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# (54) AIR CONDITIONING SYSTEM

(57) An air-conditioning system (1) constitutes a multiple refrigeration cycle including a heat-source-side circuit (10) and a use-side circuit (30). The heat-source-side circuit (10) includes a heat-source-side compressor (21), an outdoor heat exchanger (23) that causes a heat-source-side refrigerant and outdoor air to exchange heat with each other, and a refrigerant-refrigerant heat exchanger (25) that causes the heat-source-side refrigerant and a use-side refrigerant to exchange heat with each other. The use-side circuit (30) includes a use-side compressor (31), the refrigerant-refrigerant heat exchanger (25), and a plurality of indoor heat exchangers (52) that cause the use-side refrigerant and indoor air to exchange heat with each other, the use-side circuit (30) having sealed therein carbon dioxide as the use-side refrigerant. An amount of the use-side refrigerant that is sealed in the use-side circuit (30) is 7.9 kg or less.

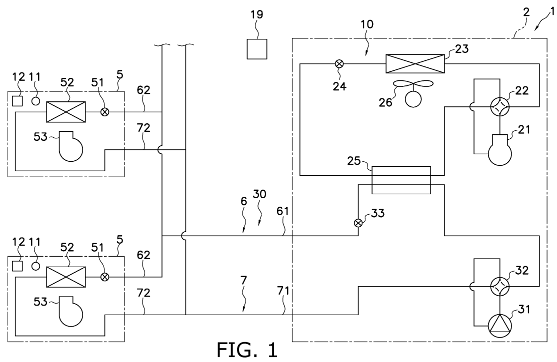


FIG. 1

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## Description

### Technical Field

**[0001]** The present disclosure relates to an air-conditioning system including a plurality of indoor heat exchangers that cause carbon dioxide, serving as a refrigerant, and indoor air to exchange heat with each other.

### Background Art

**[0002]** Hitherto, there has existed an air-conditioning system including a plurality of indoor heat exchangers that cause a refrigerant and indoor air to exchange heat with each other. As such an air-conditioning system, as described in Japanese Patent Literature 1 (International Publication No. 2011/099063), there exists an air-conditioning system that uses carbon dioxide as a refrigerant that is sealed in a refrigerant circuit in which the refrigerant circulates.

### Summary of Invention

### Technical Problem

**[0003]** When carbon dioxide is used as a refrigerant that is sealed in the refrigerant circuit, it is necessary to consider adverse effects (such as lack of oxygen) on the human body. Specifically, it is necessary to take safety measures in accordance with the concentration level of carbon dioxide that may reach an indoor space when the refrigerant has leaked from the refrigerant circuit. In particular, this tendency is noticeable in an air-conditioning system including a plurality of indoor heat exchangers because, when the amount of refrigerant that is sealed in the refrigerant circuit is large and the refrigerant has leaked from one of the plurality of indoor heat exchangers, all of the refrigerant that is sealed in the refrigerant circuit may leak to an indoor space corresponding to the indoor heat exchanger at which the refrigerant has leaked.

**[0004]** Therefore, in the air-conditioning system including the plurality of indoor heat exchangers that cause carbon dioxide, serving as a refrigerant, and indoor air to exchange heat with each other, it is desirable to reduce the number of safety measures by reducing the amount of carbon dioxide, serving as a refrigerant that is sealed in the refrigerant circuit.

### Solution to Problem

**[0005]** An air-conditioning system according to a first aspect constitutes a multiple refrigeration cycle including a heat-source-side circuit and a use-side circuit. The heat-source-side circuit includes a heat-source-side compressor that compresses a heat-source-side refrigerant, an outdoor heat exchanger that causes the heat-source-side refrigerant and outdoor air to exchange heat with each other, and a refrigerant-refrigerant heat exchanger that causes the heat-source-side refrigerant and a use-side refrigerant to exchange heat with each other. The use-side circuit includes a use-side compressor that compresses the use-side refrigerant, the refrigerant-refrigerant heat exchanger, and a plurality of indoor heat exchangers that cause the use-side refrigerant and indoor air to exchange heat with each other, the use-side circuit having sealed therein carbon dioxide as the use-side refrigerant. In addition, here, an amount of the use-side refrigerant that is sealed in the use-side circuit is 7.9 kg or less.

**[0006]** When carbon dioxide is used as the use-side refrigerant that is sealed in the use-side circuit, the concentration level at which the number of safety measures may be only one is greater than 0.074 kg per 1 $m^3$ of indoor space and 0.18 kg or less per 1 $m^3$ of indoor space. Here, in order to satisfy this condition, supposing that an air conditioned space has a small spatial volume in which the floor area is 20 $m^2$ and the ceiling height is 2.2 m, the amount of carbon dioxide (= 7.9 kg) at which the number of safety measures is one or less is calculated, and, as described above, the amount of use-side refrigerant that is sealed in the use-side circuit is reduced to 7.9 kg or less.

**[0007]** An air-conditioning system according to a second aspect is the air-conditioning system according to the first aspect, in which, among a warning device, a blocking device, and a ventilating device, one of the warning device and the ventilating device is provided.

**[0008]** Here, as described above, unlike in a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, the outdoor heat exchanger at which the refrigerant and the outdoor air exchange heat with each other is provided at the heat-source-side circuit not including the plurality of indoor heat exchangers, and the small refrigerant-refrigerant heat exchanger is provided at the use-side circuit that uses carbon dioxide as the use-side refrigerant. Therefore, here, compared with a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, it is possible to reduce the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit. By reducing the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit, in this way, here, the concentration level of carbon dioxide that may reach an indoor space when the use-side refrigerant has leaked from the use-side circuit is reduced to a concentration level that allows the number of safety measures to be one, and, as described above, among the warning device, the blocking device, and the ventilating device, only one of the warning device and the ventilating device is to be provided.

**[0009]** In this way, here, in the air-conditioning system including the plurality of indoor heat exchangers that cause carbon dioxide, serving as the refrigerant, and the indoor air to exchange heat with each other, it is possible to reduce the number of safety measures by reducing the amount of carbon dioxide, serving as the refrigerant that is sealed in the refrigerant circuit (the use-side circuit).

**[0010]** An air-conditioning system according to a third aspect is the air-conditioning system according to the second aspect, in which, of the warning device and the ventilating device, the warning device is provided.

**[0011]** Here, as described above, as a safety measure, the warning device is provided and the ventilating device is not provided. Here, when the ventilating device is provided as a safety measure, since it is necessary to satisfy setting standards, such as the ventilation amount, the number of ventilations, and the position of a ventilation opening, not providing the ventilating device as a safety measure is effective in terms of costs and construction.

**[0012]** An air-conditioning system according to a fourth aspect is the air-conditioning system according to any one of the first aspect to the third aspect, in which the indoor heat exchangers are micro-channel heat exchangers that use a flat porous tube as a heat transfer tube in which the use-side refrigerant flows.

**[0013]** Here, as described above, since the indoor heat exchangers are constituted by micro-channel heat exchangers, it is possible to reduce the volume of the indoor heat exchangers and, thus, to further reduce the amount of use-side refrigerant that is sealed in the use-side circuit.

**[0014]** An air-conditioning system according to a fifth aspect is the air-conditioning system according to any one of the first aspect to the fourth aspect, in which when a rated refrigerating capacity of the air-conditioning system is 28 kW or less, as a pipe that connects the refrigerant-refrigerant heat exchanger and the indoor heat exchangers in the use-side circuit to each other, a pipe having a nominal diameter that is 2.5/8 inches or less is used, and, as a pipe that connects the use-side compressor and the indoor heat exchangers in the use-side circuit to each other, a pipe having a nominal diameter that is 5/8 inches or less is used.

**[0015]** Here, as described above, even if the rated refrigerating capacity is 28 kW, it is possible to reduce the amount of use-side refrigerant that is sealed in the use-side circuit because, as a pipe that connects the refrigerant-refrigerant heat exchanger and the indoor heat exchangers in the use-side circuit to each other, there is used a pipe having a nominal diameter that is 2.5/8 inches or less, which is smaller than the nominal diameters known in the art, and, as a pipe that connects the use-side compressor and the indoor heat exchangers in the use-side circuit to each other, there is used a pipe having a nominal diameter that is 5/8 inches or less, which is smaller than the nominal diameters known in the art.

**[0016]** An air-conditioning system according to a sixth aspect is the air-conditioning system according to any one of the first aspect to the fifth aspect, in which the outdoor heat exchanger is provided at an outdoor unit, the refrigerant-refrigerant heat exchanger is provided at an intermediate unit that is connected to the outdoor unit via a heat-source-side refrigerant connection pipe in which the heat-source-side refrigerant flows, and the indoor heat exchangers are provided at an indoor unit that is connected to the intermediate unit via a use-side refrigerant connection pipe in which the use-side refrigerant flows.

**[0017]** Here, as described above, since the refrigerant-refrigerant heat exchanger is provided at the intermediate unit that is provided separately from the outdoor unit, it is possible to provide the refrigerant-refrigerant heat exchanger at a location that is close to the indoor units, and thus, it is possible to further reduce the amount of use-side refrigerant that is sealed in the use-side circuit.

## Brief Description of Drawings

**[0018]**

[Fig. 1] Fig. 1 is a schematic view of a configuration of an air-conditioning system according to an embodiment of the present disclosure.

[Fig. 2] Fig. 2 is a perspective view of a main portion of an indoor heat exchanger that constitutes the air-conditioning system in Fig. 1.

[Fig. 3] Fig. 3 is an explanatory view of a pipe system that connects units that constitute the air-conditioning system in Fig. 1 to each other.

[Fig. 4] Fig. 4 is a table that shows a relationship between rated refrigerating capacities and nominal pipe diameters of refrigerant connection pipes when carbon dioxide is used as a refrigerant.

[Fig. 5] Fig. 5 shows a relationship between configurations of the air-conditioning system (a unitary refrigeration cycle A and a binary refrigeration cycle A) and the amount of carbon dioxide, serving as a refrigerant.

[Fig. 6] Fig. 6 is a perspective view of a main portion of an indoor heat exchanger that constitutes an air-conditioning system of Modification 1.

[Fig. 7] Fig. 7 shows a relationship between configurations of the air-conditioning system (a unitary refrigeration cycle B, the binary refrigeration cycle A, and a binary refrigeration cycle B) and the amount of carbon dioxide, serving as a refrigerant.

[Fig. 8] Fig. 8 is a schematic view of a configuration of an air-conditioning system of Modification 2.

[Fig. 9] Fig. 9 is an explanatory view of a pipe system that connects units that constitute the air-conditioning system in Fig. 8 to each other.

[Fig. 10] Fig. 10 shows a relationship between configurations of the air-conditioning system (the binary refrigeration cycle B and a binary refrigeration cycle C) and the amount of carbon dioxide, serving as a refrigerant.

## Description of Embodiments

**[0019]** An air-conditioning system is described below based on the drawings.

(1) Configuration

**[0020]** Fig. 1 is a schematic view of a configuration of an air-conditioning system 1 according to an embodiment of the present disclosure. Fig. 2 is a perspective view of a main portion of an indoor heat exchanger 52 that constitutes the air-conditioning system 1 in Fig. 1.

<Circuit Configuration>

**[0021]** The air-conditioning system 1 constitutes a multiple refrigeration cycle including a heat-source-side circuit 10 in which a heat-source-side refrigerant circulates and a use-side circuit 30 in which a use-side refrigerant circulates, and is a system that air-conditions (cools and heats) an indoor space by causing the use-side refrigerant and indoor air to exchange heat with each other.

- Heat-Source-Side Circuit -

**[0022]** The heat-source-side circuit 10 primarily includes a heat-source-side compressor 21, an outdoor heat exchanger 23, and a refrigerant-refrigerant heat exchanger 25. As a heat-source-side refrigerant, for example, an HFC refrigerant, such as R32, an HFO refrigerant, such as 1234yf, or a mixed refrigerant thereof is sealed in the heat-source-side circuit 10. The heat-source-side circuit 10 also includes a heat-source-side flow-path switching device 22 and a heat-source-side decompressor 24.

**[0023]** The heat-source-side compressor 21 is a device that compresses the heat-source-side refrigerant. The heat-source-side compressor 21 is a compressor in which, for example, a compression element, such as a rotary compression element or a scroll compression element, is driven by a driving mechanism, such as a motor or an engine.

