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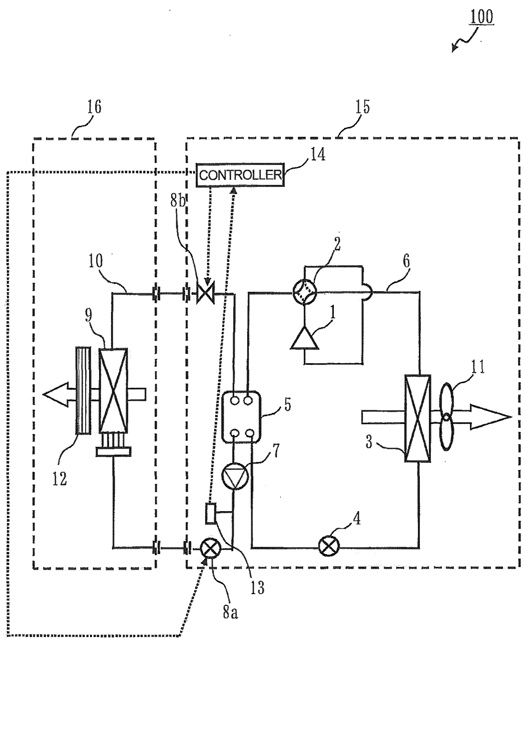
(54) HEAT PUMP DEVICE AND METHOD FOR CONTROLLING HEAT PUMP DEVICE

(57) In a heat pump apparatus of an indirect type including a primary circuit on a heat source side and a secondary circuit on a load side, a refrigerant in the primary circuit is prevented from leaking through the secondary circuit.

An air-conditioning apparatus 100 includes a leakage detecting device 13 that detects leakage of the refrigerant circulated through a refrigerant circuit, serving as the primary circuit, from an intermediate heat exchanger 5 into a water circuit 10, serving as the secondary circuit, and a controller 14 that closes valves 8a and 8b arranged on both sides of the intermediate heat exchanger 5 in the water circuit 10 to prevent water containing the refrigerant from flowing beyond the valves 8a and 8b when the leakage detecting device 13 detects the leakage.

F I G. 1



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Description

Technical Field

[0001] The present invention relates to a technique for securing safety when a refrigerant leaks from a heat pump apparatus.

Background Art

[0002] An air-conditioning apparatus (an example of a heat pump apparatus) has been known which utilizes a refrigeration cycle technique using a refrigerant as a way of cooling, heating, or dehumidifying a room.

[0003] Fluorine compounds, such as R410A that is hydrofluorocarbon (HFC), are widely used as refrigerants in air-conditioning apparatuses. These refrigerants, however, have a considerable impact on global warming. In terms of prevention of global warming, therefore, it is desirable to use refrigerants having a less impact on global warming. Accordingly, the use of refrigerants having a less impact on global warming, such as R32 that is HFC, R1234yf that is hydrofluoro-olefin (HFO), propane and isobutene that are hydrocarbons, has been proposed. Disadvantageously, all of these refrigerants are flammable, unlike the conventional refrigerants.

[0004] In an air-conditioning apparatus using a flammable refrigerant, the refrigerant may leak from a heat exchanger, a pipe, or the like included in a refrigeration cycle and an explosive atmosphere may accordingly be produced in a room. This may lead to an accident, such as fire.

[0005] Patent Literature 1 discloses an air-conditioning apparatus that addresses the above-described problem. This air-conditioning apparatus is of an indirect type including a primary circuit through which a flammable refrigerant is circulated and a secondary circuit through which a nonflammable heat medium is circulated. In the indirect air-conditioning apparatus, the heat medium circulated through the secondary circuit is heated or cooled by the flammable refrigerant circulated through the primary circuit, the flammable refrigerant circulated through the primary circuit is not permitted to flow to a room, and only the heat medium circulated through the secondary circuit is permitted to flow to the room. The indirect air-conditioning apparatus prevents the flammable refrigerant from flowing to the room, thus preventing the room from being in an explosive atmosphere.

Citation List

Patent Literature

[0006] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2009-150620

Summary of Invention

Technical Problem

[0007] In a typical indirect air-conditioning apparatus, a plate heat exchanger or a double pipe heat exchanger is used as an intermediate heat exchanger that exchanges heat between the flammable refrigerant circulated through the primary circuit and the heat medium circulated through the secondary circuit. In this case, the intermediate heat exchanger may be damaged due to freezing or deterioration over time. Unfortunately, a passage in the primary circuit may communicate with a passage in the secondary circuit, thus allowing the flammable refrigerant circulated through the primary circuit to mix with the heat medium circulated through the secondary circuit.

[0008] Additionally, mixing of the flammable refrigerant and the heat medium may cause a pressure in the secondary circuit to increase. Disadvantageously, the heat medium containing the flammable refrigerant may leak into a room from a welded seam or joint of pipes included in the secondary circuit.

[0009] A primary object of the present invention is to prevent a refrigerant in a primary circuit from leaking through a secondary circuit in a heat pump apparatus that uses an indirect system including the primary circuit on a heat source side and the secondary circuit on a load side.

Solution to Problem

[0010] The present invention provides a heat pump apparatus including a first refrigerant circuit through which a refrigerant is circulated and that includes a first compressor, a first heat source heat exchanger, a first expansion mechanism, and a first intermediate heat exchanger sequentially connected in loop by pipes, a fluid circuit through which a fluid is circulated and that includes the first intermediate heat exchanger, a first valve, a load heat exchanger, and a second valve sequentially connected in loop by pipes, a leakage detecting device that detects leakage of the refrigerant, circulated through the first refrigerant circuit, from the first intermediate heat exchanger into the fluid circuit, and a controller that closes the first valve and the second valve included in the fluid circuit when the leakage detecting device detects the leakage of the refrigerant.

Advantageous Effects of Invention

[0011] The heat pump apparatus according to the present invention closes the first valve and the second valve when the refrigerant leaks from the first refrigerant circuit, serving as a primary circuit, into the fluid circuit, serving as a secondary circuit, thus preventing the refrigerant circulated through the primary circuit from flowing beyond the first valve and the second valve in the secondary circuit. Advantageously, the refrigerant circulated through the primary circuit can be prevented from leaking beyond the first valve and the second valve in the secondary circuit to the outside. Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a diagram illustrating the configuration of an air-conditioning apparatus 100 according to Embodiment 1.

[Fig. 2] Fig. 2 is a diagram illustrating the flow of a refrigerant and the flow of water during a cooling operation in the air-conditioning apparatus 100 according to Embodiment 1.

[Fig. 3] Fig. 3 is a diagram illustrating the flow of the refrigerant and the flow of the water during a heating operation in the air-conditioning apparatus 100 according to Embodiment 1.

[Fig. 4] Fig. 4 is a flowchart illustrating an operation of a leakage detecting device 13 and that of a controller 14 in Embodiment 1.

[Fig. 5] Fig. 5 is a diagram illustrating the configuration of an air-conditioning apparatus 100 according to Embodiment 2.

[Fig. 6] Fig. 6 is a diagram illustrating the flow of the refrigerant and the flow of the water during the cooling operation in the air-conditioning apparatus 100 according to Embodiment 2.

[Fig. 7] Fig. 7 is a diagram illustrating the flow of the refrigerant and the flow of the water during the heating operation in the air-conditioning apparatus 100 according to Embodiment 2.

[Fig. 8] Fig. 8 is an exploded perspective view of a typical plate heat exchanger.

[Fig. 9] Fig. 9 is a diagram illustrating arrangement of intermediate heat exchangers 5a and 5b according to Embodiment 3.

[Fig. 10] Fig. 10 is a diagram illustrating arrangement of the intermediate heat exchangers 5a and 5b according to Embodiment 3.

[Fig. 11] Fig. 11 is a diagram illustrating arrangement of the intermediate heat exchangers 5a and 5b according to Embodiment 3.

Description of Embodiments

Embodiment 1

[0013] Fig. 1 is a diagram illustrating the configuration of an air-conditioning apparatus 100 according to Embodiment 1. In Fig. 1, each blanked arrow indicates the flow of air and each dotted arrow indicates the flow of a signal.

