat exchanger 6. The expansion device 7 may preferably be one having a variably controllable opening degree such as an electronic expansion valve, for example.

[0021] The oil return circuit 8 is disposed so as to connect the lower side of the oil separator 2 to the downstream pipe of the accumulator 5. Note that pressure reducing means 8a including a capillary tube is disposed in the oil return circuit 8. That is, the refrigerating machine oil that has been separated by the oil separator 2 flows through the oil return circuit 8, is decompressed by the pressure reducing means 8a, and then is guided to the downstream side of the accumulator 5.

[0022] Further, the outdoor unit 10 includes a controller 50. The controller 50 performs integrated control of the entire system of the air-conditioning apparatus 100. More specifically, the controller 50 controls the driving frequency of the compressor 1, the rotation speed of the outdoor air-sending device, switching of the flow switching device 3, the opening degree of the expansion device 7, and so on. That is, the controller 50 controls actuators (drive units of the compressor 1, the flow switching device 3, the outdoor air-sending device, the expansion device,

and so on), in accordance with detection information from various detection devices (not illustrated) and instructions from a remote controller. Note that the outdoor unit 10 includes the relays 33 (relays 33a through 33d). The relays 33 turn on/off a solenoid valve (not illustrated in Figs. 1 through 3), the opening and closing valve 9, the opening and closing valve 11, and so on. Note that the relays 33 will be described with reference to Fig. 8.

10 (Indoor Units 20)

[0023] Each indoor unit 20 has a function of heating or cooling the air-conditioned space such as a room, using the refrigerant supplied from the outdoor unit 10. The indoor unit 20 includes a use-side heat exchanger (indoor-side heat exchanger) 22 and an expansion device 21, which are connected in series. More specifically, the expansion device 21 and the use-side heat exchanger 22 are connected in series in this order in a direction from the opening and closing valve 9 toward the opening and closing valve 11.

[0024] The use-side heat exchanger 22 serves as a radiator (or a condenser) during heating operation and serves as an evaporator during cooling operation. The use-side heat exchanger 22 exchanges heat between air supplied from an indoor air-sending device (not illustrated), such as a fan, and the refrigerant, and generates heating air or cooling air to be supplied to the air-conditioned space. The expansion device 21 serves as a reducing valve and an expansion valve, and is configured to decompress and expand the refrigerant. The expansion device 21 may preferably be one having a variably controllable opening degree such as an electronic expansion valve, for example. Note that the indoor air-sending device (not illustrated) and the expansion device 21 are controlled by the controller 50.

[0025] In Embodiment, an exemplary case is illustrated in which four indoor units 20 are connected. In Fig. 1, the indoor units 20 are illustrated as an indoor unit 20a, an indoor unit 20b, an indoor unit 20c, and an indoor unit 20d in this order from the left side (lower side) of Fig. 1. In accordance with the indoor units 20a through 20d, the use-side heat exchangers 22 are illustrated as a use-side heat exchanger 22a, a use-side heat exchanger 22b, a use-side heat exchanger 22c, and a use-side heat exchanger 22d in this order from the left side (lower side) of Fig. 1. Similarly, the expansion devices 21 are illustrated as an expansion device 21 a, an expansion device 21 b, an expansion device 21c, and an expansion device 21 d in this order from the left side (lower side) of Fig. 1. Note that the number of indoor units 20 connected is not limited to four.

[0026] Operation modes carried out by the air-conditioning apparatus 100 will be described.

55 (Cooling Operation Mode)

[0027] Fig. 2 is a refrigerant circuit diagram illustrating

the flow of the refrigerant when the air-conditioning apparatus 100 is in the cooling operation mode. Fig. 2 illustrates an exemplary case in which all the indoor units 20 are driven. In the cooling operation mode, the flow switching device 3 is switched such that the heat-source-side heat exchanger 4 serves as a radiator, and the use-side heat exchangers 22 serve as evaporators. More specifically, the flow switching device 3 is switched such that the refrigerant discharged from the compressor 1 flows into the heat-source-side heat exchanger 4. In Fig. 2, the direction of the refrigerant flow is indicated by the arrows.

[0028] A low-temperature and low-pressure refrigerant is compressed by the compressor 1, and is discharged as a high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant that has been discharged from the compressor 1 flows through the oil separator 2 and the flow switching device 3 into the heat-source-side heat exchanger 4. In the oil separator 2, a refrigerating machine oil that is discharged together with the refrigerant from the compressor 1 is separated from a refrigerant gas. The separated refrigerating machine oil passes through the oil return circuit 8 and returns to a pipe at the suction side of the compressor 1. On the other hand, the refrigerant gas that has been separated by the oil separator 2 flows into the flow switching device 3.

[0029] The high-temperature and high-pressure refrigerant that has flowed into the heat-source-side heat exchanger 4 exchanges heat with air supplied from the outdoor air-sending device so as to be liquefied, and flows out of the heat-source-side heat exchanger 4. Part of the liquid refrigerant flows into the bypass 12, and the other part of the liquid refrigerant flows into the indoor units 20. The liquid refrigerant (bypass refrigerant) that has flowed into the bypass 12 is decompressed by the expansion device 7 so as to turn into a low-pressure two-phase gas-liquid refrigerant. The low-pressure two-phase gas-liquid refrigerant flows into the supercooling heat exchanger 6, exchanges heat with a high-pressure liquid refrigerant (main refrigerant) so as to become a low-pressure gas refrigerant, and flows out of the supercooling heat exchanger 6. The main refrigerant that has flowed into the supercooling heat exchanger 6 is cooled by the bypass refrigerant, so that the liquid temperature is reduced (the degree of supercooling is increased).

[0030] Although not illustrated, a pressure sensor and a temperature sensor are provided at the exit of the bypass 12 of the supercooling heat exchanger 6. On the basis of information from these sensors, the controller 50 adjusts the opening degree of the expansion device 7 such that the degree of superheat at the exit of the supercooling heat exchanger 6 becomes around 5 degrees C.

[0031] The part of liquid refrigerant that has not flowed into the bypass 12 passes through a pipe connecting the indoor units 20 and the outdoor unit 10, and flows out of the outdoor unit 10. Then, the liquid refrigerant flows into each of the indoor units 20a through 20d. The refrigerant

that has flowed into each of the indoor units 20a through 20d are expanded (decompressed) by the expansion devices 21 a through 21 d, respectively, and are brought into a low-temperature and low-pressure two-phase gas-liquid state. Then, the refrigerant in the two-phase gas-liquid state flows into each of the use-side heat exchangers 22a through 22d. The refrigerant in the two-phase gas-liquid state that has flowed into each of the use-side heat exchangers 22a through 22d exchanges heat with air (indoor air) supplied from the indoor air-sending device (not illustrated) so as to receive heat from the air and become low-pressure gas refrigerant, and flows out of each of the use-side heat exchangers 22a through 22d.

[0032] In general, although not illustrated, temperature sensors are provided at the refrigerant inlet and outlet of each use-side heat exchanger 22. Thus, the amount of the refrigerant to be supplied to the use-side heat exchanger 22 is adjusted using temperature information from the temperature sensors at the refrigerant inlet and outlet of the use-side heat exchanger 22. More specifically, the controller 50 calculates the degree of superheat (the refrigerant temperature at the exit side - the refrigerant temperature at the entrance side) in accordance with information from the temperature sensors. Then, the controller 50 determines the opening degree of the expansion device 21 such that the degree of superheat is around 2 to 5 degrees C, and adjusts the amount of the refrigerant to be supplied to the use-side heat exchanger 22.

[0033] The low-pressure gas refrigerant that has flowed out of the use-side heat exchangers 22a through 22d flows out of the indoor units 20a through 20d, passes through a pipe connecting the indoor units 20 and the outdoor unit 10, and flows into the outdoor unit 10. The refrigerant that has flowed into the outdoor unit 10 passes through the flow switching device 3, and flows into the accumulator 5. The refrigerant that has flowed into the accumulator 5 is separated into a liquid refrigerant and a gas refrigerant, and the gas refrigerant is suctioned into the compressor 1 again.