**[0024]** The heat-source-side flow-path switching device 22 is a device that switches between a first state (refer to the solid line of the heat-source-side flow-path switching device 22 in Fig. 1) and a second state (refer to the broken line of the heat-source-side flow-path switching device 22 in Fig. 1). In the first state, the heat-source-side flow-path switching device 22 causes the outdoor heat exchanger 23 to function as a heat dissipater of the heat-source-side refrigerant and the refrigerant-refrigerant heat exchanger 25 to function as an evaporator of the heat-source-side refrigerant. In the second state, the heat-source-side flow-path switching device 22 causes the outdoor heat exchanger 23 to function as an evaporator of the heat-source-side refrigerant and the refrigerant-refrigerant heat exchanger 25 to function as a heat dissipater of the heat-source-side refrigerant. The heat-source-side flow-path switching device 22 is, for example, a four-way switching valve. In the first state, the heat-source-side flow-path switching device 22 connects a discharge side of the heat-source-side compressor 21 and a gas side of the outdoor heat exchanger 23 to each other and connects an intake side of the heat-source-side compressor 21 and a gas side of a flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 to each other. In the second state, the heat-source-side flow-path switching device 22 connects the discharge side of the heat-source-side compressor 21 and the gas side of the flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 to each other and connects the intake side of the heat-source-side compressor 21 and the gas side of the outdoor heat exchanger 23 to each other. Note that the heat-source-side flow-path switching device 22 is not limited to a four-way switching valve, and, for example, may have the function of switching between the first state and the second state above by combining a plurality of valves (for example, electromagnetic valves or three-way valves).

**[0025]** The outdoor heat exchanger 23 is a device that causes the heat-source-side refrigerant and outdoor air to exchange heat with each other. The outdoor heat exchanger 23 is, for example, a fin-and-tube-type heat exchanger. In a state in which the heat-source-side flow-path switching device 22 has been switched to the first state, the outdoor heat exchanger 23 functions as a heat dissipater of the heat-source-side refrigerant with the outdoor air as a cooling source. In a state in which the heat-source-side flow-path switching device 22 has been switched to the second state, the outdoor heat exchanger 23 functions as an evaporator of the heat-source-side refrigerant with the outdoor air as a heating source. The gas side of the outdoor heat exchanger 23 is connected to the heat-source-side flow-path switching device 22, and a liquid side of the outdoor heat exchanger 23 is connected to a liquid side of the flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25.

**[0026]** The heat-source-side decompressor 24 is a device that decompresses the heat-source-side refrigerant. The heat-source-side decompressor 24 is, for example, an electrically powered expansion valve. In the state in which the heat-source-side flow-path switching device 22 has been switched to the first state, the heat-source-side decompressor 24 decompresses the heat-source-side refrigerant that has dissipated heat at the outdoor heat exchanger 23. In the state in which the heat-source-side flow-path switching device 22 has been switched to the second state, the heat-source-side decompressor 24 decompresses the heat-source-side refrigerant that has dissipated heat at the refrigerant-refrigerant heat exchanger 25. One end of the heat-source-side decompressor 24 is connected to the liquid side of the outdoor heat exchanger 23, and the other end of the heat-source-side decompressor 24 is connected to the liquid side of the flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25. Note that the heat-source-side decompressor 24 is not limited to an electrically powered expansion valve, and may be, for example, other types of expansion valves, a capillary tube, or an expansion device.

**[0027]** The refrigerant-refrigerant heat exchanger 25 is a device that causes the heat-source-side refrigerant and a use-side refrigerant to exchange heat with each other. The refrigerant-refrigerant heat exchanger 25 is, for example, a plate-type heat exchanger or a double-pipe-type heat exchanger. Here, the plate-type heat exchanger and the double-pipe-type heat exchanger are suited for exchanging heat between two refrigerants (here, the heat-source-side refrigerant and the use-side refrigerant), and are heat exchangers that are smaller than large heat exchangers, such as fin-and-tube-type heat exchangers at which a refrigerant and air exchange heat with each other. In the state in which the heat-source-side flow-path switching device 22 has been switched to the first state, the refrigerant-refrigerant heat exchanger 25 functions as an evaporator of a refrigerant with the use-side refrigerant as a heating source. In the state in which the heat-source-side flow-path switching device 22 has been switched to the second state, the refrigerant-refrigerant heat exchanger 25 functions as a heat dissipater of a refrigerant with the use-side refrigerant as a cooling source. The gas side of the flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 is connected to the heat-source-side flow-path switching device 22, and the liquid side of the flow path in which the heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 is connected to the heat-source-side decompressor 24.

- Use-Side Circuit -

**[0028]** The use-side circuit 30 includes a use-side compressor 31, the refrigerant-refrigerant heat exchanger 25, and a plurality of indoor heat exchangers 52. Carbon dioxide, serving as the use-side refrigerant, is sealed in the use-side circuit 30. The use-side circuit 30 also includes a use-side flow-path switching device 32, a use-side decompressor 33, and indoor decompressors 51 that correspond with the plurality of indoor heat exchangers 52. Note that, when carbon dioxide is used as the use-side refrigerant, the refrigerant may be brought into a supercritical state (a state in which a gas state and a liquid state cannot be distinguished) during a refrigeration cycle. However, regarding, for example, the names of components that constitute the use-side circuit 30, the terms "gas" and "liquid" are used in, for example, the names of components similarly to when a refrigerant (such as R410A and R32) that is not brought into a supercritical state during the refrigeration cycle is used.

**[0029]** The use-side compressor 31 is a device that compresses a use-side refrigerant. The use-side compressor 31 is a compressor in which, for example, a compression element, such as a rotary compression element or a scroll compression element, is driven by a driving mechanism, such as a motor or an engine.

**[0030]** The use-side flow-path switching device 32 is a device that switches between a first state (refer to the solid line of the use-side flow-path switching device 32 in Fig. 1) and a second state (refer to the broken line of the use-side flow-path switching device 32 in Fig. 1). In the first state, the use-side flow-path switching device 32 causes the refrigerant-refrigerant heat exchanger 25 to function as a heat dissipater of the use-side refrigerant. In the second state, the use-side flow-path switching device 32 causes the refrigerant-refrigerant heat exchanger 25 to function as an evaporator of the use-side refrigerant. In the first state, the use-side flow-path switching device 32 causes the indoor heat exchangers 52 to function as evaporators of the use-side refrigerant. In the second state, the use-side flow-path switching device 32 causes the indoor heat exchangers 52 to function as heat dissipaters of the use-side refrigerant. The use-side flow-path switching device 32 is, for example, a four-way switching valve. In the first state, the use-side flow-path switching device 32 connects a discharge side of the use-side compressor 31 and the gas side of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 to each other, and connects an intake side of the use-side compressor 31 and a gas side of the indoor heat exchangers 52 to each other. In the second state, the use-side flow-path switching device 32 connects the discharge side of the use-side compressor 31 and the gas side of the indoor heat exchangers 52 to each other, and connects the intake side of the use-side compressor 31 and the liquid side of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 to each other. Note that the use-side flow-path switching device 32 is not limited to a four-way switching valve, and, for example, may have the function of switching between the first state and the second state above by combining a plurality of valves (for example, electromagnetic valves or three-way valves).

**[0031]** The refrigerant-refrigerant heat exchanger 25 is a device that causes the heat-source-side refrigerant and the use-side refrigerant to exchange heat with each other as described above. In the state in which the heat-source-side flow-path switching device 22 has been switched to the first state and the use-side flow-path switching device 32 has been switched to the first state, the refrigerant-refrigerant heat exchanger 25 functions as a use-side heat dissipater with the heat-source-side refrigerant as a cooling source. In the state in which the heat-source-side flow-path switching device 22 has been switched to the second state and the use-side flow-path switching device 32 has been switched to the second state, the refrigerant-refrigerant heat exchanger 25 functions as an evaporator of the use-side refrigerant with the heat-source-side refrigerant as a heating source. The gas side of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 is connected to the use-side flow-path switching device 32, and the liquid side of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 is connected to a liquid side of the indoor heat exchangers 52.

**[0032]** The use-side decompressor 33 is a device that decompresses the use-side refrigerant. The use-side decompressor 33 is, for example, an electrically powered expansion valve. In the state in which the use-side flow-path switching device 32 has been switched to the first state, the use-side decompressor 33 is brought into a fully open state or is set to an opening degree corresponding to a nearly fully open state so as not to decompress to the extent possible the use-side refrigerant that has dissipated heat at the refrigerant-refrigerant heat exchanger 25. In the state in which the use-side flow-path switching device 32 has been switched to the second state, the use-side decompressor 33 decompresses the use-side refrigerant that is sent from the indoor decompressors 51. One end of the use-side decompressor 33 is connected to the liquid side of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25, and the other end of the use-side decompressor 33 is connected to the indoor decompressors 51. Note that the use-side decompressor 33 is not limited to an electrically powered expansion valve, and may be, for example, other types of expansion valves, a capillary tube, or an expansion device.

**[0033]** The indoor decompressors 51 are devices that decompress the use-side refrigerant. The indoor decompressors 51 are, for example, electrically powered expansion valves. In the state in which the use-side flow-path switching device 32 has been switched to the first state, the indoor decompressors 51 decompress the use-side refrigerant that has dissipated heat at the refrigerant-refrigerant heat exchanger 25. In the state in which the use-side flow-path switching device 32 has been switched to the second state, the indoor decompressors 51 decompress the use-side refrigerant that has dissipated heat at the indoor heat exchangers 52. One end of each indoor decompressor 51 is connected to the use-side decompressor 33, and the other end of each indoor decompressor 51 is connected to the liquid side of a corresponding one of the indoor heat exchangers 52.

**[0034]** The indoor heat exchangers 52 are devices that cause the use-side refrigerant and indoor air to exchange heat with each other. The indoor heat exchangers 52 are, for example, fin-and-tube-type heat exchangers. Here, as the indoor heat exchangers 52, fin-and-tube-type heat exchangers including a plurality of heat transfer tubes 54, which are constituted by circular tubes, and a plurality of heat transfer fins 55 are used. In the state in which the use-side flow-path switching device 32 has been switched to the first state, each indoor heat exchanger 52 functions as a heat dissipater of the use-side refrigerant with indoor air as a cooling source. In the state in which the use-side flow-path switching device 32 has been switched to the second state, each indoor heat exchanger 52 functions as an evaporator of the use-side refrigerant with the indoor air as a heating source. The gas side of each indoor heat exchanger 52 is connected to the use-side switching device 32, and the liquid side of each indoor heat exchanger 52 is connected to a corresponding one of the indoor heat exchangers 51.

<Unit Configuration>

**[0035]** The devices constituting the heat-source-side circuit 10 and the use-side circuit 30 above are provided at a heat transfer unit 2 and a plurality of indoor units 5. The indoor units 5 are provided in correspondence with the indoor heat exchangers 52.

- Heat Transfer Unit -

**[0036]** The heat transfer unit 2 is disposed outdoors. The heat-source-side circuit 10 that includes the refrigerant-refrigerant heat exchanger 25, and the use-side compressor 31 and the use-side flow-path switching device 32 in the use-side circuit 30 are provided at the heat transfer unit 2. The use-side decompressor 33 in the use-side circuit 30 is also provided at the heat transfer unit 2.

**[0037]** An outdoor fan 26 for sending outdoor air to the outdoor heat exchanger 23 is also provided at the heat transfer unit 2. The outdoor fan 26 is a fan in which a blowing element, such as a propeller fan, is driven by a driving mechanism, such as a motor.

- Indoor Units, Warning Devices -

**[0038]** Each indoor unit 5 is disposed indoors. Each indoor heat exchanger 52 of the use-side circuit 30 is provided at a corresponding one of the indoor units 5. Each indoor compressor 51 of the use-side circuit 30 is also provided at a corresponding one of the indoor units 5.

**[0039]** Indoor fans 53 for sending indoor air to the indoor heat exchangers 52 corresponding thereto are also provided at the indoor units 5 corresponding thereto. Each indoor fan 53 is a fan in which a blowing element, such as a centrifugal fan or a multiblade fan, is driven by a driving mechanism, such as a motor.

**[0040]** Refrigerant sensors 11 that detect leakage of a use-side refrigerant are provided at the indoor units 5 corresponding thereto. Each refrigerant sensor 11 detects whether the concentration of carbon dioxide, serving as the use-side refrigerant, is greater than or equal to a predetermined concentration. Warning devices 12 that, when leakage of a use-side refrigerant has occurred, gives a warning that the use-side refrigerant has leaked are provided at the indoor units 5 corresponding thereto. Here, providing the warning devices 12 is one safety measure that should be taken when leakage of carbon dioxide, serving as the use-side refrigerant, has occurred. Here, when the refrigerant sensors 11 detect leakage of a use-side refrigerant, the warning devices 12 corresponding thereto give a warning that the use-side refrigerant has leaked. As the warning devices 12, warning devices that use sound and light to give a warning that a use-side refrigerant has leaked are used.