[0014] The air-conditioning apparatus 100 includes a refrigerant circuit 6 (first refrigerant circuit or primary circuit) that includes a compressor 1 (first compressor), a four-way valve 2, a heat exchanger 3 (first heat exchanger), an expansion valve 4 (first expansion mechanism), an intermediate heat exchanger 5 (first intermediate heat exchanger) sequentially connected in loop by pipes. The air-conditioning apparatus 100 further includes a water circuit 10 (fluid circuit or secondary circuit) that includes the intermediate heat exchanger 5, a pump 7, a valve 8a (first valve), a heat exchanger 9 (load heat exchanger), and a valve 8b (second valve) sequentially connected in loop by pipes. A flammable refrigerant, such as a propane or isobutane, having a lower liquid density (liquid head) than water is circulated through the refrigerant circuit 6 and water is circulated through the water circuit 10. A fan 11 that delivers airflow to the heat exchanger 3 is disposed near the heat exchanger 3. A fan 12 that delivers airflow to the heat exchanger 9 is disposed near the heat exchanger 9.

[0015] The air-conditioning apparatus 100 further includes a leakage detecting device 13 that detects leakage of the refrigerant, circulated through the refrigerant circuit 6, from the intermediate heat exchanger 5 into the water circuit 10 and a controller 14 that closes the valves 8a and 8b when the leakage detecting device 13 detects the leakage of the refrigerant.

[0016] The compressor 1, the four-way valve 2, the heat exchanger 3, the expansion valve 4, the intermediate heat exchanger 5, the pump 7, the valves 8a and 8b, the fan 11, the leakage detecting device 13, and the controller 14 of the components included in the air-conditioning apparatus 100 are accommodated in an outdoor unit 15 (first casing) installed outside a room. The heat exchanger 9 and the fan 12 of the components included in the air-conditioning apparatus 100 are accommodated in an indoor unit 16 (second casing) installed inside the room.

[0017] The intermediate heat exchanger 5 is a plate heat exchanger or double pipe heat exchanger that has high efficiency of heat exchange. The pump 7 is a pump having a variable rotation speed. The valve 8a is a valve that includes a variable expansion mechanism capable of controlling an opening degree. The valve 8b is a valve that performs a simple opening and closing operation. The leakage detecting device 13 detects a pressure in the water circuit 10 using a pressure sensor to detect leakage of the refrigerant. The leakage detecting device 13 detects, in particular, a pressure at a point between the pump 7 and the valve 8a to detect the leakage of the refrigerant. The controller 14 is a microcomputer.

[0018] An operation of the air-conditioning apparatus 100 according to Embodiment 1 during a cooling operation will be described.

[0019] Fig. 2 is a diagram illustrating the flow of the refrigerant and that of the water during the cooling operation in the air-conditioning apparatus 100 according to Embodiment 1. In Fig. 2, solid line arrows indicate the flow of the refrigerant and broken line arrows indicate the flow of the water.

[0020] During the cooling operation, the four-way valve 2 is set so as to provide passages indicated by solid lines illustrated in Fig. 1. An opening degree of the valve 8a is set in such a manner that the water flows at a constant rate. The valve 8b is opened. Controlling the flow rate of the water flowing through the valve 8a controls the amount of heat exchange in the heat exchanger 9.

[0021] In the refrigerant circuit 6, a high-temperature high-pressure refrigerant, obtained by the compressor 1, passes through the four-way valve 2 and flows into the heat exchanger 3. The refrigerant, which has flowed into the heat exchanger 3, exchanges heat with outdoor air, so that the refrigerant condenses into a liquid refrigerant. The liquid refrigerant passes through the expansion valve 4 where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the intermediate heat exchanger 5 and exchanges heat with the water circulated through the water circuit 10, so that the refrigerant evaporates into a gas refrigerant. At this time, the water circulated through the water circuit 10 is cooled. The gas refrigerant passes through the four-way valve 2 and is sucked into the compressor 1, where the refrigerant is compressed into a high-temperature high-pressure state.

[0022] On the other hand, in the water circuit 10, low temperature water, obtained by cooling through the intermediate heat exchanger 5, passes through the pump 7 and the valve 8a in sequence and then flows into the heat exchanger 9. The water, which has flowed into the heat exchanger 9, exchanges heat with indoor air, so that the water is heated. At this time, the indoor air is cooled. The heated water passes through the valve 8b and then flows into the intermediate heat exchanger 5.

[0023] An operation of the air-conditioning apparatus 100 according to Embodiment 1 during a heating operation will be described.

[0024] Fig. 3 is a diagram illustrating the flow of the refrigerant and that of the water during the heating operation in the air-conditioning apparatus 100 according to Embodiment 1. In Fig. 3, solid line arrows indicate the flow of the refrigerant and broken line arrows indicate the flow of the water.

[0025] During the heating operation, the four-way valve 2 is set so as to provide passages indicated by broken lines illustrated in Fig. 1. The opening degree of the valve 8a is set in such a manner that the flow rate of the water reaches a predetermined value. The valve 8b is opened.

[0026] In the refrigerant circuit 6, a high-temperature high-pressure refrigerant, obtained by the compressor 1, passes through the four-way valve 2 and flows into the intermediate heat exchanger 5. The refrigerant, which has flowed into the intermediate heat exchanger 5, exchanges heat with the water circulated through the water circuit 10, so that the refrigerant condenses into a liquid refrigerant. At this time, the water circulated through the water circuit 10 is heated. The liquid refrigerant passes through the expansion valve 4, where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the heat exchanger 3 and exchanges heat with the outdoor air, so that the refrigerant evaporates into a gas refrigerant. The gas refrigerant passes through the four-way valve 2 and is sucked into the compressor 1, where the refrigerant is compressed into a high-temperature high-pressure state.

[0027] On the other hand, in the water circuit 10, high temperature water, obtained by heating through the intermediate heat exchanger 5, passes through the pump 7 and the valve 8a in sequence and then flows into the heat exchanger 9. The water, which has flowed into the heat exchanger 9, exchanges heat with the indoor air, so that the water is cooled. At this time, the indoor air is heated. The cooled water passes through the valve 8b and then flows into the intermediate heat exchanger 5.

[0028] An operation of the air-conditioning apparatus 100 according to Embodiment 1 during a defrosting operation will be described.

[0029] The defrosting operation is performed when the heat exchanger 3 is covered with frost during the heating operation.

[0030] The operation during the defrosting operation is the same as that during the cooling operation. Specifically, as illustrated in Fig. 2, the four-way valve 2 is set so as to provide the passages indicated by the solid lines illustrated in Fig. 1. In the refrigerant circuit 6, the high-temperature high-pressure refrigerant, obtained by the compressor 1, passes through the four-way valve 2 and then flows into the heat exchanger 3. The frost on the heat exchanger 3 is melted by the high-temperature high-pressure refrigerant, which has flowed into the heat exchanger 3, and is then removed. Since the rest of the operation is the same as that during the cooling operation, description therefor is omitted.

[0031] As described above, during the cooling operation or the defrosting operation, the low temperature refrigerant flows into the intermediate heat exchanger 5. The refrigerant at or below 0 degrees C may flow into the intermediate heat exchanger 5. In this case, the water circulated through the water circuit 10 may freeze in the intermediate heat exchanger 5. An increase in volume of water upon freezing may cause the intermediate heat exchanger 5 to be damaged. If the intermediate heat exchanger 5 is damaged, a refrigerant passage in the intermediate heat exchanger 5 may communicate with a water passage therein, thus causing the refrigerant circulated through the refrigerant circuit 6 to leak into the water circuit 10. Furthermore, the intermediate heat exchanger 5 may be damaged due to deterioration over time or the like, thus causing the refrigerant circulated through the refrigerant circuit 6 to leak into the water circuit 10.

[0032] In case of leakage of the refrigerant into the water circuit 10, the refrigerant would mix with the water and the mixture would be circulated through the water circuit 10. When a high pressure refrigerant mixes with water, a refrigerant gas is produced by the effect of pressure reduction. Accordingly, a pressure in the water circuit 10 may exceed a withstanding pressure of, for example, pipes included in the water circuit 10 or welded part of the pipes, thus causing the water containing the refrigerant to leak into the room.