[0034] In such cooling operation mode, the degree of superheat is controlled in each indoor unit 20, and therefore the refrigerant in a liquid state does not flow into the accumulator 5. However, if any one of the indoor units 20 is in a transient state or stopped, a small amount of the refrigerant in a liquid state (with a quality of about 0.95) may flow into the accumulator 5. The liquid refrigerant that has flowed into the accumulator 5 evaporates and is suctioned into the compressor 1, or is suctioned into the compressor 1 through an oil return hole (not illustrated) provided in the exit pipe of the accumulator 5.

(Heating Operation Mode)

[0035] Fig. 3 is a refrigerant circuit diagram illustrating the flow of the refrigerant when the air-conditioning apparatus 100 is in the heating operation mode. Fig. 3 illustrates an exemplary case in which all the indoor units

20 are driven. In the heating operation mode, the flow switching device 3 is switched such that the heat-source-side heat exchanger 4 serves as an evaporator, and the use-side heat exchangers 22 serve radiators. More specifically, the flow switching device 3 is switched such that the refrigerant discharged from the compressor 1 flows into the use-side heat exchangers 22. In Fig. 3, the direction of the refrigerant flow is indicated by the arrows.

[0036] A low-temperature and low-pressure refrigerant is compressed by the compressor 1, and is discharged as a high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant that has been discharged from the compressor 1 passes through the oil separator and the flow switching device 3, flows through the pipe connecting the indoor units 20 and the outdoor unit 10, flows out of the outdoor unit 10, and flows into each of the indoor units 20a through 20d. The function of the oil separator 2 is as described in connection with the cooling operation mode.

[0037] The high-temperature and high-pressure gas refrigerant that has flowed into the indoor units 20a through 20d exchanges heat with air (indoor air) supplied from the indoor air-sending device (not illustrated) in each of the use-side heat exchangers 22a through 22d so as to transfer heat to the air and to be liquefied, and flows out of the use-side heat exchangers 22a through 22d. The refrigerant is expanded (decompressed) by the expansion devices 21 a through 21 d, respectively, and is brought into a low-temperature and low-pressure two-phase gas-liquid state, and flows out of each of the indoor units 20a through 20d.

[0038] In general, although not illustrated, a temperature sensor and a pressure sensor are provided at the refrigerant outlet of each use-side heat exchanger 22. Thus, the amount of the refrigerant to be supplied to the use-side heat exchanger 22 is adjusted using information from the temperature sensor and the pressure sensor at the refrigerant outlet of the use-side heat exchanger 22. More specifically, the controller 50 calculates the degree of supercooling (the saturated temperature obtained by converting the pressure of the refrigerant detected at the exit side - the refrigerant temperature at the exit side) in accordance with information from the sensors. Then, the controller 50 determines the opening degree of the expansion device 21 such that the degree of supercooling is around 2 to 5 degrees C, and adjusts the amount of the refrigerant to be supplied to the use-side heat exchanger 22.

[0039] The low-temperature and low-pressure refrigerant in the two-phase gas-liquid state that have flowed out of each of the indoor units 20a through 20d passes through the pipe connecting the indoor units 20 and the outdoor unit 10, and flows into the outdoor unit 10. This refrigerant flows into the heat-source-side heat exchanger 4. The low-temperature and low-pressure refrigerant in the two-phase gas-liquid state that has flowed into the heat-source-side heat exchanger 4 exchanges heat with air supplied from the outdoor air-sending device so as to

receive heat from the air, so that the quality gradually increases. Then, the refrigerant turns into a two-phase gas-liquid refrigerant having a high quality at the exit of the heat-source-side heat exchanger 4, and flows out of the heat-source-side heat exchanger 4. The refrigerant that has flowed out of the heat-source-side heat exchanger 4 passes through the flow switching device 3, and flows into the accumulator 5. The refrigerant that has flowed into the accumulator 5 is separated into a liquid refrigerant and a gas refrigerant, and the gas refrigerant is suctioned into the compressor 1 again.

(Electrical Configuration of Air-Conditioning Apparatus 100)

[0040] Fig. 4 is a circuit diagram schematically illustrating an electrical connection state of the air-conditioning apparatus 100. The electrical configuration of the air-conditioning apparatus 100 will be described with reference to Fig. 4. Note that the installation position of an electrical component box 30 will be described in detail with reference to Figs. 5 through 7.

[0041] The controller 50 includes a rectifier 52 that converts an AC voltage of a three-phase AC power supply 51 into a DC voltage, a reactor 53 that corrects the power factor, a smoothing capacitor 54, an inverter main circuit 55, an inverter substrate 31 on which a control circuit 56 that controls the inverter main circuit 55 and so on are mounted. The controller 50 is connected to a motor 57 of the compressor 1.

[0042] The inverter main circuit 55 converts a DC power smoothed by the smoothing capacitor 54 into an AC power, and includes a plurality of switching devices made of a silicon (Si) semiconductor or a wide bandgap semiconductor, for example. Wide bandgap semiconductor is a generic term for a semiconductor device having a greater bandgap than a silicon (Si) device. Examples of wide bandgap semiconductors include not only a silicon carbide (SiC) device, but also a gallium nitride (GaN) device and a diamond device. Each switching device of the inverter main circuit 55 performs a switching operation in accordance with an operation signal (a PWM signal and a gate signal) transmitted from the control circuit 56.

[0043] The control circuit 56 includes a microcomputer, and is configured to actually control driving of various actuators in accordance with detection information from various detecting means (not illustrated) (for example, a temperature sensor, a pressure sensor, and so on) and instructions from the remote controller, and thus to perform a heating operation and a cooling operation. In Fig. 4, only the motor 57 of the compressor 1 is shown for purposes of illustration. Further, not only switching devices but also diode devices can be made of a wide bandgap semiconductor.

(Installation Position of Electrical Component Box 30)

[0044] Fig. 5 is a schematic perspective view illustrat-

ing the external view of the outdoor unit 10. Fig. 6 is a schematic side view of the outdoor unit 10 as viewed from a direction A (the front) of Fig. 5. Fig. 7 is a diagram illustrating a cross section B-C of the outdoor unit 10 of Fig. 6. The installation position of the electrical component box 30 will be described in detail with reference to Figs. 5 through 7. In Fig. 7, the direction of the air flow is indicated by the arrows. Further, a schematic view of the outdoor air-sending device 44 is also illustrated in Fig. 7.

[0045] As described above, the outdoor unit 10 constitutes part of the air-conditioning apparatus 100, and is configured to supply cooling energy or heating energy to the indoor units 20 connected thereto with a refrigerant pipe. Note that, in the following description, the side of the outdoor unit 10 viewed from the direction of the arrow A of Fig. 5 is referred to as a front side thereof.

[0046] As illustrated in Fig. 5, the outdoor unit 10 includes a housing 10a forming an outer shell of the outdoor unit 10 and has a substantially cuboid shape, and an air outlet 42 which is provided on the ceiling side of the housing 10a and in which the outdoor air-sending device is disposed. A front panel 40 is disposed on the front side of the housing 10a. Further, an air inlet 41 for suctioning air into the housing 10a is formed as an opening in each of the sides of the housing 10a other than the front side. The electrical component box 30 accommodating the controller 50 and so on is disposed at the upper part of the front panel 40, that is, the upper part of the outdoor unit 10. Further, a pipe outlet 43 for removing the pipe connecting the indoor units 20 and the outdoor unit 10 is formed as an opening in a portion of the lower side of the front panel 40.

[0047] The components illustrated in Figs. 1 through 3 are accommodated in the housing 10a of the outdoor unit 10. Of these, the heat-source-side heat exchanger 4 may preferably be disposed so as to have a substantially C-shaped cross section along the sides (inner wall) of the housing 10a. Further, the compressor 1 is heavy and therefore is fixed at the bottom of the housing 10a. The outdoor air-sending device 44 is disposed on the ceiling side, that is, the air-outlet-42 side of the housing 10a (see Fig. 7). Further, the electrical component box 30 may preferably be openable and closable about a hinge with respect to the front panel 40.