**[0041]** Note that, here, although the refrigerant sensors 11 and the warning devices 12 are provided at the indoor units 5 corresponding thereto, the refrigerant sensors 11 and the warning devices 12 are not limited thereto. The refrigerant sensors 11 and the warning devices 12 may be provided, for example, in an indoor space that is air-conditioned by the indoor units 5 or at a remote controller for operating the indoor units 5. The refrigerant sensors 11 and the warning devices 12 may be provided separately.

- Use-Side Refrigerant Connection Pipes -

**[0042]** The heat transfer unit 2 and each indoor unit 5 are connected to each other by use-side refrigerant connection pipes 6 and 7 that constitute a part of the use-side circuit 30.

**[0043]** The use-side liquid-refrigerant connection pipe 6 is a part of a pipe that connects the refrigerant-refrigerant heat exchanger 25 and the indoor heat exchangers 52 to each other. Specifically, the use-side liquid-refrigerant connection pipe 6 is a pipe that connects the use-side decompressor 33 and each indoor decompressor 51 to each other. The use-side liquid-refrigerant connection pipe 6 primarily includes use-side liquid-refrigerant connection branch pipes 62 that are connected to the indoor units 5 corresponding thereto, and a use-side liquid-refrigerant connection main pipe 61 that connects the heat transfer unit 2 and a portion at which all of the use-side liquid-refrigerant connection branch pipes 62 merge.

**[0044]** The use-side gas-refrigerant connection pipe 7 is a part of a pipe that connects the use-side compressor 31 and each indoor heat exchanger 52 to each other. Specifically, the use-side gas-refrigerant connection pipe 7 is a pipe that connects the use-side flow-path switching device 32 and the gas side of each indoor heat exchanger 52 to each other. The use-side gas-refrigerant connection pipe 7 primarily includes use-side gas-refrigerant connection branch pipes 72 that are connected to the indoor units 5 corresponding thereto, and a use-side gas-refrigerant connection main pipe 71 that connects the heat transfer unit 2 and a portion at which all of the use-side gas-refrigerant connection branch pipes 72 merge.

- Control Unit -

**[0045]** The devices that constitute the heat transfer unit 2 and the indoor units 5 above are controlled by a control unit 19. The control unit 19 is constituted by subjecting to communication connection a control board or the like provided at the heat transfer unit 2 and the indoor units 5. For convenience sake, Fig. 1 illustrates the control unit 19 at a position situated away from, for example, the heat transfer unit 2 and the indoor units 5. In this way, the control unit 19 controls the operations of the devices 11, 12, 21, 22, 24, 26, 31, 32, 33, 51, and 53 that constitute the air-conditioning system 1, that is, the operation of the entire air-conditioning system 1.

(2) Operation

**[0046]** Next, the operation of the air-conditioning system 1 is described by using Fig. 1. In order to air-condition the interior of a room, the air-conditioning system 1 is capable of performing a cooling operation for cooling indoor air and a heating operation for heating the indoor air. When a use-side refrigerant leaks from the use-side circuit 30, the warning devices 12 give a warning that the use-side refrigerant has leaked. Note that the cooling operation, the heating operation, and the operation that is performed when a use-side refrigerant has leaked are performed by the control unit 19.

- Cooling Operation -

**[0047]** In the cooling operation, for example, when all of the indoor units 5 perform the cooling operation (that is, when all indoor heat exchangers 52 function as evaporators of a use-side refrigerant and indoor air is cooled), the heat-source-side flow-path switching device 22 switches to the first state (refer to the solid line of the heat-source-side flow-path switching device 22 in Fig. 1), and the use-side flow-path switching device 32 switches to the first state (refer to the solid line of the use-side flow-path switching device 32 in Fig. 1).

**[0048]** This causes a heat-source-side refrigerant discharged from the heat-source-side compressor 21 to be sent to the outdoor heat exchanger 23 via the heat-source-side flow-path switching device 22. At the outdoor heat exchanger 23 that functions as a heat dissipater of the heat-source-side refrigerant, the heat-source-side refrigerant that has been sent to the outdoor heat exchanger 23 exchanges heat with outdoor air that is supplied by the outdoor fan 26 and is cooled, and is thus condensed. The refrigerant that has dissipated heat at the outdoor heat exchanger 23 is, after being decompressed by the heat-source-side decompressor 24, sent to the refrigerant-refrigerant heat exchanger 25. At the refrigerant-refrigerant heat exchanger 25 that functions as an evaporator of the heat-source-side refrigerant, the heat-source-side refrigerant that has been sent to the refrigerant-refrigerant heat exchanger 25 exchanges heat with a use-side refrigerant and is heated, and is thus evaporated. The heat-source-side refrigerant that has been evaporated at the refrigerant-refrigerant heat exchanger 25 is sucked into the heat-source-side compressor 21 via the heat-source-side flow-path switching device 22, and is discharged again from the heat-source-side compressor 21.

**[0049]** On the other hand, a use-side refrigerant discharged from the use-side compressor 31 is sent to the refrigerant-refrigerant heat exchanger 25 via the use-side flow-path switching device 32. At the refrigerant-refrigerant heat exchanger 25 that functions as an evaporator of the use-side refrigerant, the use-side refrigerant that has been sent to the refrigerant-refrigerant heat exchanger 25 exchanges heat with the heat-source-side refrigerant and is cooled. The use-side refrigerant that has dissipated heat at the refrigerant-refrigerant heat exchanger 25 is sent to the use-side liquid-refrigerant connection pipe 6 via the use-side medium decompressor 33. The use-side refrigerant that has been sent to the use-side liquid medium connection pipe 6 is, after being decompressed by the indoor decompressors 51, sent to the indoor heat exchangers 52 corresponding thereto. At the indoor heat exchangers 52 that function as evaporators of the use-side refrigerant, the use-side refrigerant that has been sent to the indoor heat exchangers 52 exchange heat with indoor air that is supplied by the indoor fans 53 corresponding thereto and is cooled, and is thus evaporated. Therefore, the cooling operation that cools the indoor air is performed. The use-side refrigerant that has evaporated at the indoor heat exchangers 52 is sent to the use-side gas-refrigerant connection pipe 7. The use-side refrigerant that has been sent to the use-side gas-refrigerant connection pipe 7 is sucked into the use-side compressor 31 via the use-side flow-path switching device 32, and is discharged again from the use-side compressor 31.

- Heating Operation -

**[0050]** In the heating operation, for example, when all of the indoor units 5 perform the heating operation (that is, when all indoor heat exchangers 52 function as heat dissipaters of a use-side refrigerant and indoor air is heated), the heat-source-side flow-path switching device 22 switches to the second state (refer to the broken line of the heat-source-side flow-path switching device 22 in Fig. 1), and the use-side flow-path switching device 32 switches to the second state (refer to the broken line of the use-side flow-path switching device 32 in Fig. 1).

**[0051]** This causes a heat-source-side refrigerant discharged from the heat-source-side compressor 21 to be sent to the refrigerant-refrigerant heat exchanger 25 via the heat-source-side flow-path switching device 22. At the refrigerant-refrigerant heat exchanger 25 that functions as a heat dissipater of the heat-source-side refrigerant, the heat-source-side refrigerant that has been sent to the refrigerant-refrigerant heat exchanger 25 exchanges heat with a use-side refrigerant and is cooled, and is thus condensed. The heat-source-side refrigerant that has dissipated heat at the refrigerant-refrigerant heat exchanger 25 is, after being decompressed by the heat-source-side decompressor 24, sent to the outdoor heat exchanger 23. At the outdoor heat exchanger 23 that functions as an evaporator of the heat-source-side refrigerant, the heat-source-side refrigerant that has been sent to the outdoor heat exchanger 23 exchanges heat with outdoor air that is supplied by the outdoor fan 26 and is heated, and is thus evaporated. The heat-source-side refrigerant that has been evaporated at the outdoor heat exchanger 23 is sucked into the heat-source-side compressor 21 via the heat-source-side flow-path switching device 22, and is discharged again from the heat-source-side compressor 21.

**[0052]** On the other hand, a use-side refrigerant discharged from the use-side compressor 31 is sent to the use-side gas-refrigerant connection pipe 7 via the use-side flow-path switching device 32. The use-side refrigerant that has been sent to the use-side gas-refrigerant connection pipe 7 is sent to the indoor heat exchangers 52. At the indoor heat exchangers 52 that function as heat dissipaters of the use-side refrigerant, the use-side refrigerant that has been sent to the indoor heat exchangers 52 exchange heat with indoor air that is supplied by the indoor fans 53 corresponding thereto and is cooled. Therefore, the heating operation that heats the indoor air is performed. The use-side refrigerant that has dissipated heat at the indoor heat exchangers 52 is, after being decompressed by the indoor heat exchangers 51 corresponding thereto, sent to the use-side liquid-refrigerant connection pipe 6. The use-side refrigerant that has been sent to the use-side liquid-refrigerant connection pipe 6 is, after being further decompressed by the use-side decompressor 33, sent to the refrigerant-refrigerant heat exchanger 25. At the refrigerant-refrigerant heat exchanger 25 that functions as an evaporator of the use-side refrigerant, the use-side refrigerant that has been sent to the refrigerant-refrigerant heat exchanger 25 exchanges heat with a heat-source-side refrigerant and is heated, and is thus evaporated. The use-side refrigerant that has been evaporated at the refrigerant-refrigerant heat exchanger 25 is sucked into the use-side compressor 31 via the use-side flow-path switching device 32, and is discharged again from the use-side compressor 31.

- When Use-Side Refrigerant Has Leaked -

**[0053]** When leakage of a use-side refrigerant from the use-side circuit 30 occurs, the refrigerant sensors 11 detect the leakage of the use-side refrigerant, and the warning devices 12 give a warning that the use-side refrigerant has leaked.

**[0054]** Note that, here, since the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit 30, is reduced, the concentration level of carbon dioxide that may reach an indoor space when the use-side refrigerant has leaked from the use-side circuit 30 can be reduced to a concentration level that allows the number of safety measures that should be taken to be one when the leakage of carbon dioxide, serving as the use-side refrigerant, has occurred. Therefore, here, only the warning devices 12 are selectively provided as a safety measure.

(3) Selection of Safety Measure

**[0055]** Here, selection of a safety measure that should be taken when leakage of carbon dioxide, serving as a refrigerant, has occurred is described by using Figs. 1 to 5. Here, Fig. 3 is an explanatory view of a pipe system that connects the unit 2 and units 5a to 5j that constitute the air-conditioning system 1 in Fig. 1 to each other. Fig. 4 is a table that shows a relationship between rated refrigerating capacities and nominal pipe diameters of the refrigerant connection pipes when carbon dioxide is used as a refrigerant. Fig. 5 shows a relationship between configurations of the air-conditioning system (a unitary refrigeration cycle A and a binary refrigeration cycle A) and the amount of carbon dioxide, serving as a refrigerant.

**[0056]** When, as in the use-side circuit 30 of the air-conditioning system 1, carbon dioxide is used as a refrigerant that is sealed in the refrigerant circuit including the plurality of indoor heat exchangers that cause the refrigerant and indoor air to exchange heat with each other, it is necessary to take safety measures in accordance with the concentration level of carbon dioxide that may reach an indoor space when the refrigerant has leaked from the refrigerant circuit. The concentration level of carbon dioxide at which no safety measures need to be provided is 0.074 kg or less per 1 $m^3$ of indoor space; the concentration level at which the number of safety measures may be only one is greater than 0.074 kg per 1 $m^3$ of indoor space and 0.18 kg or less per 1 $m^3$ of indoor space; and the concentration level at which the number of safety measures need to be two or more is greater than 0.18 kg per 1 $m^3$ of indoor space. Therefore, in order to reduce the number of safety measures to one or less, it is necessary to satisfy the condition in which the concentration level is 0.18 kg or less per 1 $m^3$ of indoor space. Note that, here, as a safety measure, in addition to providing warning devices that give a warning that a refrigerant has leaked, blocking devices that, when a refrigerant has leaked, block circulation of the refrigerant may be provided, or ventilating devices that, when a refrigerant has leaked, ventilate a space that is air-conditioned by indoor air that has exchanged heat at the indoor heat exchangers may be provided.