[0033] An operation of the air-conditioning apparatus 100 according to Embodiment 1 upon leakage of the refrigerant from the intermediate heat exchanger 5 into the water circuit 10 will be described.

[0034] Fig. 4 is a flowchart illustrating an operation of the leakage detecting device 13 and that of the controller 14 in Embodiment 1.

[0035] The leakage detecting device 13 detects a pressure in the water circuit 10 at all times (S1: pressure detecting step) and determines whether the pressure in the water circuit 10 has increased (S2: increase determining step). When determining that the pressure has increased (YES in S2), the leakage detecting device 13 determines that the refrigerant has leaked into the water circuit 10 and transmits a detection signal indicating the leakage of the refrigerant to the controller 14 (S3: signal transmitting step). The controller 14 closes the valves 8a and 8b in response to reception of detection signal (S4: valve control step). Closing the valves 8a and 8b can prevent the water containing the refrigerant from flowing into the indoor unit 16.

[0036] In S2, depending on the situation, namely, while the air-conditioning apparatus 100 is stopped, alternatively, while the air-conditioning apparatus 100 is operating, the leakage detecting device 13 determines the increase of the pressure as follows.

[0037] While the air-conditioning apparatus 100 is stopped, the pressure in the water circuit 10 is atmospheric pressure. Accordingly, a threshold value to be used during stop of the air-conditioning apparatus 100 is set to a pressure that is higher than the atmospheric pressure by a predetermined value. When detecting a pressure higher than the threshold value, the leakage detecting device 13 determines that the pressure has increased.

[0038] While the air-conditioning apparatus 100 is operating, the pressure in the water circuit 10 is higher than that detected during stop of the air-conditioning apparatus 100 because the water is circulated. The rate of the water circulated varies depending on, for example, the rotation speed of the pump 7, so that the pressure in the water circuit 10 also varies. Accordingly, a value that is higher than a maximum pressure, which may be measured so long as the refrigerant does not leak, in the water circuit 10 by a given value is determined as a threshold value in advance. When detecting a pressure higher than the threshold value, the leakage detecting device 13 determines that the pressure has increased. The threshold values may be determined when the air-conditioning apparatus 100 is designed, for example. Alternatively, upon installation of the air-conditioning apparatus 100 in situ, operation simulation may be performed in consideration of actual conditions, such as the lengths of arranged pipes and the amount of refrigerant enclosed, and the threshold values may be determined on the basis of the simulation. Alternatively, a threshold value may be determined in association with, for example, each of the rotation speed of the pump 7, an indoor air temperature, and an outdoor air temperature. The leakage detecting device 13 may change a threshold value to be used depending on the rotation speed of the pump 7, the indoor air temperature, or the outdoor air temperature upon pressure detection.

[0039] In case of leakage of the refrigerant, a pressure increases in the entire water circuit 10 in principle. If the opening degree of the valve 8a is controlled in such a manner that the flow rate of the water circulated through the water circuit 10 is constant, however, the water containing a gas refrigerant is in a two-phase gas-liquid state. Accordingly, the difference between a pressure at a point prior to the valve 8a and a pressure at a point after the valve 8a may increase and a pressure at a point downstream of the valve 8a may be kept low, or increase very little. The leakage detecting device 13 therefore detects a pressure at a point between the pump 7 and the valve 8a in the water circuit 10. Consequently, an increase in pressure can be reliably detected, irrespective of the opening degree of the valve 8a.

[0040] As described above, the air-conditioning apparatus 100 according to Embodiment 1 detects the leakage of the refrigerant circulated through the refrigerant circuit 6 into the water circuit 10 and closes the valves 8a and 8b. Thus, the water containing the refrigerant can be prevented from flowing into the indoor unit 16. Consequently, the leakage of the refrigerant into the room can be prevented, thus preventing the room from being in an explosive atmosphere.

[0041] In the above description, the controller 14 closes the valves 8a and 8b in response to reception of detection signal. When receiving the detection signal during operation of the air-conditioning apparatus 100, the controller 14 may close the valves 8a and 8b and stop the compressor 1 or the pump 7. Consequently, the leakage of the refrigerant can be prevented more reliably.

[0042] Furthermore, the controller 14 may prompt a user to ventilate the room upon receiving the detection signal. For example, the controller 14 may allow a remote control, which is used to enter an instruction for the indoor unit 16 or the air-conditioning apparatus 100, to output an audio message in order to prompt the user to ventilate the room. The controller 14 may allow a display of the indoor unit 16 or the remote control to display a message in order to prompt the user to ventilate the room.

[0043] In the above description, the leakage detecting device 13 detects a pressure in the water circuit 10 to detect the leakage of the refrigerant. The leakage detecting device 13 may detect the leakage of the refrigerant by any other method.

[0044] For example, the leakage detecting device 13 that detects the leakage of the refrigerant may be of, for example, a semiconductor type that utilizes a reduction in electrical resistance of a semiconductor caused by adsorption of a gas on the surface of the semiconductor, a contact burning type that utilizes an increase in electrical resistance of a platinum wire, through which current flows, caused by slight burning due to contact between the platinum wire and a gas, or a gas thermal conductivity type that utilizes a change in temperature of a platinum wire, through which current flows, (typically in contact with air) caused by contact between the platinum wire and a flammable gas because the thermal conductivity of the air differs from that of the gas. Note that a change in temperature of the platinum wire in the gas thermal conductivity type means a change in electrical resistance.

[0045] The above-described types use methods of detecting a flammable gas in a nonflammable gas (e.g., air). An additional mechanism is therefore needed which allows the water circuit 10 to discharge a certain amount of water (or the mixture of the water and the refrigerant if the refrigerant has leaked) into the atmosphere at regular time intervals and detects the refrigerant using any of the above methods after removal of the water. For example, when a pressure in the water circuit 10 is at or above a given pressure, the certain amount of water may be discharged from the water circuit 10 into the atmosphere using a relief valve that is opened when the pressure is at or above the given pressure.

[0046] To detect the leakage of the refrigerant using any of these methods, the relief valve may be disposed at the highest position in the water circuit 10 and the leakage of the refrigerant may be detected from the discharged mixture. A low density flammable refrigerant tends to accumulate at the highest position in the water circuit 10. Accordingly, the leakage of the refrigerant can be reliably detected, irrespective of during operation or non-operation.

Embodiment 2

[0047] Embodiment 2 will be described with respect to an air-conditioning apparatus 100 including a plurality of primary circuits. Although the air-conditioning apparatus 100 including two primary circuits will be described below as an example, the air-conditioning apparatus 100 may include three or more primary circuits.

[0048] In the air-conditioning apparatus 100 according to Embodiment 2, the same components as those in the air-conditioning apparatus 100 according to Embodiment 1 are designated by the same reference numerals.

[0049] Fig. 5 is a diagram illustrating the configuration of the air-conditioning apparatus 100 according to Embodiment 2. In Fig. 1, each blanked arrow indicates the flow of air and each dotted arrow indicates the flow of a signal.

[0050] The air-conditioning apparatus 100 includes a refrigerant circuit 6a (first refrigerant circuit or primary circuit) including a compressor 1 a (first compressor), a four-way valve 2a, a heat exchanger 3a (first heat exchanger), an expansion valve 4a (first expansion mechanism), an intermediate heat exchanger 5a (first intermediate heat exchanger) sequentially connected in loop by pipes. The air-conditioning apparatus 100 further includes a refrigerant circuit 6b (second refrigerant circuit or primary circuit) including a compressor 1 b (second compressor), a four-way valve 2b, a heat exchanger 3b (second heat exchanger), an expansion valve 4b (second expansion mechanism), an intermediate heat exchanger 5b (second intermediate heat exchanger) sequentially connected in loop by pipes. The air-conditioning apparatus 100 further includes a water circuit 10 (fluid circuit or secondary circuit) including the intermediate heat exchanger 5a, the intermediate heat exchanger 5b, a pump 7, a valve 8a (first valve), a heat exchanger 9 (load heat exchanger), and a valve 8b (second valve) sequentially connected in loop by pipes. A flammable refrigerant, such as a propane or isobutane, having a lower liquid density than water is circulated through each of the refrigerant circuits 6a and 6b, and water is circulated through the water circuit 10. A fan 11 that delivers airflow to the heat exchangers 3a and 3b is disposed near the heat exchangers 3a and 3b. A fan 12 that delivers airflow to the heat exchanger 9 is disposed near the heat exchanger 9.