[0048] The flow of air in the outdoor unit 10 will be described with reference to Fig. 7. When the outdoor air-sending device 44 is driven, air is suctioned into the housing 10a through the air inlet 41. The air that has been suctioned into the housing 10a passes through the heat-source-side heat exchanger 4 disposed in the housing 10a, and exchanges heat with a refrigerant supplied to the heat-source-side heat exchanger 4. The air that has exchanged heat in the heat-source-side heat exchanger 4 is discharged outside the outdoor unit 10 from the air outlet 42 of the housing 10a by the outdoor air-sending device 44. This air flow is formed by the outdoor air-sending device 44. That is, air flows into the housing 10a from the right side of Fig. 7, and is blown out to the upper side

of the housing 10a.

[0049] As can be seen from Figs. 5 through 7, the electrical component box 30 is attached to the upper part of the outdoor unit 10. Further, as illustrated in Fig. 7, in order to ensure smooth air flow, components other than the electrical component box 30 are not disposed in the upper space inside the housing 10a of the outdoor unit 10. This is because if components other than the electrical component box 30 are present in the upper space inside the housing 10a of the outdoor unit 10, the components become an obstacle to the air flow. On the other hand, the refrigerant circuit components, such as the compressor 1, the oil separator 2, and the accumulator 5, pipes, and so on are densely arranged in the lower space inside the housing 10a of the outdoor unit 10 (the area indicated by the broken line in Fig. 7).

[0050] Table 1 shows the refrigerant gas density of the currently promising next-generation refrigerants at 25 degrees C and atmospheric pressure (101.3 kPa abs). The physical property values are based on REFPROP Version 9.0 available from NIST (National Institute of Standards and Technology).

[0051]

[Table 1]

Table 1 List of Refrigerant Gas Density

Refrigerant	Density [kg/m ³]
R32	2.1526
HFO1234yf	4.7654
HFO1234ze(E)	4.7738

[0052] It is found from Table 1 that the gas density of the currently promising next-generation refrigerants is greater than an air density of 1.2 [kg/m³]. As shown in Table 1, the currently promising next-generation refrigerants are R32, HFO1234yf, and HFO1234ze(E). That is, the refrigerants shown in Table 1 are heavier than air, and are likely to settle on the bottom of the outdoor unit 10 when the refrigerants leak from the outdoor unit 10. This indicates that it is desirable that the electrical component box 30 accommodating electrical components that can be a source of ignition be located as high as possible in the housing 10a.

[0053] Accordingly, in the outdoor unit 10, the electrical component box 30 is disposed such that a bottom surface E1 of the electrical component box 30 is located at a height greater than 1/3 (line F of Fig. 6) a height h1 of the housing 10a from a bottom surface E2 of the housing 10a. Thus, even if the refrigerant leaks, the electrical component box 30 is not exposed to the area where the concentration is greater than the lower explosive limit.

[0054] It was found that, in the case where the refrigerants shown in Table 1 leak from a currently widely used outdoor unit, the leaked refrigerants accumulate in the area below a height of about 10 cm from the bottom sur-

face of the outdoor unit. Accordingly, it suffices to locate the electrical component box 30 at a height greater than 10 cm from the bottom surface of the outdoor unit. However, in consideration of not only the safety but also maintainability, airflow resistance, and the like, in the outdoor unit 10, the electrical component box 30 is disposed such that the bottom surface E1 of the electrical component box 30 is located at a height greater than 1/3 the height h1 of the outdoor unit 10 from the bottom surface E2 of the outdoor unit 10 (housing 10a).

(Layout of Electrical Components in Electrical Component Box 30)

[0055] Fig. 8 is a schematic diagram schematically illustrating the layout of electrical components in the electrical component box 30. The layout of electrical components in the electrical component box 30 will be described with reference to Fig. 8. As mentioned above, the controller 50 as an electrical component is accommodated in the electrical component box 30. The controller 50 includes the inverter substrate 31. Further, electrical components such as the relays 33a through 33d for turning on/off a solenoid valve (not illustrated in Figs. 1 through 3), the opening and closing valve 9, the opening and closing valve 11, and so on are accommodated in the electrical component box 30, in addition to the controller 50. Note that the controller 50 controls the rotation speed of the motor of the compressor 1 such that the rotation speed varies from several hertz to several hundred hertz.

[0056] As described above, a wide bandgap semiconductor is used as a part of electronic parts included in the inverter substrate 31. In Fig. 8, a wide bandgap semiconductor mounted on the inverter substrate 31 is shown as a wide bandgap semiconductor 32 for purposes of illustration. As mentioned above, examples of the wide bandgap semiconductor 32 include not only a silicon carbide (SiC) device, but also a gallium nitride (GaN) device, and a diamond device.

[0057] The semiconductor devices (for example, the inverter main circuit 55 of Fig. 4, and so on) made of the wide bandgap semiconductor 32 are excel in heat resistance, and thus can resist high temperatures. Therefore, there is no need to provide a slit and a hole for suppressing temperature increase inside the electrical component box 30, so that it is possible to realize a configuration that does not allow ambient air to easily enter. Accordingly, the electrical component box 30 is made of a non-combustible material such as sheet metal, and has a configuration such that a cover of the electrical component box 30 can be removed using a driver or the like from the front side (the direction A of Fig. 5) so as to allow wires to be connected and to allow services such as replacing electrical components to be performed. Further, although a hole through which a wire is inserted is formed in the electrical component box 30, the hole is sealed by rubber bush or the like.

[0058] Since the electrical component box 30 has the

configuration described above, even if a refrigerant leaks, it is possible to significantly suppress entry of the refrigerant into the electrical component box 30, and thus to further improve the safety. That is, the electrical component box 30 is disposed in the upper part of the housing 10a, and this is one countermeasure against entry of the refrigerant. In addition to that, a configuration that does not allow ambient air to easily enter is employed, which further strengthens the countermeasures against entry of refrigerant. Even though such a configuration that does not allow ambient air to easily enter is employed for the electrical component box 30, since the wide bandgap semiconductor 32 having excellent heat resistance is used, it is possible to suppress temperature increase in the electrical component box 30 by only transferring heat from the electrical component box 30 to the environment.

[0059] The wide bandgap semiconductor 32 has high heat resistance and is capable of operating at high temperature, which makes it possible to employ a fan-less structure, or a radiation-fin-less structure (or a compact radiation fin structure), and thus allows the electrical component box 30 to have a substantially enclosed structure. Further, the switching device and the diode device made of the wide bandgap semiconductor 32 have high withstand voltage and have high allowable current density. Therefore, it is possible to reduce the size of the switching device, and thus to reduce the size of the semiconductor module having these devices therein. Furthermore, since the wide bandgap semiconductor 32 has low power loss, it is possible to increase the efficiency of the switching device, and hence increase the efficiency of the semiconductor module.

[0060] Further, as shown in Fig. 8, in the electrical component box 30, the relays 33a through 33d that can be a source of ignition, and electrical components such as the wide bandgap semiconductor 32 that can reach a high temperature are located as high as possible. Accordingly, in the electrical component box 30, the electrical components are disposed such that bottom surfaces E4 and E5 of the electrical components are located at a height greater than 1/3 (line G of Fig. 8) a height h2 of the electrical component box 30 from a bottom surface E3 of the electrical component box 30. Thus, even if the refrigerant leaks, the electrical components are not exposed to the area where the concentration is greater than the lower explosive limit. With this configuration, even if a leaked refrigerant enters from a gap in the electrical component box 30, the refrigerant accumulates in the lower part of the electrical component box 30. Therefore, safety is further improved.