**[0057]** Here, it is assumed that, with the floor area of an air conditioned space being 20 $m^2$ per rated refrigerating capacity of 2.8 kW, an air-conditioning system whose rated refrigerating capacity is 28 kW with respect to a plurality of air conditioned spaces having a total floor area of 200 $m^2$ is provided. In this case, when carbon dioxide, serving as a refrigerant, has leaked from the air conditioned space having the smallest spatial volume among the plurality of air conditioned spaces, the amount of refrigerant (carbon dioxide) that allows the number of safety measures to be one or less is calculated. Here, "rated refrigerating capacity" means, for example, a value that is equivalent to the "rated cooling capacity" or the "nominal capacity" of the indoor units 5 or the heat transfer unit 2 described in product catalogs or instruction manuals, when the air-conditioning system 1 is taken as an example. First, the ceiling height of the air conditioned space having the smallest spatial volume is 2.2 m. Therefore, the spatial volume of the air conditioned space is 44 $m^3$ (=$20m^2 \times 2.2m$). Consequently, in order for the number of safety measures to be one or less, it is necessary to satisfy the condition in which the amount of refrigerant is 7.9 kg (=$0.18kg/m^3 \times 44m^3$) or less. In order not to provide any safety measures, it is necessary to satisfy the condition in which the amount of refrigerant is 3.3 kg (=$0.074kg/m^3 \times 44m^3$) or less. On the other hand, if the number of safety measures to be provided is two or more, the amount of refrigerant may be greater than 7.9 kg. Note that, since in this supposition, the spatial volume of the air conditioned space into which the refrigerant leaks is estimated at a considerably small value, even if the amount of refrigerant is larger than the aforementioned values, as long as the spatial volume of the air conditioned space is large, there may be cases in which the number of safety measures can be one or less. In this sense, the value of the calculated amount of refrigerant corresponds to the condition on the safest side. If the condition of the amount of refrigerant is satisfied, it is practically possible for the number of safety measures to be one or less in any air-conditioning system.

**[0058]** Next, the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit 30 of the air-conditioning system 1, is described taking as an a example a configuration in which ten indoor units 5 (5a to 5j) having a rated refrigerating capacity of 2.8 kW are connected to the heat transfer unit 2. Regarding the lengths of the use-side refrigerant connection pipes 6 and 7, it is assumed that the length of each of the use-side refrigerant connection main pipes 61 and 71 is 50 m, and the total lengths of the use-side refrigerant connection branch pipes 62 and 72 (62a to 62j, 72a to 72j) are 20 m. As shown in Fig. 4, the pipe diameters of the use-side refrigerant connection pipes 6 and 7 are selected and used in accordance with the rated refrigerating capacity. Here, as the use-side liquid-refrigerant connection main pipe 61, a pipe having a nominal diameter of 2.5/8 inches is used, and, as the use-side liquid-refrigerant connection branch pipes 62, pipes having a nominal diameter of 1.5/8 inches are used. As the use-side gas-refrigerant connection main pipe 71, a pipe having a nominal diameter of 5/8 inches is used, and, as the use-side gas-refrigerant connection branch pipes 72, pipes having a nominal diameter of 2.5/8 inches are used. That is, here, since the total refrigerating capacity is 28 kW or less, as the use-side liquid-refrigerant connection pipe 6, a pipe having a nominal diameter of 2.5/8 inches or less is used, and, as the use-side gas-refrigerant connection pipe 7, a pipe having a nominal diameter of 5/8 inches or less is used.

**[0059]** Here, in an air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, it is assumed that a refrigerant circuit constituting a unitary refrigeration cycle is used, with the refrigerant circuit having a refrigerating capacity that is the same as that of the air-conditioning system 1 (the refrigerating capacity of ten indoor units each having a rated refrigerating capacity of 2.8 kW) and including refrigerant connection pipes having pipe lengths and pipe diameters that are the same as the pipe lengths and the pipe diameters of the refrigerant connection pipes of the air-conditioning system 1. In this case, when the amount of refrigerant (carbon dioxide) that is sealed in this refrigerant circuit is calculated, the amount of refrigerant is 9.0 kg (refer to the value of the unitary refrigeration cycle A in Fig. 5).

**[0060]** When, based on this amount of refrigerant, the amount of use-side refrigerant (carbon dioxide) that is sealed in the use-side circuit 30 of the air-conditioning system 1 constituting a binary refrigeration cycle is calculated, the calculated amount of use-side refrigerant becomes 6.6 kg, which is smaller by 2.4 kg than the amount of use-side refrigerant in the air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as the refrigerant (refer to the value of the binary refrigeration cycle A in Fig. 5).

**[0061]** Here, the amount of use-side refrigerant (carbon dioxide) that is sealed in the use-side circuit 30 of the air-conditioning system 1 constituting a binary refrigeration cycle can be reduced because the large outdoor heat exchanger at which a refrigerant and outdoor air exchange heat with each other is provided at the heat-source-side circuit 10 not including the plurality of indoor heat exchangers 52, and the small refrigerant-refrigerant heat exchanger 25 is provided at the use-side circuit 30 that uses carbon dioxide as the use-side refrigerant. That is, the difference between the volume of the outdoor heat exchanger that constitutes the air-conditioning system constituting a unitary refrigeration cycle and the volume of the flow path in which the use-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 that constitutes the air-conditioning system 1 constituting a binary refrigeration cycle generally corresponds to the difference between the amounts of refrigerants (= 2.4 kg).

**[0062]** Therefore, in the air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, since the amount of refrigerant (carbon dioxide) that is sealed in the refrigerant circuit is greater than 7.9 kg, the number of safety measures needs to be two or more. On the other hand, in the air-conditioning system 1 constituting a binary refrigeration cycle, since the amount of use-side refrigerant (carbon dioxide) that is sealed in the use-side circuit 30 can be 7.9 kg or less, the number of safety measures can be one.

**[0063]** In addition, in the air-conditioning system 1, as a safety measure, as described above, the warning devices 12 that, when leakage of a use-side refrigerant has occurred, give a warning that the use-side refrigerant has leaked are provided. Here, as the warning devices 12, warning devices are required that are in accordance with specifications in which a warning that a use-side refrigerant has leaked is given by using sound and light. However, since other safety measures (blocking devices or ventilating devices) need not be provided, costs are reduced and construction is facilitated.

**[0064]** In contrast, when the number of safety measures needs to be two or more (when the amount of refrigerant is greater than 7.9 kg), providing only warning devices is not sufficient and thus blocking devices or ventilating devices need to be provided, as a result of which costs are increased and construction becomes troublesome.

(4) Features

**[0065]** Next, the features of the air-conditioning system 1 is described.

<A>

**[0066]** Here, as described above, the air-conditioning system 1 constitutes a binary refrigeration cycle including the heat-source-side circuit 10 and the use-side circuit 30. The heat-source-side circuit 10 includes the heat-source-side compressor 21 that compresses a heat-source-side refrigerant, the outdoor heat exchanger 23 that causes the heat-source-side refrigerant and outdoor air to exchange heat with each other, and the refrigerant-refrigerant heat exchanger 25 that causes the heat-source-side refrigerant and a use-side refrigerant to exchange heat with each other. The use-side circuit 30 includes the use-side compressor 31 that compresses a use-side refrigerant, the refrigerant-refrigerant heat exchanger 25, and the plurality of indoor heat exchangers 52 that cause the use-side refrigerant and indoor air to exchange heat with each other. Carbon dioxide, serving as the use-side refrigerant, is sealed in the use-side circuit 30. Here, as a safety measure that should be taken when leakage of carbon dioxide, serving as the use refrigerant, has occurred, the warning devices 12 or ventilating devices among the warning devices 12, blocking devices, and the ventilating devices are provided.

**[0067]** Here, an air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as a refrigerant includes an outdoor heat exchanger that causes carbon dioxide, serving as a refrigerant in the refrigerant circuit, and outdoor air to exchange heat with other, and the volume of the outdoor heat exchanger in the refrigerant circuit is very large. Moreover, the air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as a refrigerant is, in terms of its physical properties, less efficient compared with those using refrigerants (such as an HFC refrigerant) known in the art. This becomes noticeable particularly in an operation (cooling operation) in which the outdoor heat exchanger functions as a heat dissipater of the refrigerant and the indoor heat exchangers function as evaporators of the refrigerant. Therefore, in the air-conditioning system constituting a unitary refrigeration cycle that uses carbon dioxide as the refrigerant, methods devised for increasing the efficiency are performed, for example, increasing the heat transfer area of the outdoor heat exchanger or providing an intermediate cooler that cools the refrigerant during a compression process or a subcooler that further cools the refrigerant that has dissipated heat at the outdoor heat exchanger. However, such devised methods for increasing the efficiency increase the amount of carbon dioxide, serving as the refrigerant that is sealed in the refrigerant circuit, and thus make it difficult to reduce the number of safety measures.

**[0068]** Therefore, here, as described above, the binary refrigeration cycle including the use-side circuit 30 and the heat-source-side circuit 10 is formed, with the use-side circuit 30 including the plurality of indoor heat exchangers 52 and having carbon dioxide sealed therein, and the heat-source-side circuit 10 being where heat is exchanged with a use-side refrigerant via the refrigerant-refrigerant heat exchanger 25 and having sealed therein a heat-source-side refrigerant. Consequently, here, unlike in a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, the outdoor heat exchanger 23 at which a refrigerant and outdoor air exchange heat with each other is provided at the heat-source-side circuit 10 not including the plurality of indoor heat exchangers 52, and the refrigerant-refrigerant heat exchanger 25 is provided at the use-side circuit 30 that uses carbon dioxide as a use-side refrigerant. Here, the refrigerant-refrigerant heat exchanger 25 is not a large heat exchanger at which a refrigerant and air exchange heat with each other. For the refrigerant-refrigerant heat exchanger 25, a small heat exchanger using two refrigerants (here, the heat-source-side refrigerant and the use-side refrigerant), such as a plate-type heat exchanger or a double-pipe-type heat exchanger, can be used. Here, unlike in a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, in the heat-source-side circuit 10, methods devised for increasing the efficiency, such as using a refrigerant (such as R32 or R1234yf) having physical properties that are capable of increasing the efficiency than carbon dioxide or providing an intermediate cooler or a subcooler, are performed to make it possible to increase the entire efficiency including that of the use-side circuit 30. Therefore, here, compared with a unitary refrigeration cycle that uses carbon dioxide as a refrigerant, it is possible to reduce the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit 30, and to increase the efficiency.

**[0069]** Here, since the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit 30, is reduced, the concentration level of carbon dioxide that may reach an indoor space when the use-side refrigerant has leaked from the use-side circuit 30 is reduced to a concentration level that allows the number of safety measures to be one (a concentration level that satisfies the condition in which the concentration level is greater than 0.074 kg per 1 $m^3$ of indoor space and 0.18 kg or less per 1 $m^3$ of indoor space). Note that, when this concentration level is converted into the amount of carbon dioxide, serving as the use-side refrigerant that is sealed in the use-side circuit 30, the amount of carbon dioxide is greater than 3.3 kg and 7.9 kg or less.

**[0070]** In this way, here, the concentration level is reduced to a concentration level that allows the number of safety measures to be one, and, as described above, the warning devices 12 or ventilating devices among the warning devices 12, blocking devices, and the ventilating devices are provided. That is, here, the number of safety measures is reduced to one, and blocking devices are not provided as a safety measure. Here, since blocking devices are devices that must be provided at the use-side circuit 30 and setting standards, such as blocking performance, need to be satisfied, not providing blocking devices as a safety measure is effective in terms of costs and construction. Here, among the warning devices 12 and ventilating devices, the warning devices 12 are provided. That is, here, as described above, as a safety measure, the warning devices 12 are provided and ventilating devices are not provided. Here, when the ventilating device is provided as a safety measure, since it is necessary to satisfy setting standards, such as the ventilation amount, the number of ventilations, and the position of a ventilation opening, not providing the ventilating device as a safety measure is effective in terms of costs and construction.

**[0071]** In this way, here, in the air-conditioning system 1 including the plurality of indoor heat exchangers 52 that cause carbon dioxide, serving as a refrigerant, and indoor air to exchange heat with each other, it is possible to reduce the number of safety measures by reducing the amount of carbon dioxide, serving as a refrigerant that is sealed in the refrigerant circuit (the use-side circuit 30).

<B>

**[0072]** Here, as described above, even if the rated refrigerating capacity is 28 kW, that is, when the rated refrigerating capacity is 28 kW or less, as a pipe that connects the refrigerant-refrigerant heat exchanger 25 and the indoor heat exchangers 52 in the use-side circuit 30 to each other (the use-side liquid-refrigerant connection pipe 6), there is used a pipe having a nominal diameter that is 2.5/8 inches or less, which is smaller than nominal diameters known in the art, and, as a pipe that connects the use-side compressor 31 and the indoor heat exchangers 52 in the use-side circuit 30 to each other (the use-side gas-refrigerant connection pipe 7), there is used a pipe having a nominal diameter that is 5/8 inches or less, which is smaller than nominal diameters known in the art.