[0051] The air-conditioning apparatus 100 further includes a leakage detecting device 13 that detects leakage of the refrigerant, circulated through the refrigerant circuits 6, into the water circuit 10 from any of the intermediate heat exchangers 5 and a controller 14 that closes the valves 8a and 8b when the leakage detecting device 13 detects the leakage of the refrigerant.

[0052] The compressors 1 a and 1b, the four-way valves 2a and 2b, the heat exchangers 3a and 3b, the expansion valves 4a and 4b, the intermediate heat exchangers 5a and 5b, the pump 7, the valves 8a and 8b, the fan 11, the leakage detecting device 13, and the controller 14 of the components included in the air-conditioning apparatus 100 are accommodated in an outdoor unit 15 (first casing). The heat exchanger 9 and the fan 12 of the components included in the air-conditioning apparatus 100 are accommodated in an indoor unit 16 (second casing).

[0053] Each of the intermediate heat exchangers 5a and 5b is a plate heat exchanger or double pipe heat exchanger that has high efficiency of heat exchange.

[0054] An operation of the air-conditioning apparatus 100 according to Embodiment 2 during the cooling operation will be described.

[0055] Fig. 6 is a diagram illustrating the flow of the refrigerant and that of the water during the cooling operation in the air-conditioning apparatus 100 according to Embodiment 2. In Fig. 6, solid line arrows indicate the flow of the refrigerant and broken line arrows indicate the flow of the water.

[0056] During the cooling operation, the four-way valves 2a and 2b are set so as to provide passages indicated by solid lines illustrated in Fig. 5. An opening degree of the valve 8a is set in such a manner that the water flows at a constant rate. The valve 8b is opened.

[0057] In the refrigerant circuit 6a, a high-temperature high-pressure refrigerant, obtained by the compressor 1a, passes through the four-way valve 2a and flows into the heat exchanger 3a. The refrigerant, which has flowed into the heat exchanger 3a, exchanges heat with outdoor air, so that the refrigerant condenses into a liquid refrigerant. The liquid refrigerant passes through the expansion valve 4a, where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the intermediate heat exchanger 5a and exchanges heat with the water circulated through the water circuit 10, so that the refrigerant evaporates into a gas refrigerant. At this time, the water circulated through the water circuit 10 is cooled. The gas refrigerant passes through the four-way valve 2a and is sucked into the compressor 1 a, where the refrigerant is compressed into a high-temperature high-pressure state.

[0058] As in the refrigerant circuit 6a, in the refrigerant circuit 6b, a high-temperature high-pressure refrigerant, obtained by the compressor 1 b, passes through the four-way valve 2b and flows into the heat exchanger 3b. The refrigerant, which has flowed into the heat exchanger 3b, exchanges heat with the outdoor air, so that the refrigerant condenses into a liquid refrigerant. The liquid refrigerant passes through the expansion valve 4b, where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the intermediate heat exchanger 5b and exchanges heat with the water circulated through the water circuit 10, so that the refrigerant evaporates into a gas refrigerant. At this time, the water circulated through the water circuit 10 is cooled. The gas refrigerant passes through the four-way valve 2b and is sucked into the compressor 1b, where the refrigerant is compressed into a high-temperature high-pressure state.

[0059] On the other hand, in the water circuit 10, the water is cooled in the intermediate heat exchanger 5a and is further cooled to a low temperature in the intermediate heat exchanger 5b. The low temperature water passes through the pump 7 and the valve 8a in sequence and then flows into the heat exchanger 9. The water, which has flowed into the heat exchanger 9, exchanges heat with indoor air, so that the water is heated. At this time, the indoor air is cooled. The heated water passes through the valve 8b and then flows into the intermediate heat exchanger 5a.

[0060] Since the intermediate heat exchangers 5a and 5b are connected in series in the water circuit 10 as described above, the water is successively cooled by the refrigerant circulated through the refrigerant circuit 6a and the refrigerant circulated through the refrigerant circuit 6b. Accordingly, the water can be adequately cooled if the capacity of each of the refrigerant circuits 6a and 6b is not high.

[0061] An operation of the air-conditioning apparatus 100 according to Embodiment 2 during the heating operation will be described.

[0062] Fig. 7 is a diagram illustrating the flow of the refrigerant and that of the water during the heating operation in the air-conditioning apparatus 100 according to Embodiment 2. In Fig. 7, solid line arrows indicate the flow of the refrigerant and broken line arrows indicate the flow of the water.

[0063] During the heating operation, the four-way valves 2a and 2b are set so as to provide passages indicated by broken lines illustrated in Fig. 5. The opening degree of the valve 8a is set in such a manner that the flow rate of the water reaches a predetermined value. The valve 8b is opened.

[0064] In the refrigerant circuit 6a, a high-temperature high-pressure refrigerant, obtained by the compressor 1a, passes through the four-way valve 2a and flows into the intermediate heat exchanger 5a. The refrigerant, which has flowed into the intermediate heat exchanger 5a, exchanges heat with the water circulated through the water circuit 10, so that the refrigerant condenses into a liquid refrigerant. At this time, the water circulated through the water circuit 10 is heated. The liquid refrigerant passes through the expansion valve 4a, where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the heat exchanger 3a and exchanges heat with the outdoor air, so that the refrigerant evaporates into a gas refrigerant. The gas refrigerant passes through the four-way valve 2a and is sucked into the compressor 1 a, where the refrigerant is compressed into a high-temperature high-pressure state.

[0065] As in the refrigerant circuit 6a, in the refrigerant circuit 6b, a high-temperature high-pressure refrigerant, obtained by the compressor 1b, passes through the four-way valve 2b and flows into the intermediate heat exchanger 5b. The refrigerant, which has flowed into the intermediate heat exchanger 5b, exchanges heat with the water circulated through the water circuit 10, so that the refrigerant condenses into a liquid refrigerant. At this time, the water circulated through the water circuit 10 is heated. The liquid refrigerant passes through the expansion valve 4b, where the refrigerant is expanded into a low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the heat exchanger 3b and exchanges heat with the outdoor air, so that the refrigerant evaporates into a gas refrigerant. The gas refrigerant passes through the four-way valve 2b and is sucked into the compressor 1 b, where the refrigerant is compressed into a high-temperature high-pressure state.

[0066] On the other hand, in the water circuit 10, the water is heated in the intermediate heat exchanger 5a and is further heated to a high temperature in the intermediate heat exchanger 5b. The high temperature water passes through the pump 7 and the valve 8a in sequence and then flows into the heat exchanger 9. The water, which has flowed into the heat exchanger 9, exchanges heat with the indoor air, so that the water is cooled. At this time, the indoor air is heated. The cooled water passes through the valve 8b and then flows into the intermediate heat exchanger 5a.

[0067] Since the intermediate heat exchangers 5a and 5b are connected in series in the water circuit 10 as described above, the water is successively heated by the refrigerant circulated through the refrigerant circuit 6a and the refrigerant circulated through the refrigerant circuit 6b. Accordingly, the water can be adequately heated if the capacity of each of the refrigerant circuits 6a and 6b is not high.

[0068] An operation of the air-conditioning apparatus 100 according to Embodiment 2 during the defrosting operation will be described.

[0069] The defrosting operation is performed when the heat exchangers 3a and 3b are covered with frost during the heating operation.

[0070] The operation during the defrosting operation is the same as that during the cooling operation. Specifically, as illustrated in Fig. 6, the four-way valves 2a and 2b are set so as to provide the passages indicated by the solid lines illustrated in Fig. 5. In the refrigerant circuit 6a, the high-temperature high-pressure refrigerant, obtained by the compressor 1 a, passes through the four-way valve 2a and flows into the heat exchanger 3a. Similarly, in the refrigerant circuit 6b, the high-temperature high-pressure refrigerant, obtained by the compressor 1 b, passes through the four-way valve 2b and flows into the heat exchanger 3b. The frost on the heat exchangers 3a and 3b is melted by the high-temperature high-pressure refrigerant which has flowed into the heat exchangers 3a and 3b and is then removed. Since the rest of the operation is the same as that during the cooling operation, description is omitted.