[0061] It was found that, in the case where the refrigerants shown in Table 1 enter a currently widely used electrical component box, the refrigerants that have entered accumulate in the area below a height of about several tens of centimeters from the bottom surface of the electrical component box. Accordingly, it suffices to locate the electrical component box 30 at a height greater than several tens of centimeters from the bottom surface

of the electrical component box. However, in consideration of not only the safety but also maintainability, operability, and the like, in the outdoor unit 10, the electrical components are disposed such that the bottom surfaces E4 and E5 of the electrical components are located at a height greater than 1/3 the height h2 of the electrical component box from the bottom surface E3 of the electrical component box 30.

(Suppression of Temperature Increase of Wide Bandgap Semiconductor 32)

[0062] Fig. 9 is a schematic diagram schematically illustrating an installation example of the wide bandgap semiconductor 32. The following describes the case where safety is further improved by suppressing temperature increase of the wide bandgap semiconductor 32 with reference to Fig. 9. Fig. 9(a) is a perspective view of the wide bandgap semiconductor 32 and temperature detecting means 34 as viewed from the front, and Fig. 9(b) illustrates the wide bandgap semiconductor 32 and the temperature detecting means 34 as viewed from the direction H of Fig. 8.

[0063] Table 2 shows the ignition temperature of each of the currently promising next-generation refrigerants. [Table 2]

Table 2 List of Ignition Temperature of Refrigerant

Refrigerant	Ignition Temperature [Degrees C]
R32	648
HFO1234yf	405
HFO1234ze(E)	288 - 293

[0064] The ignition temperature shown in Table 2 is the temperature at which a refrigerant ignites spontaneously. That is, when the wide bandgap semiconductor 32 reaches a temperature equal to or higher than the temperature shown in Table 2 and the concentration of the refrigerant becomes equal to or greater than the lower explosive limit, the refrigerant may ignite. This indicates that the surface temperature of the wide bandgap semiconductor 32, which generates the highest temperature among the electrical components in the electrical component box 30, needs to be lower than the ignition temperature of the refrigerant used in the air-conditioning apparatus 100.

[0065] Accordingly, in order to appropriately detect the temperature of the wide bandgap semiconductor 32, the temperature detecting means 34 may preferably be in contact with the surface of the wide bandgap semiconductor 32. By appropriately detecting the temperature of the wide bandgap semiconductor 32, it is possible to efficiently suppress temperature increase of the wide bandgap semiconductor 32. For example, the temperature de-

tecting means 34 may be attached to the surface of the wide bandgap semiconductor 32 with a thermal conductive adhesive such that the two can be placed in contact with each other. Alternatively, as shown in Fig. 9, the temperature detecting means 34 and the wide bandgap semiconductor 32 can be placed in contact with each other using an attachment 35 and fixtures 36.

[0066] Note that a thermistor may preferably be used as the temperature detecting means 34. Alternatively, other temperature sensors such as a thermocouple may be used as the temperature detecting means 34. The material, shape, size, and the number of attachments 35 and fixtures 36 are not limited to those illustrated in Fig. 9, and any configuration may be employed as long as the wide bandgap semiconductor 32 and the temperature detecting means 34 can be placed in contact with each other.

[0067] An operation of suppressing temperature increase of the wide bandgap semiconductor 32 will be described. When the temperature detecting means 34 detects that the surface temperature of the wide bandgap semiconductor 32 is equal to a predetermined temperature, the controller 50 stops the operation of the air-conditioning apparatus 100. Alternatively, the controller 50 reduces the rotation speed of the compressor 1. This control operation makes it possible to suppress further heat generation in the wide bandgap semiconductor 32, and thus to suppress temperature increase of the wide bandgap semiconductor 32.

[0068] In the case where the heating temperature of the wide bandgap semiconductor 32 does not decrease less than the predetermined temperature even though this control operation is performed, the controller 50 completely stops the air-conditioning apparatus 100. That is, when the temperature of the wide bandgap semiconductor 32 reaches the predetermined temperature (suppression control start temperature) used as a condition for starting suppression control of temperature increase of the wide bandgap semiconductor 32, the controller 50 performs control for suppressing temperature increase of the wide bandgap semiconductor 32. By performing this control operation, it is possible to reduce the risk in the event of refrigerant leakage, and thus to provide an air-conditioning apparatus 100 with significantly improved safety. Note that, in the case where this control operation is performed, this information may preferably be notified by sound or display.

[0069] Next, a description will be given of the predetermined temperature (suppression control start temperature). The suppression control start temperature as the predetermined temperature used as a condition for starting suppression control of temperature increase of the wide bandgap semiconductor 32 needs to be determined in view of variation in a thermistor, variation in mounting of the thermistor on the wide bandgap semiconductor, and the like. Further, the ignition temperature of refrigerant varies in accordance with the humidity and temperature around the refrigerant. That is, if the predetermined

temperature is set to be equal to the ignition temperature, the suppression control of temperature increase of the wide bandgap semiconductor 32 may or may not be performed depending on the conditions.

[0070] Accordingly, the predetermined temperature needs to be set with a very large margin. For this reason, in the case of the air-conditioning apparatus 100, the predetermined temperature is set to be "around the ignition temperature of refrigerant to be used - 100 degrees C" in view of various environmental influences, aging degradation, individual differences and the like. Although the predetermined temperature may be changed in accordance with a refrigerant to be used, the predetermined temperature may preferably be set using HFO1234ze(E) having the lowest ignition temperature among the refrigerants of Table 2 as a reference, in view of versatility. In this case, the predetermined temperature is about 188 degrees C.

[0071] Further, although the wide bandgap semiconductor 32 is excel in heat resistance, the risk of failure increases when the temperature is 200 degrees C or higher. Accordingly, in order to ensure the safety and to ensure the reliability of the wide bandgap semiconductor 32, the predetermined temperature is set to around 150 degrees C. Thus, the safety is ensured, and the reliability of the wide bandgap semiconductor 32 is also ensured. Hence, the reliability of the air-conditioning apparatus 100 is significantly enhanced.

[0072] As described above, in the outdoor unit 10 according to Embodiment, the installation position of the electrical component box 30 is specified. Therefore, even if a flammable refrigerant leaks, it is possible to significantly suppress entry of the leaked refrigerant into the electrical component box 30. Therefore, according to the outdoor unit 10 of Embodiment, it is possible to significantly improve the safety. Further, according to the outdoor unit 10 of Embodiment, since the wide bandgap semiconductor 32 is used as a part of the inverter substrate 31, it is possible to provide excellent heat resistance and to ensure high reliability. Further, the air-conditioning apparatus 100 of Embodiment includes the outdoor unit 10. Therefore, similar to the outdoor unit 10, the safety and reliability thereof are significantly improved.

Reference Signs List

[0073] 1 compressor 2 oil separator 3 flow switching device 4 heat-source-side heat exchanger 5 accumulator 6 supercooling heat exchanger 7 expansion device 8 oil return circuit 8a pressure reducing means 9 opening and closing valve 10 outdoor unit 10a housing 11 opening and closing valve 12 bypass 20 indoor unit 20a indoor unit 20b indoor unit 20c indoor unit 20d indoor unit 21 expansion device 21 a expansion device 21 b expansion device 21 c expansion device 21 d expansion device 22 use-side heat exchanger 22a use-side heat exchanger 22b use-side heat exchanger 22c use-side heat ex-

changer 22d use-side heat exchanger 30 electrical component box 31 inverter substrate 32 wide bandgap semiconductor 33a relay 33b relay 33c relay 33d relay 34 temperature detecting means 35 attachment 36 fixture 40 front panel 41 air inlet 42 air outlet 43 pipe outlet 44 outdoor air-sending device 50 controller 51 three-phase AC power supply 52 rectifier 53 reactor 54 smoothing capacitor 55 inverter main circuit 56 control circuit 57 motor 100 air-conditioning apparatus

Claims

1. An outdoor unit constituting part of an air-conditioning apparatus using a flammable refrigerant, the outdoor unit comprising:

a housing;
a compressor disposed inside the housing and configured to compress a refrigerant;
a heat-source-side heat exchanger disposed along a part of an inner wall of the housing, and into which the refrigerant discharged from the compressor or the refrigerant that is to be suctioned into the compressor flows;
an outdoor air-sending device disposed on a top of the housing and configured to form an air flow inside the housing;
a controller configured to control the compressor and the outdoor air-sending device; and
an electrical component box disposed in the housing and configured to accommodate at least the controller and an electrical component used for controlling a drive unit included in the air-conditioning apparatus, wherein the electrical component box is disposed such that a bottom surface of the electrical component box is located at a height greater than 1/3 a height of the housing from a bottom surface of the housing, and wherein the controller and the electrical component are disposed such that bottom surfaces thereof are located at a height greater than 1/3 a height of the electrical component box from the bottom surface of the electrical component box.