**[0073]** Therefore, it is possible to reduce the amount of use-side refrigerant that is sealed in the use-side circuit 30.

**[0074]** Here, as described above, as the use-side liquid-refrigerant connection pipe 6, there is used a pipe having a nominal diameter of 1.5/8 inches when the rated refrigerating capacity is in the range of 2.2 kW to 8.0 kW, and having a nominal diameter of 2.5/8 inches when the rated refrigerating capacity is in the range of 22.4 kW to 28.0 kW; and, as the use-side gas-refrigerant connection pipe 7, there is used a pipe having a nominal diameter of 2.5/8 when the rated refrigerating capacity is in the range of 2.2 kW to 4.5 kW. In this way, here, since pipes having nominal diameters in increments of 0.5/8 inches that are not used as refrigerant pipes known in the art are used, it is possible to increase the size of pipes that can be used as refrigerant pipes and to contribute to optimizing the refrigerant pipes.

(5) Modifications

<Modification 1>

**[0075]** In the embodiment above, as the indoor heat exchangers 52, the fin-and-tube-type heat exchangers including the plurality of heat transfer tubes 54, which are constituted by circular tubes, are used (see Fig. 2), and the amount of use-side refrigerant (carbon dioxide) that is sealed in the use-side circuit 30 is 6.6 kg (refer to the value of the binary refrigeration cycle A in Fig. 5).

**[0076]** In contrast, here, as the indoor heat exchangers 52, instead of the heat exchangers including the plurality of heat transfer tubes 54, which are constituted by circular tubes, micro-channel heat exchangers including a plurality of heat transfer tubes 56, which are constituted by flat porous tubes, are used as shown in Fig. 6. Note that, here, although, as the micro-channel heat exchangers, as in Fig. 2, fin-and-tube-type heat exchangers including the plurality of heat transfer tubes 56 and a plurality of heat transfer fins 57 are used, the micro-channel heat exchangers are not limited thereto.

**[0077]** Therefore, here, it is possible to reduce the volumes of the indoor heat exchangers 52, and the amount of use-side refrigerant that is sealed in the use-side circuit 30 becomes 6.1 kg, which is smaller by 0.5 kg than the amount of use-side refrigerant when the fin-and-tube-type heat exchangers including the plurality of heat transfer tubes 54, which are constituted by circular tubes, is used (refer to the value of a binary refrigeration cycle B in Fig. 7).

**[0078]** In this way, here, since the indoor heat exchangers 52 are constituted by the micro-channel heat exchangers, it is possible to reduce the volume of the indoor heat exchangers 52 and, thus, to further reduce the amount of use-side refrigerant that is sealed in the use-side circuit 30.

**[0079]** Note that, in an air-conditioning system constituting a unitary refrigeration cycle, when micro-channel heat exchangers are used as the indoor heat exchangers, similarly to the relationship between the binary refrigeration cycle A and the binary refrigeration cycle B, the amount of refrigerant becomes 8.5 kg (refer to the value in a unitary refrigeration cycle B in Fig. 7), which is smaller by 0.5 kg than the amount of refrigerant in the unitary refrigeration cycle A (= 9.0 kg, refer to Fig. 5). However, even in this case, since the amount of refrigerant does not become 7.9 kg or less, as long as an air-conditioning system constituting a unitary refrigeration cycle is used, the number of safety measures cannot be one.

<Modification 2>

**[0080]** In the embodiment and Modification 1 above, the use-side compressor 31 and the refrigerant-refrigerant heat exchanger 25 in the use-side circuit 30 are provided together with the heat-source-side circuit 10 at the heat transfer unit 2 (see Fig. 1). In Modification 1 (when the indoor heat exchangers 52 are constituted by micro-channel heat exchangers), the amount of use-side refrigerant (carbon dioxide) that is sealed in the use-side circuit 30 is 6.1 kg (refer to the value of the binary refrigeration cycle B in Fig. 7).

**[0081]** In contrast, here, as shown in Fig. 8, the heat transfer unit 2 is divided into an outdoor unit 3 and an intermediate unit 4, and the units 3 and 4 are connected to each other via heat-source-side refrigerant connection pipes 8 and 9.

**[0082]** The outdoor unit 3 is disposed outdoors. As shown in Fig. 8, portions of the heat-source-side circuit 10 excluding the refrigerant-refrigerant heat exchanger 25 (the heat-source-side compressor 21, the heat-source-side flow-path switching device 22, the outdoor heat exchanger 23, and the heat-source-side decompressor 24) are provided at the outdoor unit 3.

**[0083]** As shown in Fig. 9, the intermediate unit 4 is disposed at a location that is close to a branched portion that branches into each indoor unit 5. As shown in Fig. 8, the use-side compressor 31, the use-side flow-path switching device 32, the refrigerant-refrigerant heat exchanger 25, and the use-side decompressor 33 in the use-side circuit 30 are provided at the intermediate unit 4.

**[0084]** The heat-source-side liquid-refrigerant connection pipe 8 is a part of a pipe that connects the outdoor heat exchanger 23 and the refrigerant-refrigerant heat exchanger 25 to each other. Specifically, the heat-source-side liquid-refrigerant connection pipe 6 is a pipe that connects the heat-source-side decompressor 24 and the liquid side of the flow path in which a heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25. The heat-source-side gas-refrigerant connection pipe 9 is a part of a pipe that connects the heat-source-side compressor 21 and the refrigerant-refrigerant heat exchanger 25 to each other. Specifically, the heat-source-side gas-refrigerant connection pipe 9 is a pipe that connects the heat-source-side flow-path switching device 22 and the gas side of the flow path in which a heat-source-side refrigerant flows in the refrigerant-refrigerant heat exchanger 25 to each other.

**[0085]** In this way, here, the outdoor heat exchanger 23 is provided at the outdoor unit 3, the refrigerant-refrigerant heat exchanger 25 is provided at the intermediate unit 4 that is connected to the outdoor unit 3 via the heat-source-side refrigerant connection pipes 8 and 9 in which a heat-source-side refrigerant flows, and the indoor heat exchangers 52 are provided at the indoor units 5 corresponding thereto that are connected to the intermediate unit 4 via the use-side refrigerant connection pipes 6 and 7 in which a use-side refrigerant flows.

**[0086]** Therefore, here, it is possible to provide the intermediate unit 4 at which the refrigerant-refrigerant heat exchanger 25 is provided at a location that is close to the branched portion that branches into each indoor unit 5, and, for example, it is possible to reduce to 10 m the lengths of the use-side refrigerant connection main pipe 61 and the use-side refrigerant connection main pipe71 of a corresponding one of the use-side refrigerant connection pipe 6 and the use-side refrigerant connection pipe 7 extending toward the indoor units 5 from the intermediate unit 4. Therefore, the amount of use-side refrigerant that is sealed in the use-side circuit 30 becomes 5.0 kg (refer to the value in a binary refrigeration cycle C in Fig. 10), which is smaller by 1.1 kg than the amount of use-side refrigerant when the refrigerant-refrigerant heat exchanger 25 is provided at the outdoor heat transfer unit 2 (when the lengths of the use-side refrigerant connection main pipes 61 and 71 are 50 m).

**[0087]** In this way, here, since the refrigerant-refrigerant heat exchanger 25 is provided at the intermediate unit 4 that is provided separately from the outdoor unit 3, it is possible to provide the refrigerant-refrigerant heat exchanger 25 at a location that is close to the indoor units 5, and, thus, it is possible to further reduce the amount of use-side refrigerant that is sealed in the use-side circuit 30.

<C>

**[0088]** Although, in the embodiment and the modifications above, the binary refrigeration cycle including one heat-source-side circuit is used, the cycle is not limited thereto. A multiple refrigeration cycle including a plurality of heat-source-side circuits may be used.

<D>

**[0089]** Although, in the embodiment and the modifications above, a configuration that is capable of performing a cooling operation and a heating operation is taken as an example in the description, the configuration is not limited thereto and may be a configuration used exclusively for a cooling operation.

**[0090]** Although the embodiment of the present disclosure is described above, it is to be understood that various changes can be made in the forms and details without departing from the spirit and the scope of the present disclosure described in the claims.

Industrial Applicability

**[0091]** The present disclosure is widely applicable to an air-conditioning system including a plurality of indoor heat exchangers that cause carbon dioxide, serving as a refrigerant, and indoor air to exchange heat with each other.

Reference Signs List

**[0092]**

1 air-conditioning system
3 outdoor unit
4 intermediate unit
5 indoor unit
6 use-side liquid-refrigerant connection pipe
7 use-side gas-refrigerant connection pipe
8 heat-source-side liquid-refrigerant connection pipe
9 heat-source-side gas-refrigerant connection pipe
10 heat-source-side circuit
12 warning device
21 heat-source-side compressor
23 outdoor heat exchanger
25 refrigerant-refrigerant heat exchanger
30 use-side circuit
31 use-side compressor
56 flat porous tube

Citation List

Patent Literature

**[0093]** Patent Literature 1
International Publication No. 2011/099063

## Claims

1. An air-conditioning system (1) that constitutes a multiple refrigeration system, the multiple refrigeration system comprising:

   a heat-source-side circuit (10) including a heat-source-side compressor (21) that compresses a heat-source-side refrigerant, an outdoor heat exchanger (23) that causes the heat-source-side refrigerant and outdoor air to exchange heat with each other, and a refrigerant-refrigerant heat exchanger (25) that causes the heat-source-side refrigerant and a use-side refrigerant to exchange heat with each other; and
   a use-side circuit (30) including a use-side compressor (31) that compresses the use-side refrigerant, the refrigerant-refrigerant heat exchanger, and a plurality of indoor heat exchangers (52) that cause the use-side refrigerant and indoor air to exchange heat with each other, the use-side circuit (30) having sealed therein carbon dioxide as the use-side refrigerant,
   wherein an amount of the use-side refrigerant that is sealed in the use-side circuit is 7.9 kg or less.

2. The air-conditioning system according to Claim 1, wherein, among a warning device (12) that, when

the use-side refrigerant has leaked, gives a warning that the use-side refrigerant has leaked, a blocking device that, when the use-side refrigerant has leaked, blocks a circulation of the use-side refrigerant, and a ventilating device that, when the use-side refrigerant has leaked, ventilates a space that is air-conditioned by the indoor air that has exchanged heat at the indoor heat exchanger, one of the warning device and the ventilating device is provided.

**3.** The air-conditioning system according to Claim 2, wherein, of the warning device and the ventilating device, the warning device is provided.

**4.** The air-conditioning system according to any one of Claims 1 to 3,
wherein the indoor heat exchangers are micro-channel heat exchangers that use a flat porous tube (56) as a heat transfer tube in which the use-side refrigerant flows.

**5.** The air-conditioning system according to any one of Claims 1 to 4,
wherein when a rated refrigerating capacity of the air-conditioning system is 28 kW or less, as a pipe that connects the refrigerant-refrigerant heat exchanger and the indoor heat exchangers in the use-side circuit to each other, a pipe having a nominal diameter that is 2.5/8 inches or less is used, and, as a pipe that connects the use-side compressor and the indoor heat exchangers in the use-side circuit to each other, a pipe having a nominal diameter that is 5/8 inches or less is used.

**6.** The air-conditioning system according to any one of Claims 1 to 5,
wherein the outdoor heat exchanger is provided at an outdoor unit (3),
wherein the refrigerant-refrigerant heat exchanger is provided at an intermediate unit (4) that is connected to the outdoor unit via a heat-source-side refrigerant connection pipe (8, 9) in which the heat-source-side refrigerant flows, and
wherein the indoor heat exchangers are provided at an indoor unit (5) that is connected to the intermediate unit via a use-side refrigerant connection pipe (6, 7) in which the use-side refrigerant flows.