[0071] As in the air-conditioning apparatus 100 according to Embodiment 1, in the air-conditioning apparatus 100 according to Embodiment 2, the intermediate heat exchangers 5a and 5b may be damaged and the refrigerant circulated through the refrigerant circuits 6 may leak into the water circuit 10. If the refrigerant leaks into the water circuit 10, the water containing the refrigerant may leak into a room.

[0072] When the leakage of the refrigerant circulated through the refrigerant circuits 6 into the water circuit 10 is detected, the controller 14 closes the valves 8a and 8b. This prevents the leakage of the water containing the refrigerant from flowing into the indoor unit 16. In addition, the controller 14 may stop the compressors 1 a and 1b or the pump 7 to reliably prevent the leakage of the refrigerant.

[0073] As described above, like the air-conditioning apparatus 100 according to Embodiment 1, the air-conditioning apparatus 100 according to Embodiment 2 detects the leakage of the refrigerant circulated through the refrigerant circuits 6a and 6b into the water circuit 10 and closes the valves 8a and 8b. Thus, the water containing the refrigerant can be prevented from flowing into the indoor unit 16. Consequently, the leakage of the refrigerant into the room can be prevented, thus preventing the room from being in an explosive atmosphere.

[0074] Furthermore, it is preferred that the amount of refrigerant enclosed in each primary circuit be below a predetermined amount (for example, 150 g, based on the F-gas Regulation in Europe, in the use of propane as a refrigerant, for example) so that a room is prevented from being in an explosive atmosphere if the refrigerant leaks into the room. Typically, however, a large amount of refrigerant is enclosed in a large air-conditioning apparatus having a high capacity.

[0075] In the air-conditioning apparatus 100 according to Embodiment 2 including the two primary circuits, namely, the refrigerant circuits 6a and 6b, if the refrigerant enclosed in each of the refrigerant circuits 6a and 6b is restricted to a small amount and the capacity of each of the refrigerant circuits 6a and 6b is accordingly low, the air-conditioning apparatus 100 can demonstrate a high capacity. In other words, if the air-conditioning apparatus 100 according to Embodiment 2 is a large air-conditioning apparatus that demonstrates a high capacity, the amount of refrigerant enclosed in each primary circuit can be small.

[0076] Furthermore, as illustrated in Fig. 5, the airflow delivered by the fan 11 passes through the heat exchanger 3a and then passes through the heat exchanger 3b. For example, during the cooling operation, therefore, the heat exchanger 3a exchanges heat between the air and the refrigerant circulated through the refrigerant circuit 6a and the heated air is delivered to the heat exchanger 3b. In other words, the temperature of the airflow supplied to the heat exchanger 3a differs from that of the airflow supplied to the heat exchanger 3b. Consequently, a condensing temperature in the refrigerant circuit 6a can be allowed to differ from that in the refrigerant circuit 6b.

[0077] In addition, as illustrated in Fig. 5, the water circulated through the water circuit 10 passes through the intermediate heat exchanger 5a and then passes through the intermediate heat exchanger 5b. For example, during the cooling operation, therefore, the intermediate heat exchanger 5a exchanges heat between the water and the refrigerant circulated through the refrigerant circuit 6a and the cooled water is delivered to the intermediate heat exchanger 5b. In other words, the temperature of the water supplied to the intermediate heat exchanger 5a differs from that of the water supplied to the intermediate heat exchanger 5b. Consequently, an evaporating temperature in the refrigerant circuit 6a can be allowed to differ from that in the refrigerant circuit 6b.

[0078] In other words, the condensing temperature and the evaporating temperature in the refrigerant circuit 6a can be allowed to differ from those in the refrigerant circuit 6b. Although the above description has been made with respect to the cooling operation, the condensing temperature and the evaporating temperature in the refrigerant circuit 6a during the heating operation can similarly be allowed to differ from those in the refrigerant circuit 6b. Since the condensing temperature and the evaporating temperature in the refrigerant circuit 6a are allowed to differ from those in the refrigerant circuit 6b, the temperature of the refrigerant is allowed to change depending on the temperature of water or air, thus enabling the air-conditioning apparatus to achieve high efficiency.

[0079] In the case illustrated in Fig. 5, during the cooling operation, the air heated by heat exchange through the heat exchanger 3a is delivered to the heat exchanger 3b, so that the condensing temperature in the heat exchanger 3a is low and the condensing temperature in the heat exchanger 3b is high. In addition, the water cooled by heat exchange through the intermediate heat exchanger 5a flows into the intermediate heat exchanger 5b, so that the evaporating temperature in the intermediate heat exchanger 5a is high and the evaporating temperature in the intermediate heat exchanger 5b is low. During the heating operation, the air cooled by heat exchange through the heat exchanger 3a is delivered to the heat exchanger 3b, so that the evaporating temperature in the heat exchanger 3a is high and the evaporating temperature in the heat exchanger 3b is low. In addition, the water heated by heat exchange through the intermediate heat exchanger 5a flows into the intermediate heat exchanger 5b, so that the condensing temperature in the intermediate heat exchanger 5a is low and the condensing temperature in the intermediate heat exchanger 5b is high.

[0080] Specifically, in the case illustrated in Fig. 5, the refrigerant circuit 6a is a circuit in which the condensing temperature is low and the evaporating temperature is high and the refrigerant circuit 6b is a circuit in which the condensing temperature is high and the evaporating temperature is low. Accordingly, the difference between a high pressure and a low pressure is reduced in the refrigerant circuit 6a and the difference therebetween is increased in the refrigerant circuit 6b.

[0081] The difference in high-low pressure difference between the refrigerant circuit 6a and the refrigerant circuit 6b may be reduced by allowing the airflow generated by the fan 11 to pass through the heat exchanger 3b and then pass through the heat exchanger 3a, or allowing the water circulated through the water circuit 10 to pass through the intermediate heat exchanger 5b and then pass through the intermediate heat exchanger 5a.

[0082] As regards increasing or decreasing the difference in high-low pressure difference between the refrigerant circuits 6a and 6b, the increase or the decrease may be selected depending on the difference in performance between the compressors included in the refrigerant circuits 6a and 6b, an installation environment of the air-conditioning apparatus 100, or the like so that high efficiency is achieved.

Embodiment 3

[0083] Embodiment 3 will be described with respect to placement of the intermediate heat exchanger 5 (5a, 5b) in Embodiments 1 and 2. The placement will be described with respect to the air-conditioning apparatus 100 according to Embodiment 2 as an example.

[0084] Fig. 8 is an exploded perspective view of a typical plate heat exchanger.

[0085] Figs. 9 to 11 are diagrams illustrating arrangement of the intermediate heat exchangers 5a and 5b according to Embodiment 3. In Figs. 9 to 11, solid line arrows indicate the flow of refrigerant during the cooling operation and broken line arrows indicate the flow of water. During the heating operation, the refrigerant flows in a direction opposite to that indicated by the solid line arrows. In Figs. 9 to 11, an up-down direction corresponds to a vertical direction.

[0086] In Figs. 9 to 11, it is assumed that each of the intermediate heat exchangers 5a and 5b is a plate heat exchanger. As illustrated in Fig. 8, the plate heat exchanger includes a plurality of substantially rectangular plates 51 arranged and has a thin rectangular-parallelepiped shape in appearance. The plate 51 at one end of the stacked plates 51 has connection ports 52 and 53 for the primary circuit and connection ports 54 and 55 for the secondary circuit. Refrigerant passages 56 through which the refrigerant circulated through the primary circuit flows and water passages 57 through which the water circulated through the secondary circuit flows are alternately arranged between the adjacent plates.

[0087] In Fig. 9, the two rectangular-parallelepiped intermediate heat exchangers 5a and 5b are vertically stacked. To accommodate the two refrigerant circuits 6a and 6b, the outdoor unit 15 is increased in size and the area of installation of the outdoor unit 15 is also increased. Since the two intermediate heat exchangers 5a and 5b are vertically stacked as illustrated in Fig. 9, however, the intermediate heat exchangers 5a and 5b can be arranged with efficiency. Thus, the installation area of the outdoor unit 15 can be reduced.