2. The outdoor unit of claim 1, wherein at least a part of devices included in the controller is made of a wide bandgap semiconductor.

3. The outdoor unit of claim 2, further comprising temperature detecting means configured to detect a temperature of the wide bandgap semiconductor, wherein the temperature detecting means is disposed so as to be in contact with a surface of the wide bandgap semiconductor.

4. The outdoor unit of claim 3, wherein when the temperature detecting means detects that a detected temperature detected by the temperature detecting means reaches a predetermined temperature set in advance, the controller stops operation of the air-conditioning apparatus. 5
5. The outdoor unit of claim 3, wherein when the temperature detecting means detects a predetermined temperature set in advance, the controller reduces a rotation speed of the compressor such that the rotation speed is reduced to lower than a current rotation speed. 10
6. The outdoor unit of claim 5, wherein when the temperature of the wide bandgap semiconductor is not lower than the predetermined temperature after a predetermined time period elapses, the controller stops operation of the air-conditioning apparatus. 15
20
7. The air-conditioning apparatus of any one of claims 4 to 6, wherein the predetermined temperature is set at 150 degrees C or higher.
8. The outdoor unit of any one of claims 2 to 7, wherein the wide bandgap semiconductor is made of at least one of a silicon carbide device, a gallium nitride device, and a diamond device. 25
9. The outdoor unit of any one of claims 1 to 8, wherein R32 is used as the flammable refrigerant. 30
10. The outdoor unit of any one of claims 1 to 8, wherein HFO1234yf is used as the flammable refrigerant. 35
11. The outdoor unit of any one of claims 1 to 8, wherein HFO1234ze(E) is used as the flammable refrigerant.
12. The outdoor unit of any one of claims 1 to 8, wherein a refrigerant mixture of R32 and HFO1234fy is used as the flammable refrigerant. 40
13. The outdoor unit of any one of claims 1 to 8, wherein a refrigerant mixture of R32 and HFO1234ze(E) is used as the flammable refrigerant. 45
14. An air-conditioning apparatus comprising:

the outdoor unit of any one of claims 1 to 12; and
an indoor unit including a use-side heat exchanger and connected to the outdoor unit with a refrigerant pipe. 50