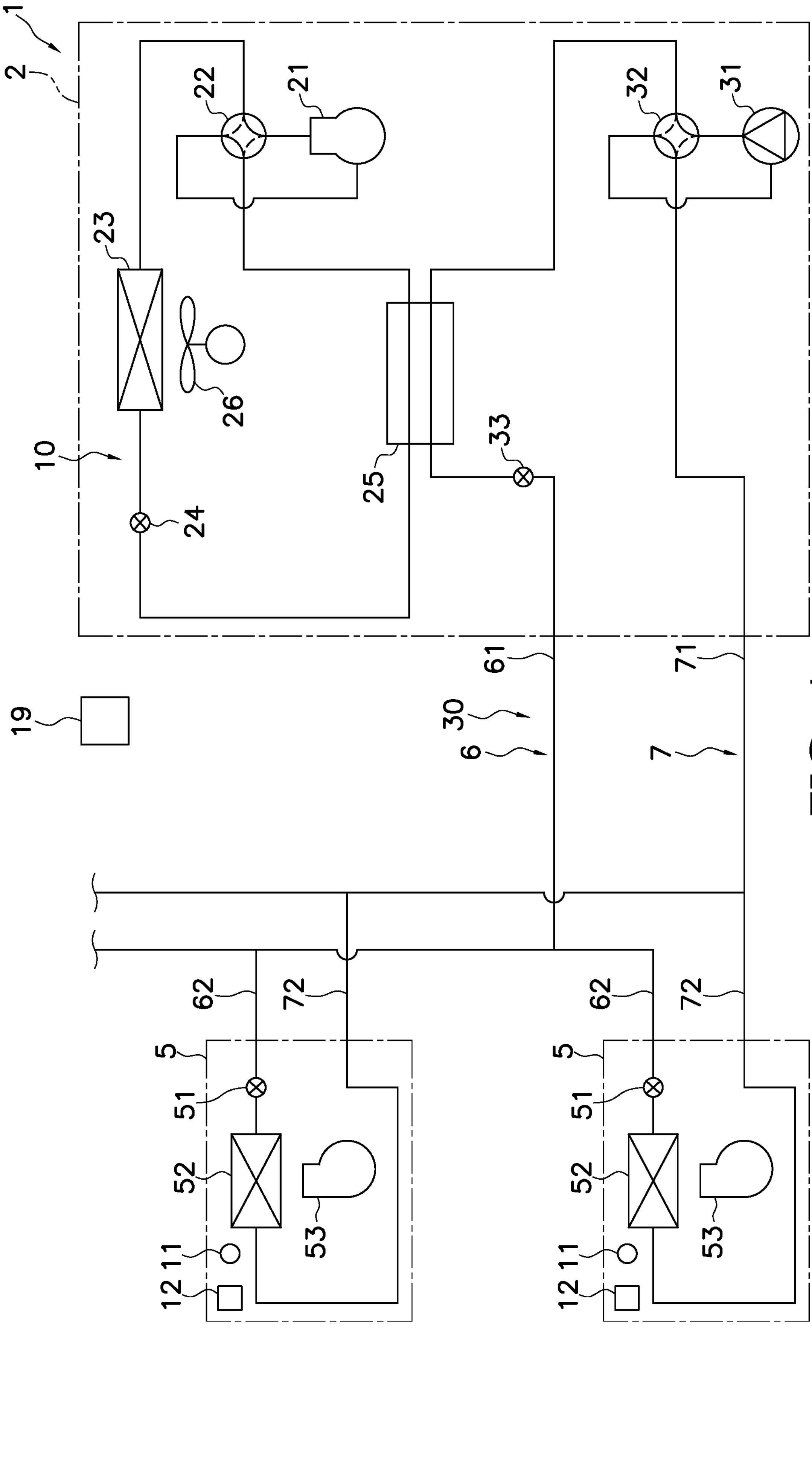



FIG. 1

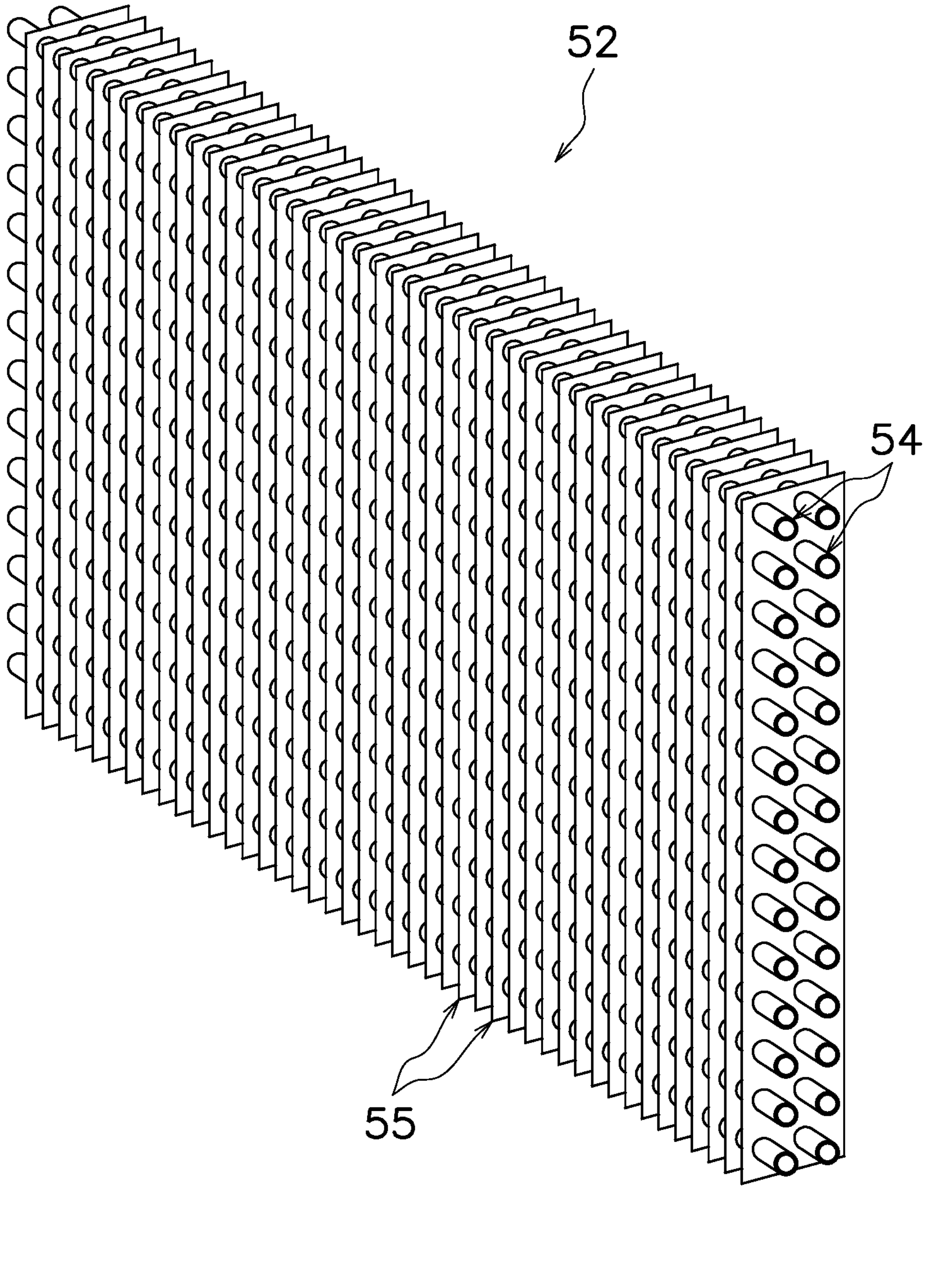
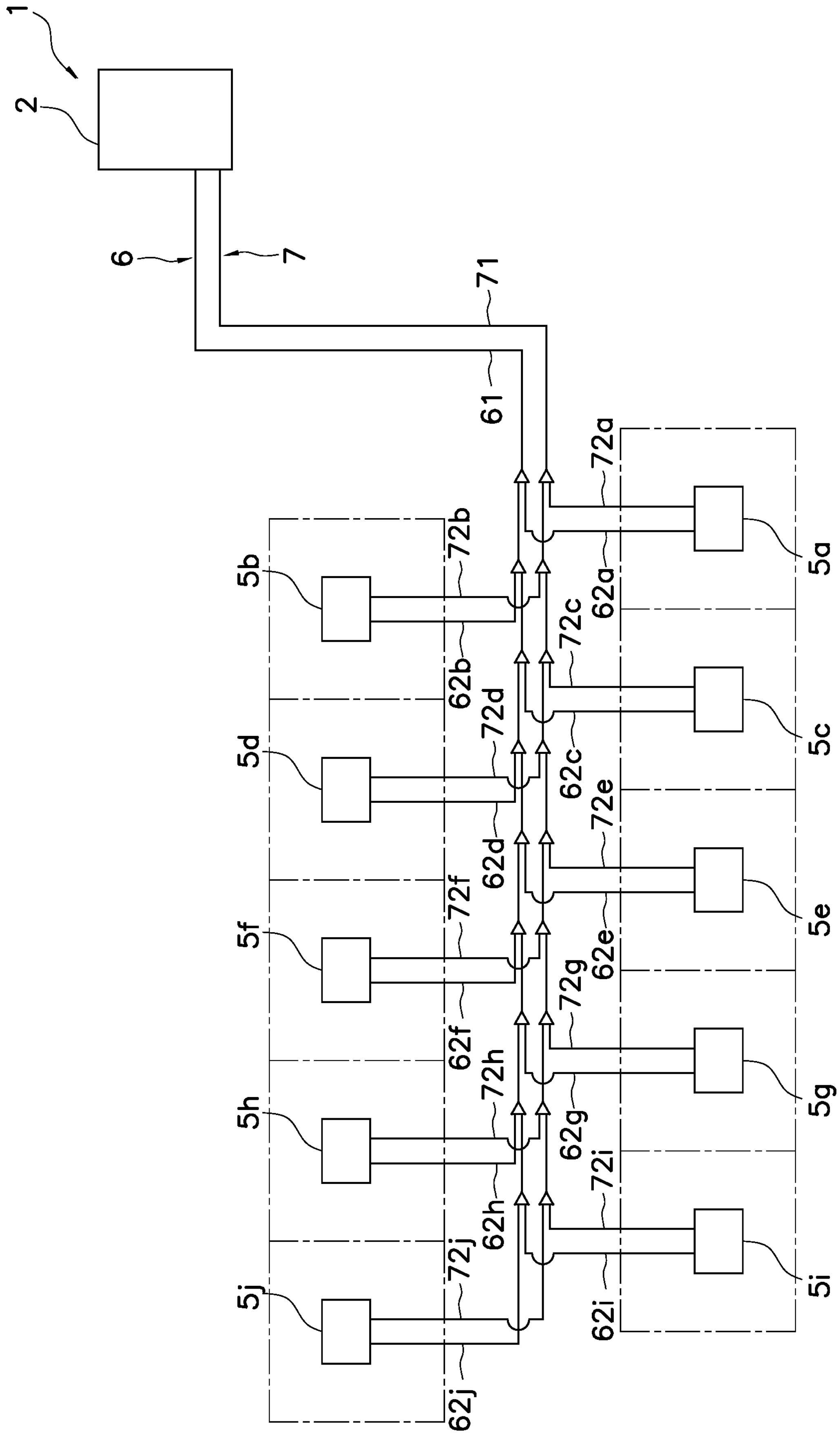



FIG. 2


1
2
6
7
71
61
72a
5a
62a
72b
5b
62b
72c
5c
62c
72d
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72e
5e
62e
72f
5f
62f
72g
5g
62g
72h
5h
62h
72i
5i
62i
72j
5j
62j

FIG. 3

| RATED REFRIGERATING CAPACITY [kW] | REFRIGERANT CONNECTION PIPE (CARBON DIOXIDE) NOMINAL DIAMETER [INCHES] | |
|---|---|---|
| | GAS | LIQUID |
| 2.2 | 2.5/8 | 1.5/8 |
| 2.8 | 2.5/8 | 1.5/8 |
| 3.6 | 2.5/8 | 1.5/8 |
| 4.5 | 2.5/8 | 1.5/8 |
| 5.6 | 3/8 | 1.5/8 |
| 7.1 | 3/8 | 1.5/8 |
| 8.0 | 3/8 | 1.5/8 |
| 9.0 | 1/2 | 1/4 |
| 11.2 | 1/2 | 1/4 |
| 14.0 | 1/2 | 1/4 |
| 16.0 | 1/2 | 1/4 |
| 22.4 | 5/8 | 2.5/8 |
| 28.0 | 5/8 | 2.5/8 |