[0088] Note that connection ports 53a and 53b adjacent to the expansion valves 4a and 4b and connection ports 55a and 55b adjacent to the pump 7 are arranged on a lower side and connection ports 52a and 52b adjacent to the four-way valves 2a and 2b and connection ports 54a and 54b adjacent to the valve 8b are arranged on an upper side. During the cooling operation and the defrosting operation, the two-phase refrigerant enters through the connection ports 53a and 53b and the gas refrigerant leaves through the connection ports 52a and 52b. During the heating operation, the gas refrigerant enters through the connection ports 52a and 52b and the liquid refrigerant leaves through the connection ports 53a and 53b. In this arrangement in which the connection ports 52a and 52b through which the gas refrigerant passes are arranged on the upper side, therefore, accumulation of the gas refrigerant in the intermediate heat exchangers 5a and 5b can be prevented.

[0089] Referring to Figs. 10 and 11, the intermediate heat exchangers 5a and 5b are inclined in such a manner that the connection ports 52a, 52b, 54a, and 54b face obliquely upward. In this arrangement, whereas the area of installation of the outdoor unit 15 is slightly increased, the area of accumulation of the gas refrigerant in an upper portion (area 58a or 58b indicated by a broken line in Fig. 9) of each of the intermediate heat exchangers 5a and 5b can be reduced.

[0090] In Fig. 11 which illustrates a modification of the configuration of Fig. 10, the connection ports 52a, 52b, 54a, and 54b are arranged at one ends and the connection ports 53a, 53b, 55a, and 55b are provided in the plates 51 arranged at the another ends, respectively. The connection ports 53a and 53b are inlets for the refrigerant during the cooling operation and the defrosting operation.

[0091] In case of leakage of a small amount of refrigerant, the refrigerant gas may accumulate in the intermediate heat exchangers 5a and 5b and detection of the leakage of the refrigerant may accordingly be delayed. The above-described arrangement manner, however, can reduce the areas where the refrigerant gas accumulates in the intermediate heat exchangers 5a and 5b. Consequently, the leakage of the refrigerant can be immediately detected.

[0092] The intermediate heat exchangers 5a and 5b in Embodiment 2 have been described above as an example. As regards the air-conditioning apparatus 100 according to Embodiment 1, the intermediate heat exchanger 5 may be placed vertically as illustrated in Fig. 9. Alternatively, the intermediate heat exchanger 5 may be inclined as illustrated in Fig. 10. The connection ports may be provided in the plates 51 arranged at the another ends as illustrated in Fig. 11.

[0093] In a configuration in which at least two primary refrigerant circuits are arranged and R32, HFO-1234yf, a refrigerant mixture containing R32, or a refrigerant mixture containing HFO-1234yf having a higher liquid density (liquid head) than water is used as a flammable refrigerant circulated through each primary refrigerant circuit, each intermediate heat exchanger is vertically placed and the intermediate heat exchangers are arranged side by side horizontally. Specifically, the intermediate heat exchangers 5a and 5b are arranged side by side horizontally in a state in which the connection ports 53a, 53b, 55a, and 55b are arranged on the lower side and the connection ports 52a, 52b, 54a, and 54b are arranged on the upper side. Consequently, the performance can be ensured and an upper space within the outdoor unit 15 can be used as a refrigerant pipe space, so that the area of installation can be reduced.

[0094] In Embodiments 1, 2 and 3 the water is circulated through the water circuit 10 which serves as the secondary circuit. The fluid circulated through the secondary circuit is not limited to water. Any other nonflammable fluid, such as brine, may be used.

[0095] If brine is circulated through the secondary circuit, the brine would not freeze in the intermediate heat exchanger 5 (or the intermediate heat exchangers 5a and 5b in Embodiment 2). The intermediate heat exchanger 5, however, may be damaged due to deterioration over time or the like. The air-conditioning apparatus 100 according to each of Embodiments 1 and 2 is effective in the case where brine is circulated through the secondary circuit.

[0096] In Embodiments 1 and 2, the pump 7 is disposed between the intermediate heat exchanger 5 (the intermediate heat exchanger 5b in Embodiment 2) and the valve 8a in the water circuit 10. The pump 7 may be disposed at any other position between the valves 8a and 8b in a direction in which the water is circulated.

[0097] The leakage detecting device 13 can detect a pressure at a point between the pump 7 and the valve 8a in the water circuit 10 to reliably detect the leakage of the refrigerant, irrespective of the position of the pump 7.

[0098] Embodiments 1 and 2 have been described with respect to the air-conditioning apparatus as an example of the heat pump apparatus. The air-conditioning apparatus is not limited to a room air-conditioning apparatus in which the amount of refrigerant is relatively small and may include a large air-conditioning apparatus, such as a package air-conditioning apparatus for business use or a multi-air-conditioning apparatus for a building. The heat pump apparatus is not limited to an air-conditioning apparatus and may be, for example, a chiller or a cooler. In this case, instead of water, brine has to be used as a fluid for the secondary circuit. Furthermore, the four-way valve is not needed because the apparatus is used only for refrigeration or cooling in this case.

Reference Signs List

[0099] 1 compressor, 2 four-way valve, 3 heat exchanger, 4 expansion valve, 5 intermediate heat exchanger, 6 refrigerant circuit, 7 pump, 8 valve, 9 heat exchanger, 10 water circuit, 11, 12 fan, 13 leakage detecting device, 14 controller, 15 outdoor unit, 16 indoor unit, 51 plate, 52, 53, 54, 55 connection port, 56 refrigerant passage, 57 water passage, 58 area where a gas refrigerant tends to accumulate, 100 air-conditioning apparatus

Claims

1. A heat pump apparatus comprising:

a first refrigerant circuit through which a refrigerant is circulated, the first refrigerant circuit including a first compressor, a first heat source heat exchanger, a first expansion mechanism, and a first intermediate heat exchanger sequentially connected in loop by pipes;

a fluid circuit through which a fluid is circulated, the fluid circuit including the first intermediate heat exchanger, a first valve, a load heat exchanger, and a second valve sequentially connected in loop by pipes;

a leakage detecting device that detects leakage of the refrigerant, circulated through the first refrigerant circuit, from the first intermediate heat exchanger into the fluid circuit; and
a controller that closes the first valve and the second valve included in the fluid circuit when the leakage detecting device detects the leakage of the refrigerant.

2. The heat pump apparatus of claim 1, further comprising:

a first casing that accommodates the first compressor, the first heat source heat exchanger, the first expansion mechanism, the first intermediate heat exchanger, the first valve, and the second valve; and
a second casing that accommodates the load heat exchanger.

3. The heat pump apparatus of claim 1 or 2,
wherein the refrigerant circulated through the first refrigerant circuit is flammable, and
wherein the fluid circulated through the fluid circuit is nonflammable.

4. The heat pump apparatus of any one of claims 1 to 3, wherein when the leakage detecting device detects the leakage of the refrigerant, the controller stops the first compressor.

5. The heat pump apparatus of any one of claims 1 to 4, wherein the fluid circuit further includes a pump that circulates the fluid in such a manner that the fluid flows through the first intermediate heat exchanger, the first valve, the load heat exchanger, and the second valve in that order and the pump is connected between the second valve and the first valve in a direction in which the fluid is circulated,
wherein the first valve has an opening degree that is controlled in such a manner that the fluid circulated through the fluid circuit flows at a predetermined flow rate, and
wherein the leakage detecting device detects the leakage of the refrigerant by detecting a pressure at a point between the pump and the first valve in the fluid circuit.

6. The heat pump apparatus of any one of claims 1 to 5, wherein the first intermediate heat exchanger is placed in such a manner that a connection port for the pipe connected to the first compressor is disposed in upper part of the first intermediate heat exchanger and a connection port for the pipe connected to the first expansion mechanism is disposed in lower part thereof.

7. The heat pump apparatus of claim 6,
wherein the first intermediate heat exchanger is a plate heat exchanger including a plurality of plates stacked on one another and a plate at one end of the stacked plates has the connection port for the pipe connected to the first compressor and the connection port for the pipe connected to the first expansion mechanism, and
wherein the first intermediate heat exchanger is inclined in such a manner that the connection port for the pipe connected to the first compressor faces obliquely upward.