55

FIG. 1

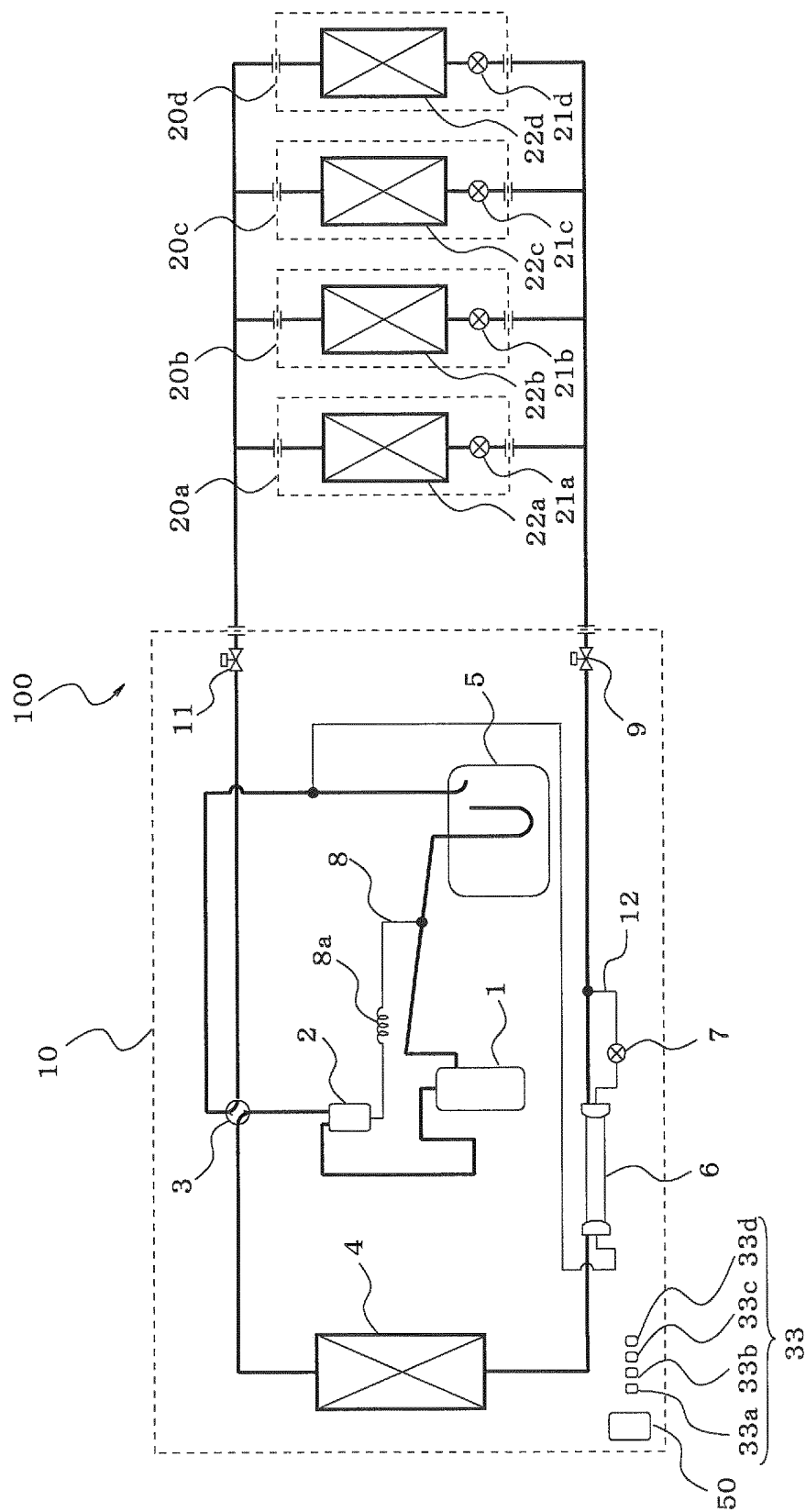


FIG. 2

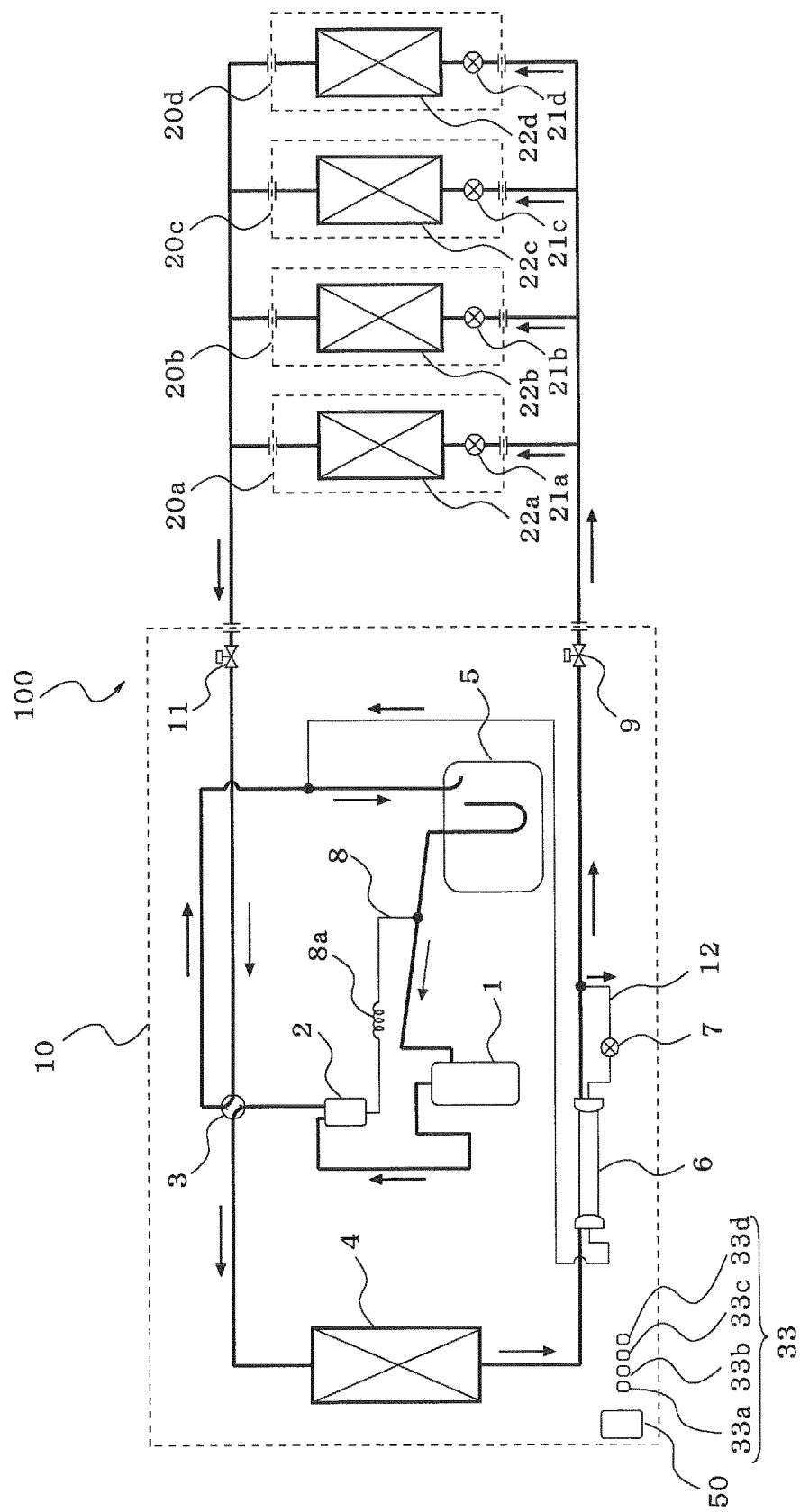


FIG. 3

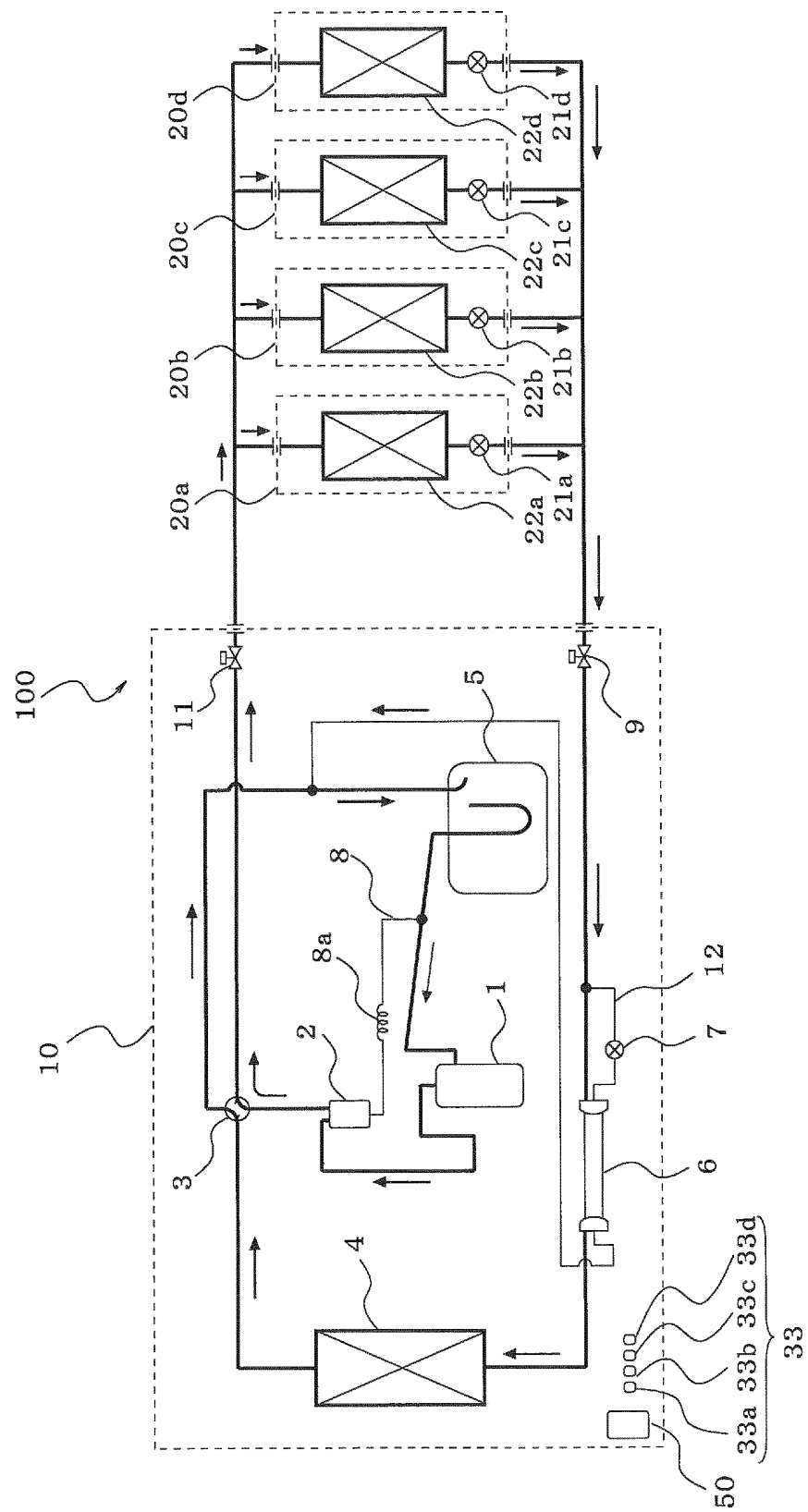


FIG. 4