FIG. 4

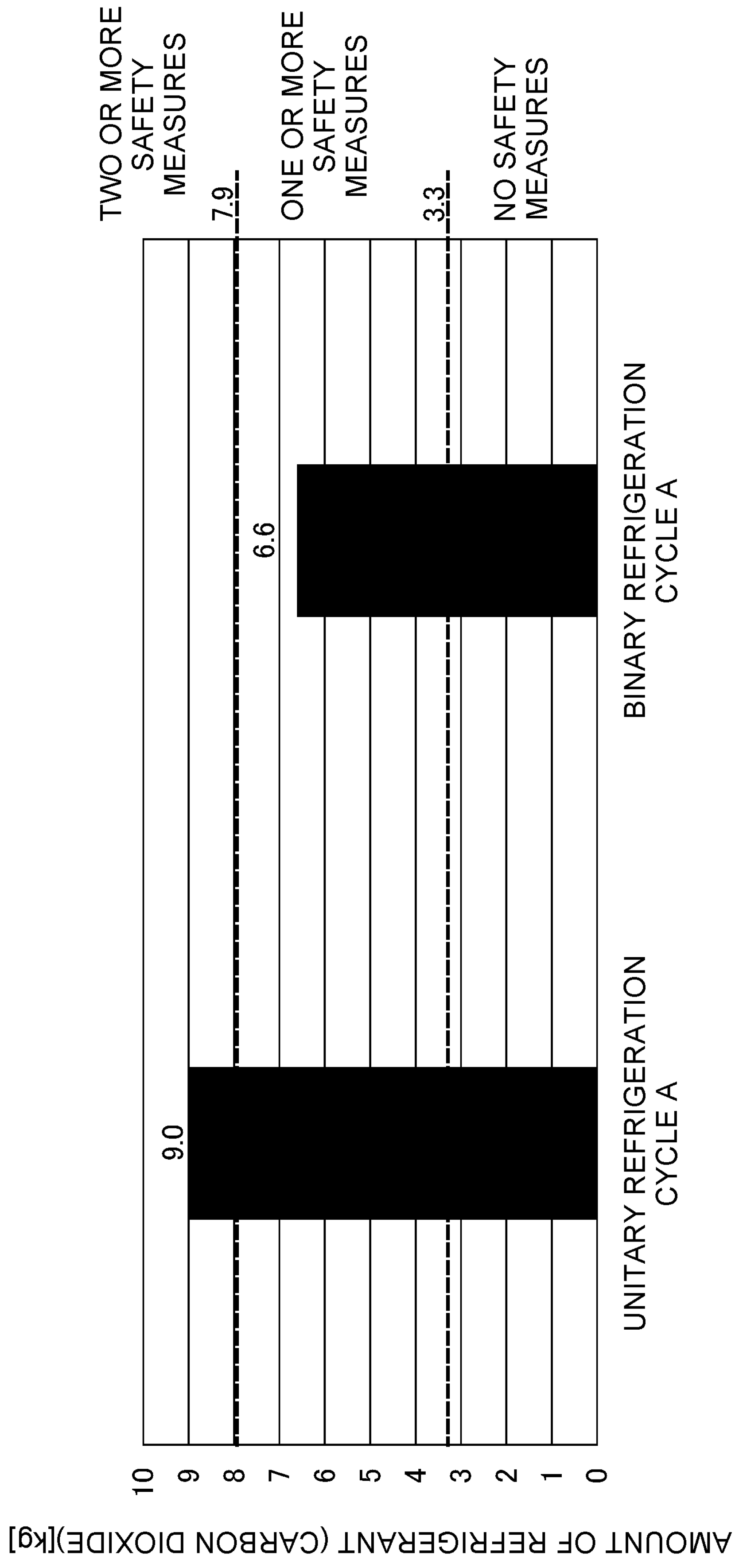

TWO OR MORE SAFETY MEASURES
7.9
ONE OR MORE SAFETY MEASURES
3.3
NO SAFETY MEASURES
9.0
6.6
UNITARY REFRIGERATION CYCLE A
BINARY REFRIGERATION CYCLE A
AMOUNT OF REFRIGERANT (CARBON DIOXIDE)[kg]
10
9
8
7
6
5
4
3
2
1
0

FIG. 5

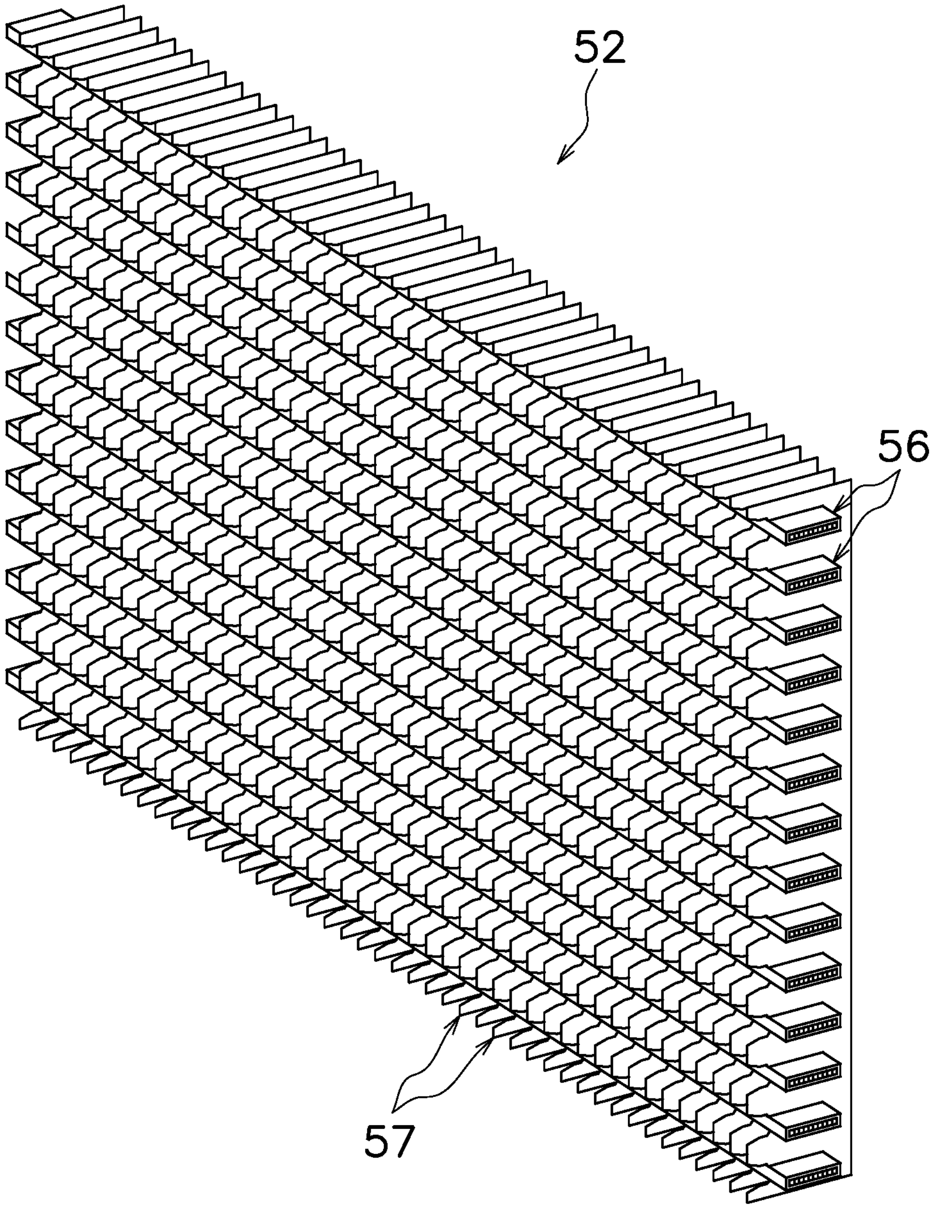



FIG. 6

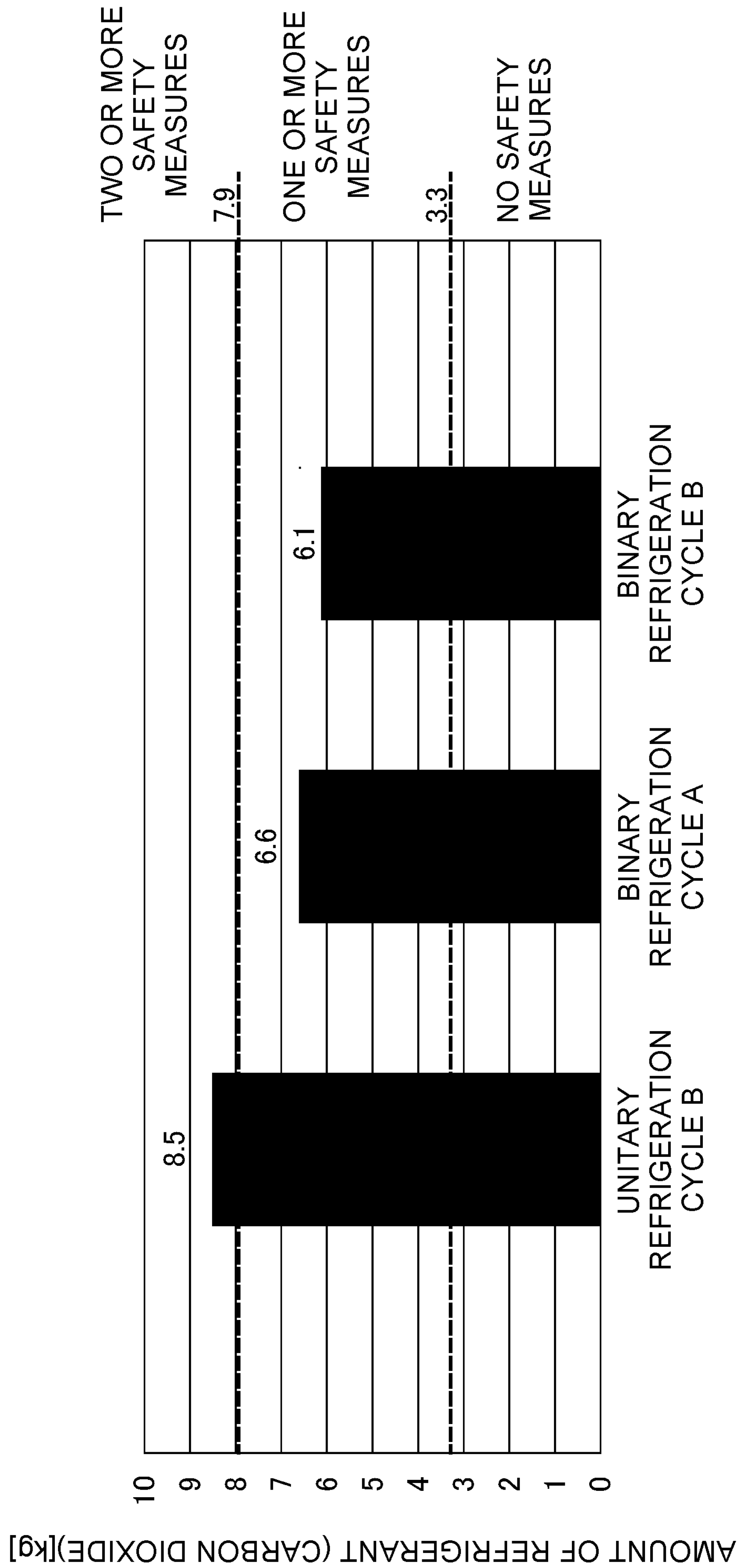
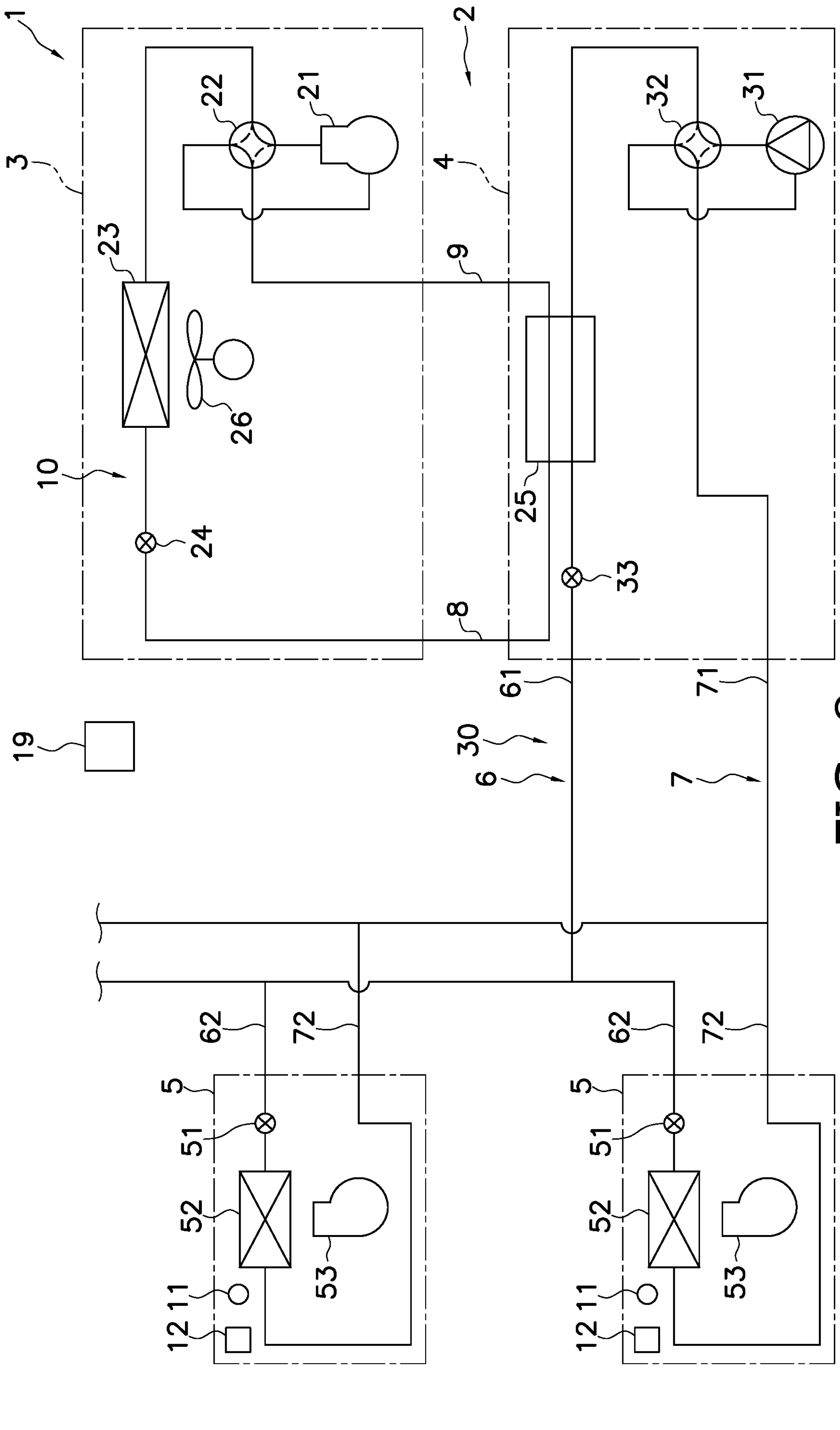