8. The heat pump apparatus of claim 7,
wherein the first intermediate heat exchanger is the plate heat exchanger in which the connection port for the pipe connected to the first compressor is disposed in a plate at an end of the plurality of plates another than one end at which the plate having the connection port for the pipe connected to the first expansion mechanism is disposed, and
wherein the first intermediate heat exchanger is inclined in such a manner that the connection port for the pipe connected to the first compressor faces obliquely upward and the connection port for the pipe connected to the first expansion mechanism faces obliquely downward.

9. The heat pump apparatus of any one of claims 1 to 8, further comprising:

a second refrigerant circuit through which the refrigerant is circulated, the second refrigerant circuit including a second compressor, a second heat source heat exchanger, a second expansion mechanism, and a second intermediate heat exchanger sequentially connected in loop by pipes,
wherein the second intermediate heat exchanger is connected between the first intermediate heat exchanger and the first valve in the fluid circuit,
wherein the leakage detecting device detects leakage of the refrigerant circulated through the first refrigerant circuit and the refrigerant circulated through the second refrigerant circuit from the first intermediate heat exchanger into the fluid circuit.

10. The heat pump apparatus of claim 9 as dependent on any one of claims 1 to 5, wherein the refrigerant circulated through the first and second refrigerant circuits is R32 or a refrigerant mixture containing R32,
wherein each of the first and second intermediate heat exchangers is a plate heat exchanger including a plurality of plates stacked on one another, and
wherein each of the first and second intermediate heat exchangers is placed in such a manner that the

connection ports for the pipes are positioned on an upper side and a lower side, and the first and second intermediate heat exchangers are arranged side by side horizontally.

11. The heat pump apparatus of claim 9 or 10, further comprising:

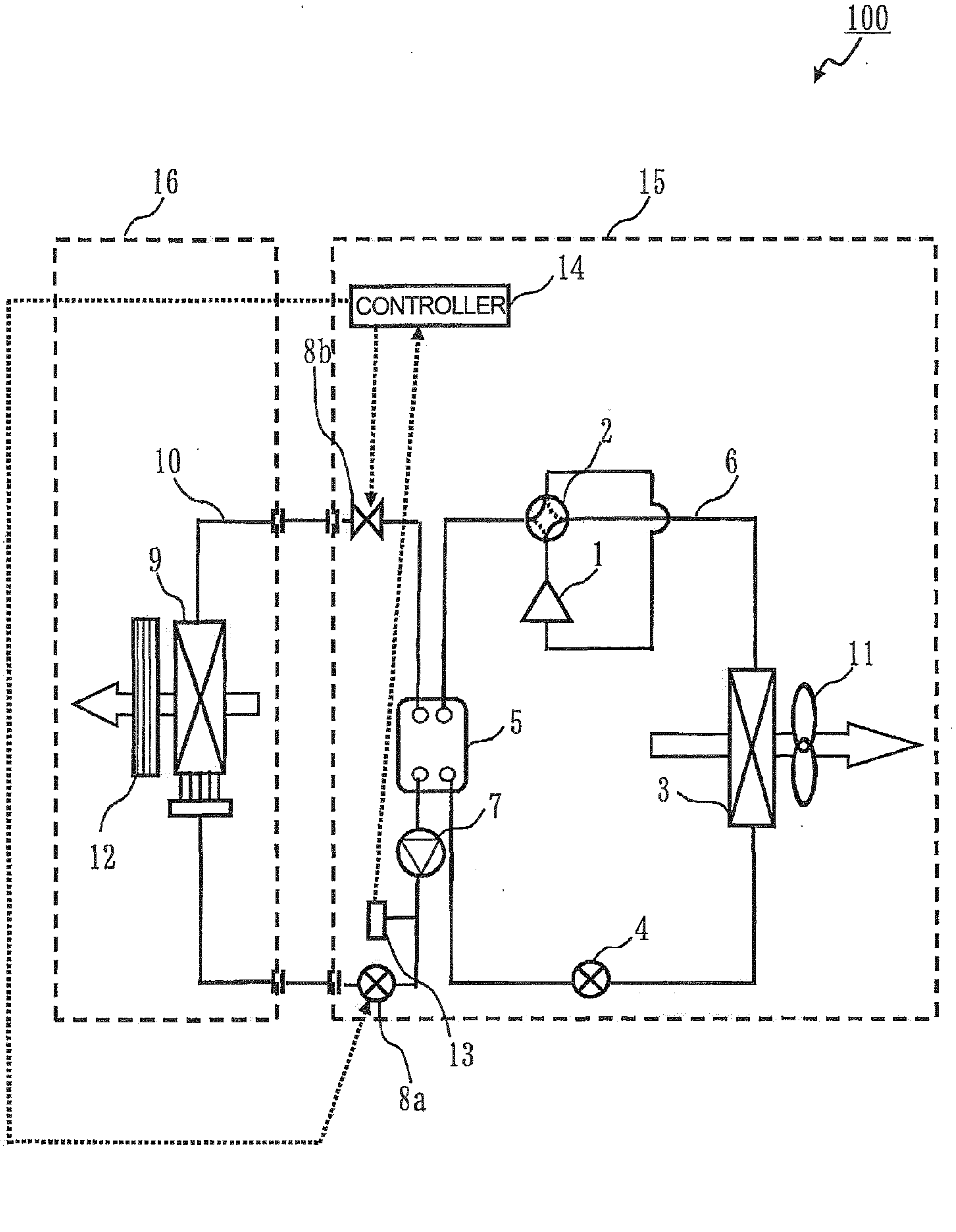
a fan that generates airflow to deliver air which has exchanged heat with the refrigerant in one of the first and second heat source heat exchangers to the other one of the first and second heat source heat exchangers and allow the delivered air to exchange heat with the refrigerant in the other heat source heat exchanger.

12. The heat pump apparatus of claim 2,
wherein the heat pump apparatus is an air-conditioning apparatus that conditions air in a room,
wherein the first casing is an outdoor unit installed outside the room, and wherein the second casing is an indoor unit installed inside the room.

13. A method of controlling a heat pump apparatus including a first refrigerant circuit through which a refrigerant is circulated and that includes a first compressor, a first heat source heat exchanger, a first expansion mechanism, and a first intermediate heat exchanger sequentially connected in loop by pipes and a fluid circuit through which a fluid is circulated and that includes the first intermediate heat exchanger, a first valve, a load heat exchanger, and a second valve sequentially connected in loop by pipes, the method comprising:

a leakage detecting step of detecting, by a leakage detecting device, leakage of the refrigerant circulated through the first refrigerant circuit from the first intermediate heat exchanger into the fluid circuit; and
a valve control step of closing, by a controller, the first valve and the second valve included in the fluid circuit when the leakage detecting device detects the leakage of the refrigerant.