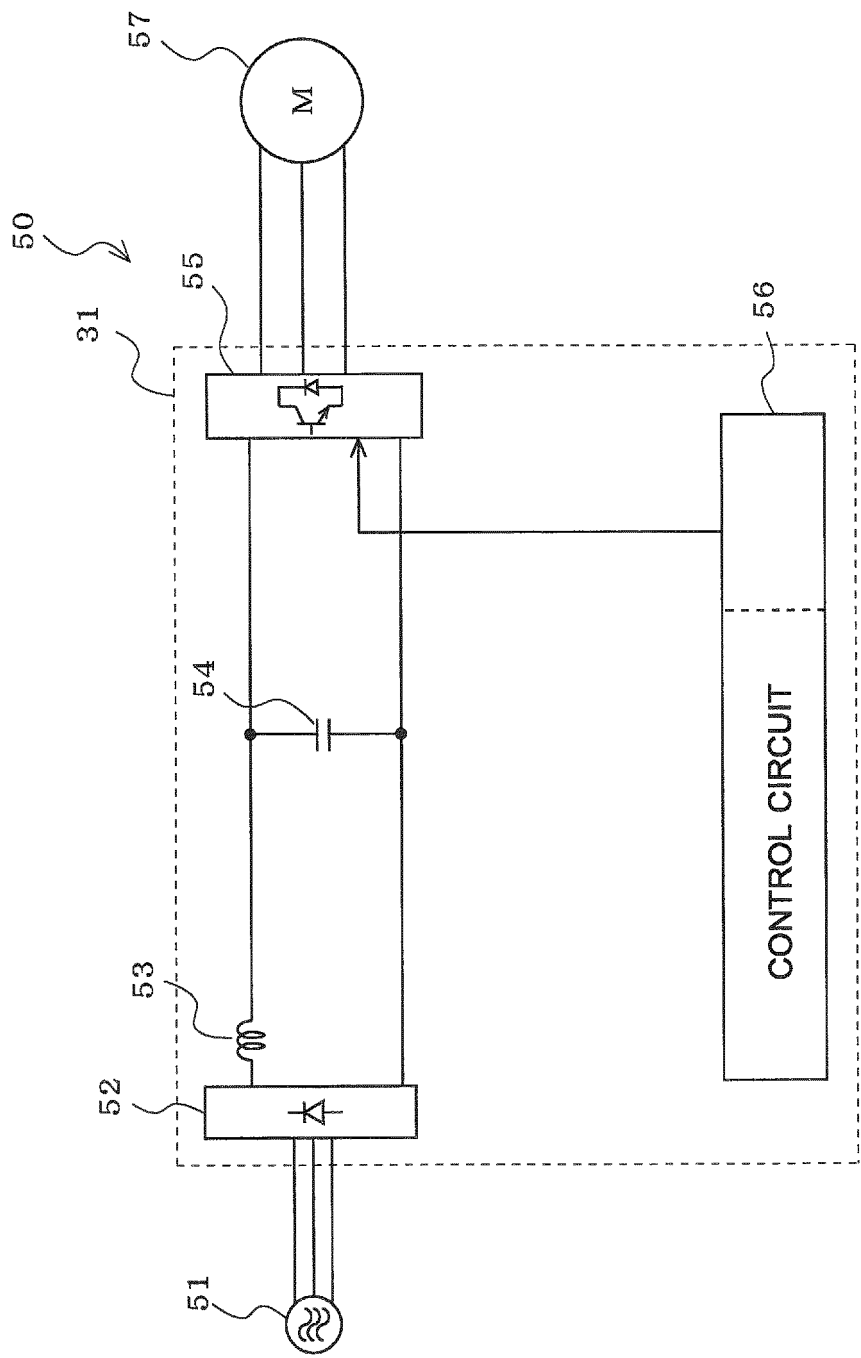


FIG. 5

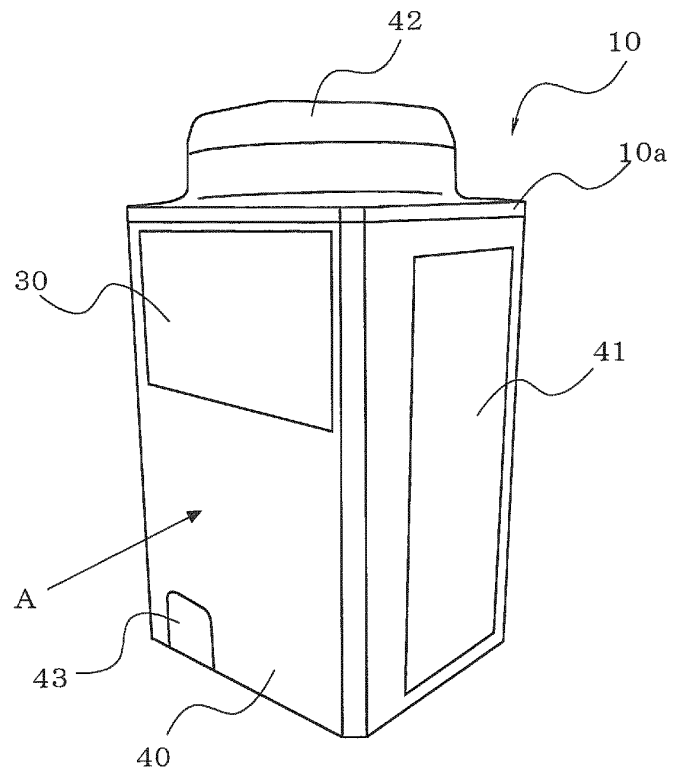


FIG. 6

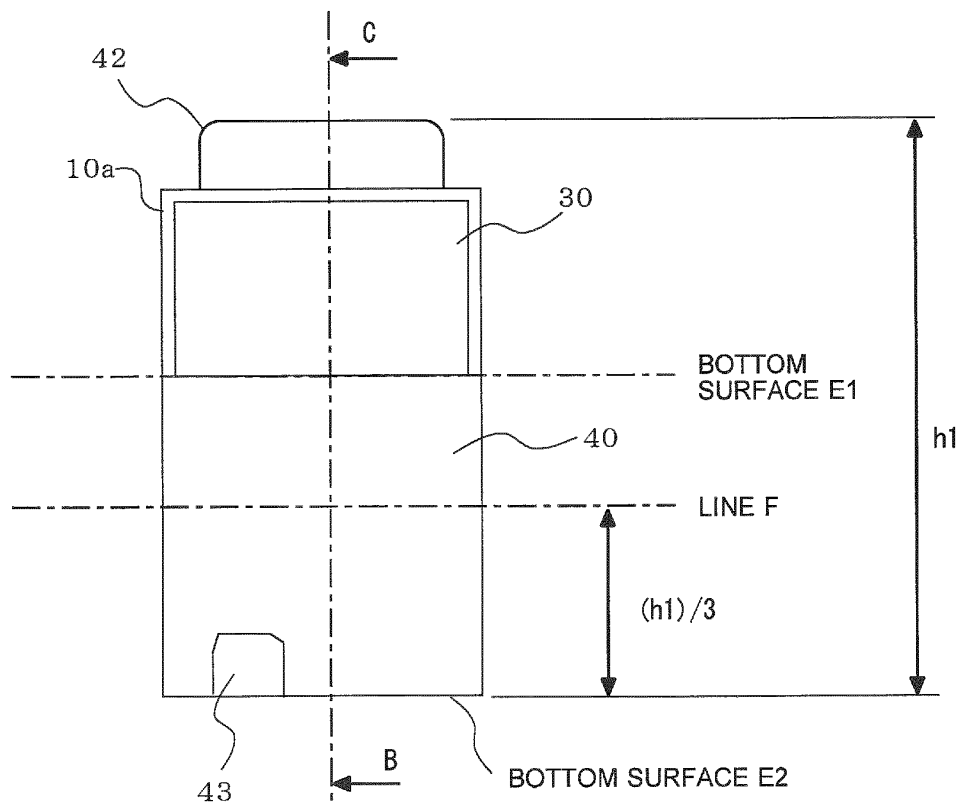
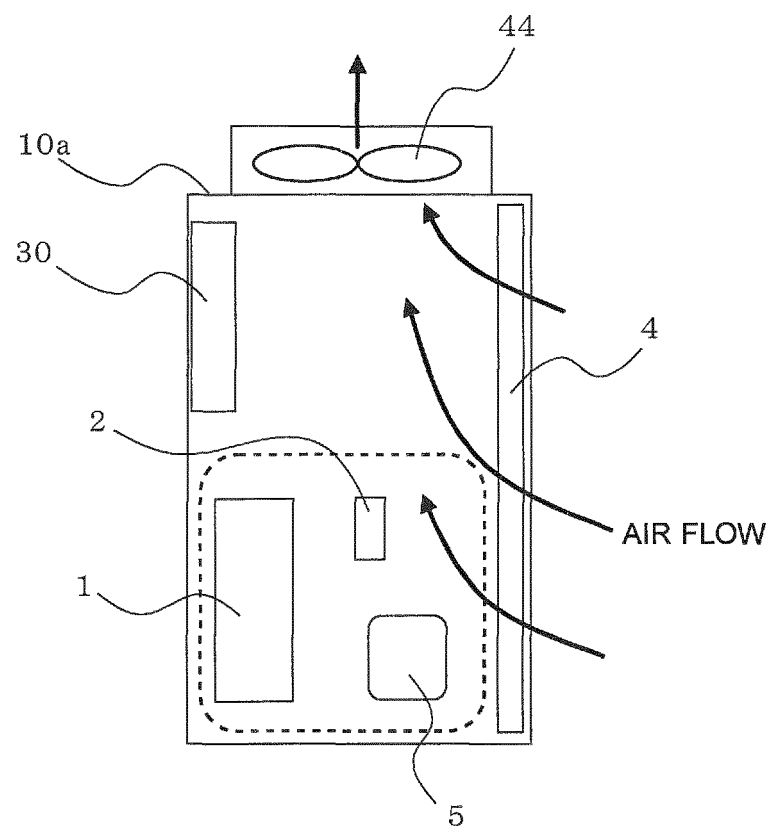