TWO OR MORE SAFETY MEASURES
7.9
ONE OR MORE SAFETY MEASURES
3.3
NO SAFETY MEASURES
8.5
6.6
6.1
UNITARY REFRIGERATION CYCLE B
BINARY REFRIGERATION CYCLE A
BINARY REFRIGERATION CYCLE B
10
9
8
7
6
5
4
3
2
1
0
AMOUNT OF REFRIGERANT (CARBON DIOXIDE)[kg]

FIG. 7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22
21
32
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23
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26
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25
24
33
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61
71
19
30
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62
72
62
72
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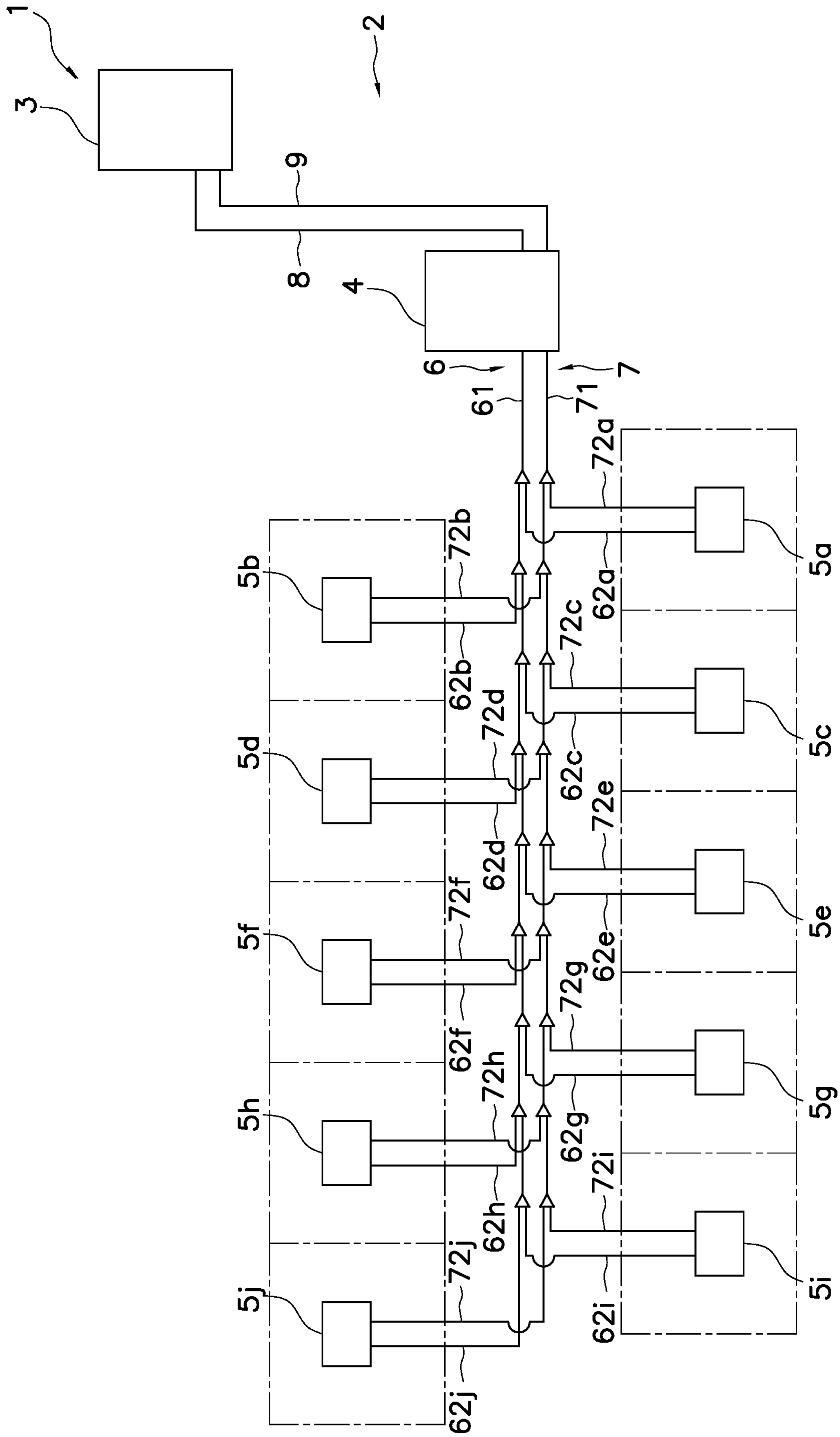
51
51
52
52
53
53
12
11
12
11

FIG. 8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3
4
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8
9
61
71
5a
5b
5c
5d
5e
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5j
62a
62b
62c
62d
62e
62f
62g
62h
62i
62j
72a
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72c
72d
72e
72f
72g
72h
72i
72j

FIG. 9

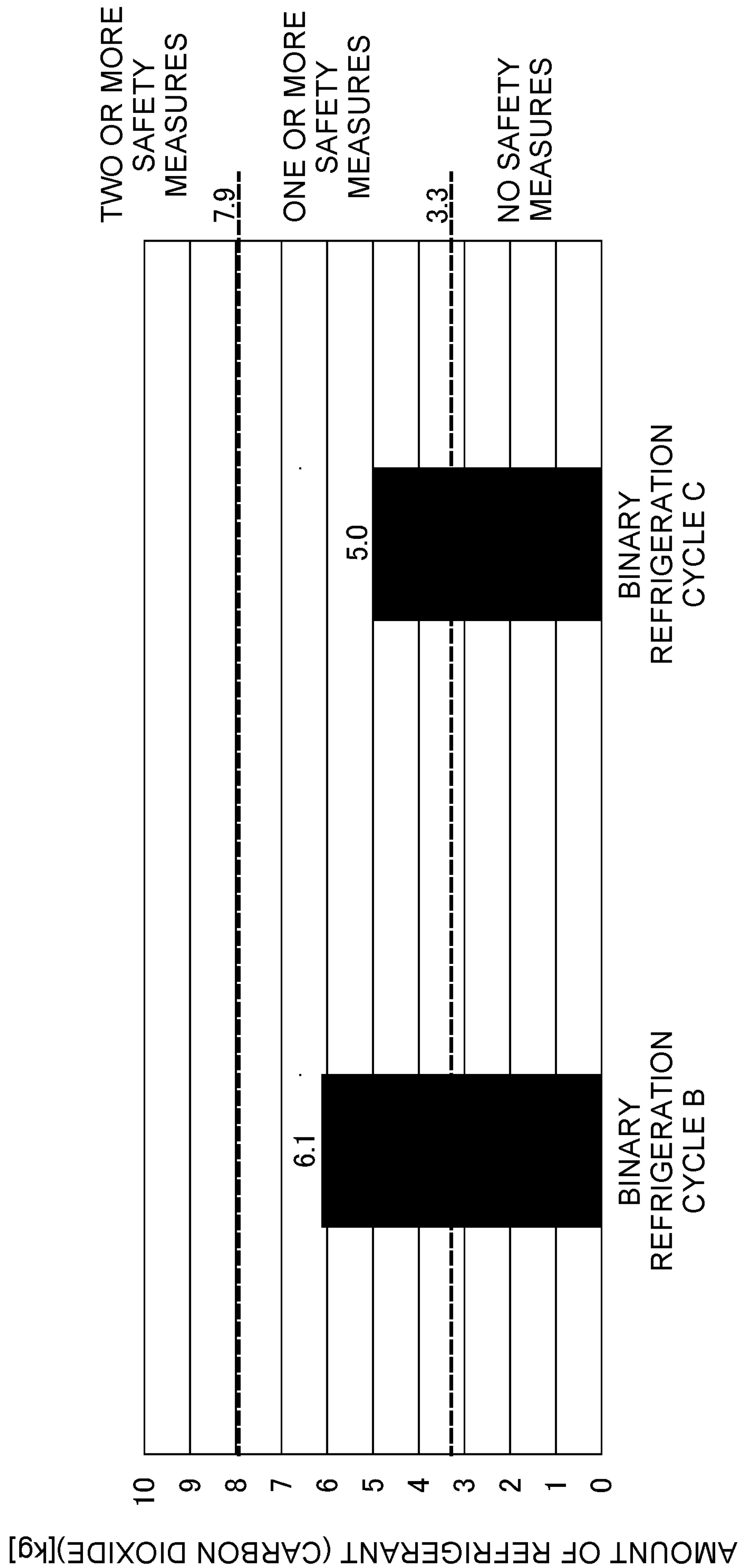
TWO OR MORE SAFETY MEASURES
ONE OR MORE SAFETY MEASURES
NO SAFETY MEASURES
7.9
3.3
6.1
5.0
10
9
8
7
6
5
4
3
2
1
0
AMOUNT OF REFRIGERANT (CARBON DIOXIDE)[kg]
BINARY REFRIGERATION CYCLE B
BINARY REFRIGERATION CYCLE C

FIG. 10

## INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/023941

**A. CLASSIFICATION OF SUBJECT MATTER**

Int. Cl. F24F11/36(2018.01)i, F24F1/0067(2019.01)i, F24F1/0068(2019.01)i, F24F11/89(2018.01)i, F25B1/00(2006.01)i, F25B7/00(2006.01)i, 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)

Int. Cl. F24F11/36, F24F1/0067, F24F1/0068, F24F11/89, F25B1/00, F25B7/00, F25B49/02

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

| | |
|---|---|
| Published examined utility model applications of Japan | 1922-1996 |
| Published unexamined utility model applications of Japan | 1971-2019 |
| Registered utility model specifications of Japan | 1996-2019 |
| Published registered utility model applications of Japan | 1994-2019 |

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 2014-20673 A (MITSUBISHI ELECTRIC CORP.) 03 February 2014, paragraphs [0013]-[0029], fig. 1-5 (Family: none) | 1-6 |
| Y | JP 2009-139012 A (MITSUBISHI ELECTRIC CORP.) 25 June 2009, paragraphs [0008]-[0019], fig. 1-3 (Family: none) | 1-6 |
| Y | JP 2011-106697 A (MITSUBISHI ELECTRIC CORP.) 02 June 2011, paragraphs [0010]-[0023], fig. 1-8 (Family: none) | 2-6 |
| Y | JP 2013-164246 A (MITSUBISHI ELECTRIC CORP.) 22 August 2013, paragraphs [0011]-[0039], fig. 1-4 (Family: none) | 4-6 |

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

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- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "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
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 26.07.2019 | 06.08.2019 |

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

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

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2019/023941

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | WO 2016/203507 A1 (MITSUBISHI ELECTRIC CORP.) 22 December 2016, paragraphs [0010]-[0032], fig. 1, 2 (Family: none) | 6 |

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2011099063 A **[0002]**
- WO 2011099063 A **[0093]**