FIG. 7



CROSS SECTION B-C

FIG. 8

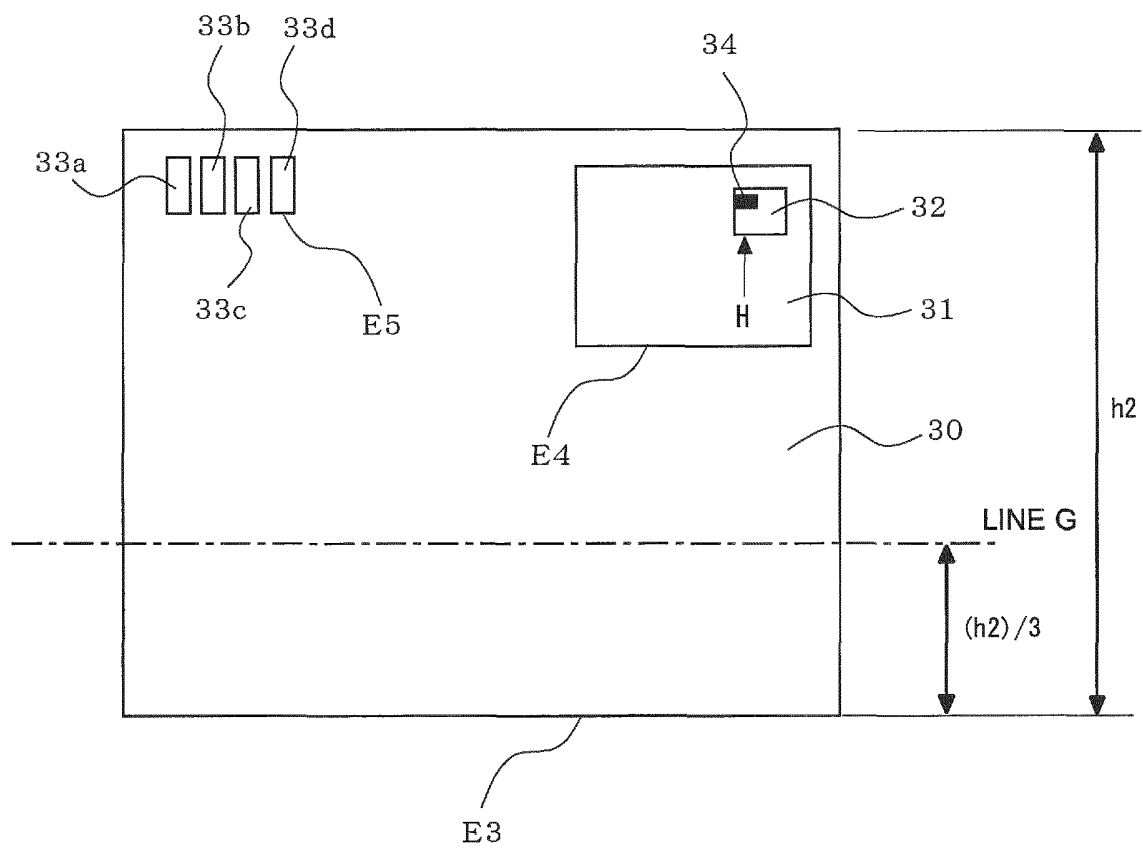
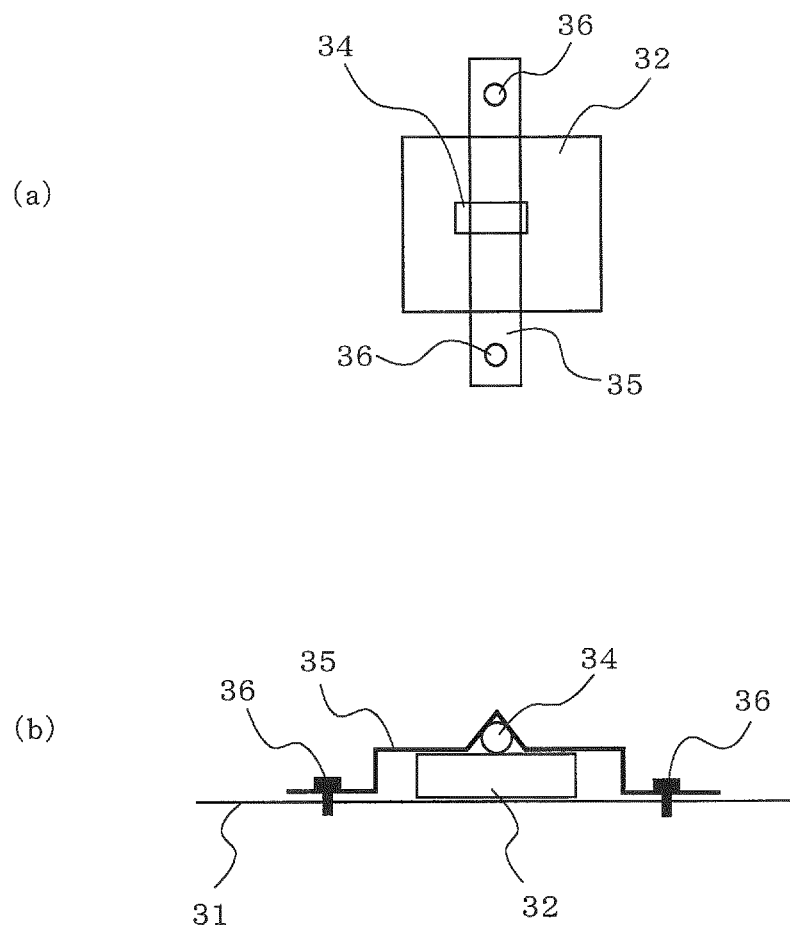


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/002200

A. CLASSIFICATION OF SUBJECT MATTER

F24F1/22 (2011.01) 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)

F24F1/22

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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 10-220824 A (Daikin Industries, Ltd.), 21 August 1998 (21.08.1998), paragraphs [00444] to [0054]; fig. 4 to 6 (Family: none)	1-14
Y	JP 2003-101266 A (Mitsubishi Heavy Industries, Ltd.), 04 April 2003 (04.04.2003), paragraphs [0002] to [0004]; fig. 7 to 8 (Family: none)	1-14
Y	JP 2005-113695 A (Matsushita Electric Industrial Co., Ltd.), 28 April 2005 (28.04.2005), paragraphs [0045] to [0049] (Family: none)	2-14

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

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Date of the actual completion of the international search
10 July, 2012 (10.07.12)Date of mailing of the international search report
17 July, 2012 (17.07.12)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/002200

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 9-213380 A (Sanyo Electric Co., Ltd.), 15 August 1997 (15.08.1997), paragraph [0041] (Family: none)	4, 7-14
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REFERENCES CITED IN THE DESCRIPTION

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