F I G. 1



F I G. 2

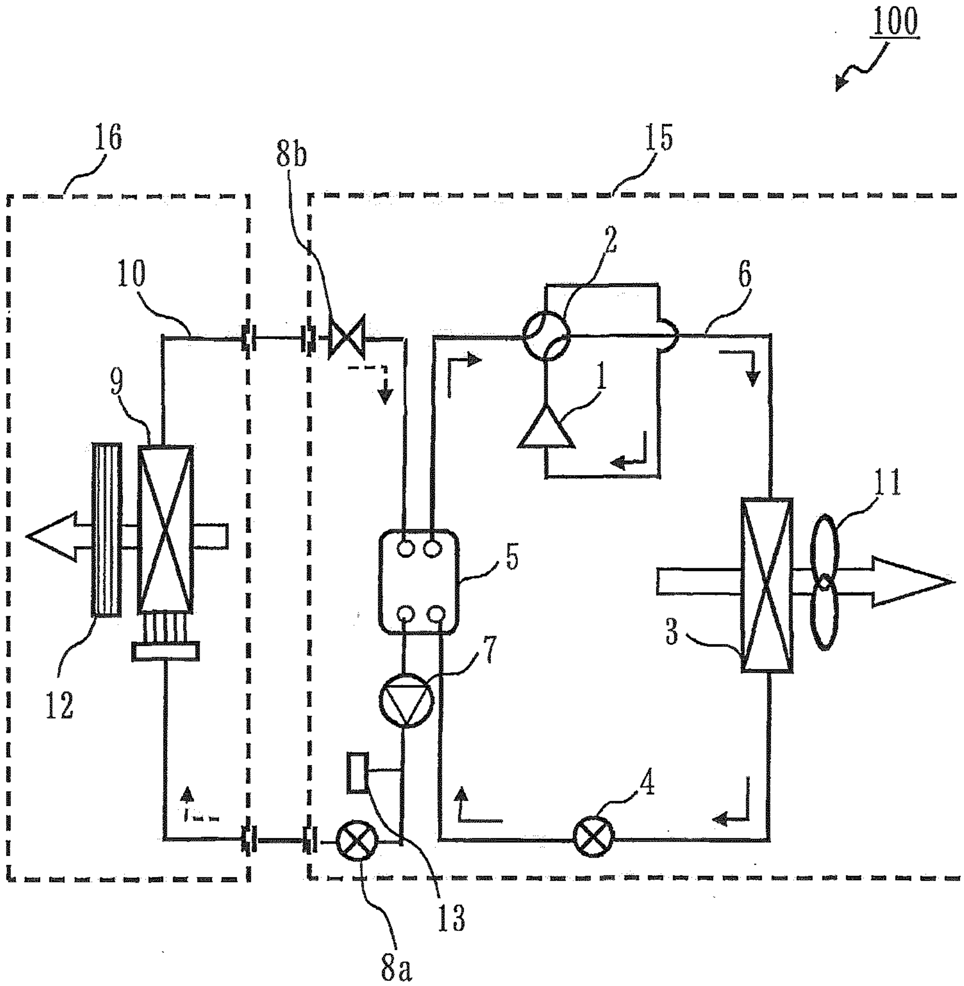
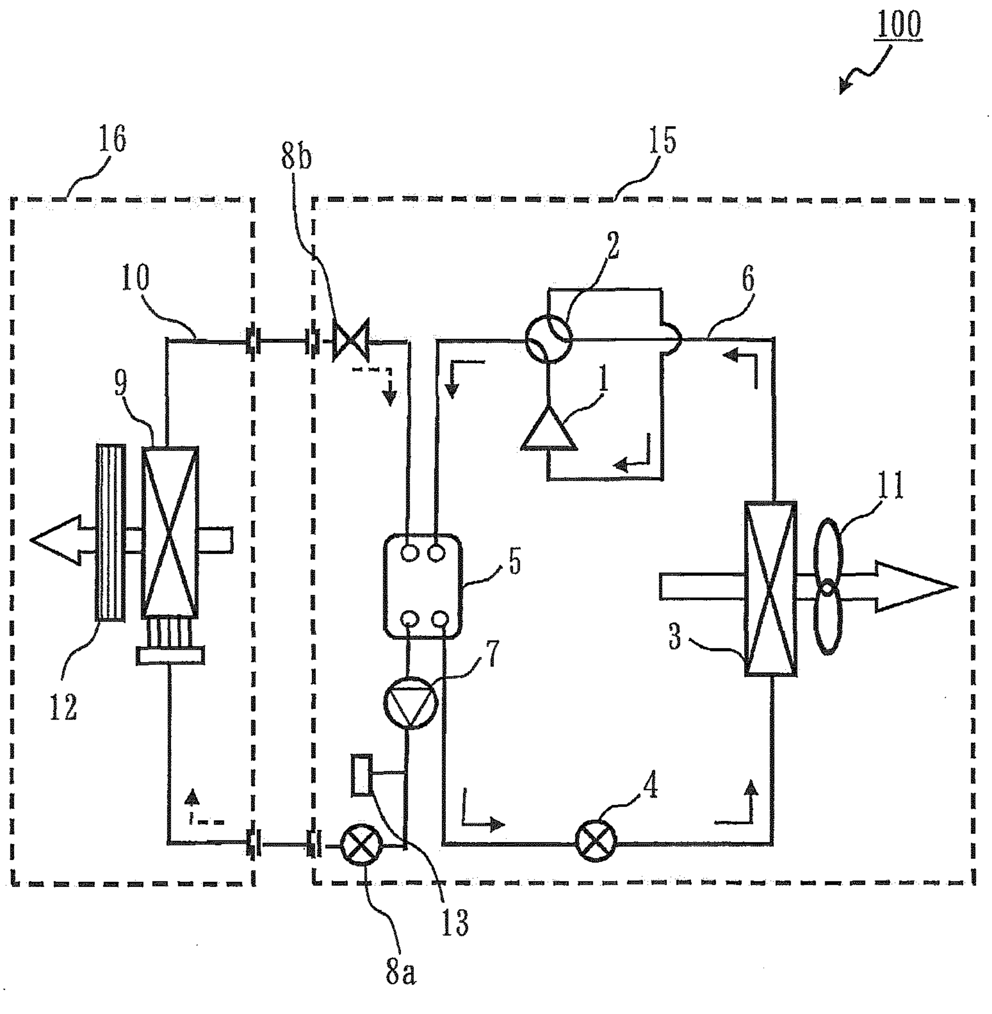


FIG. 3



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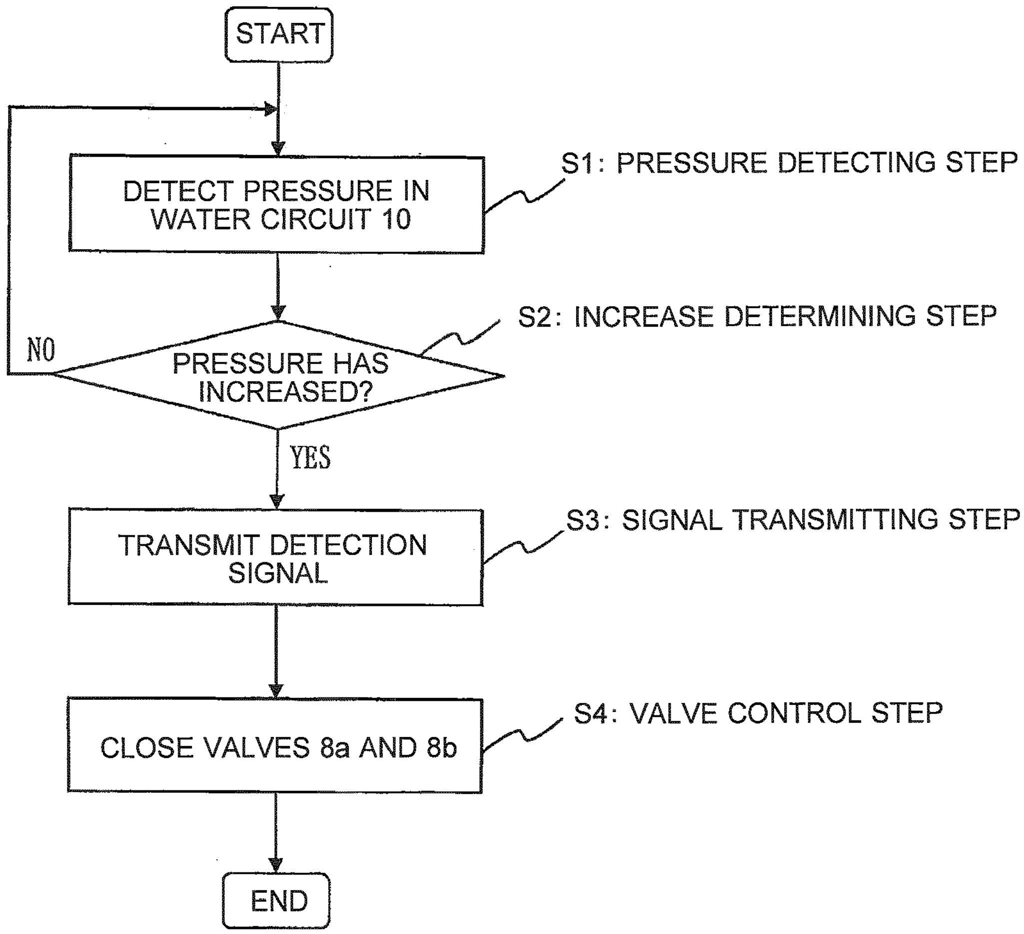
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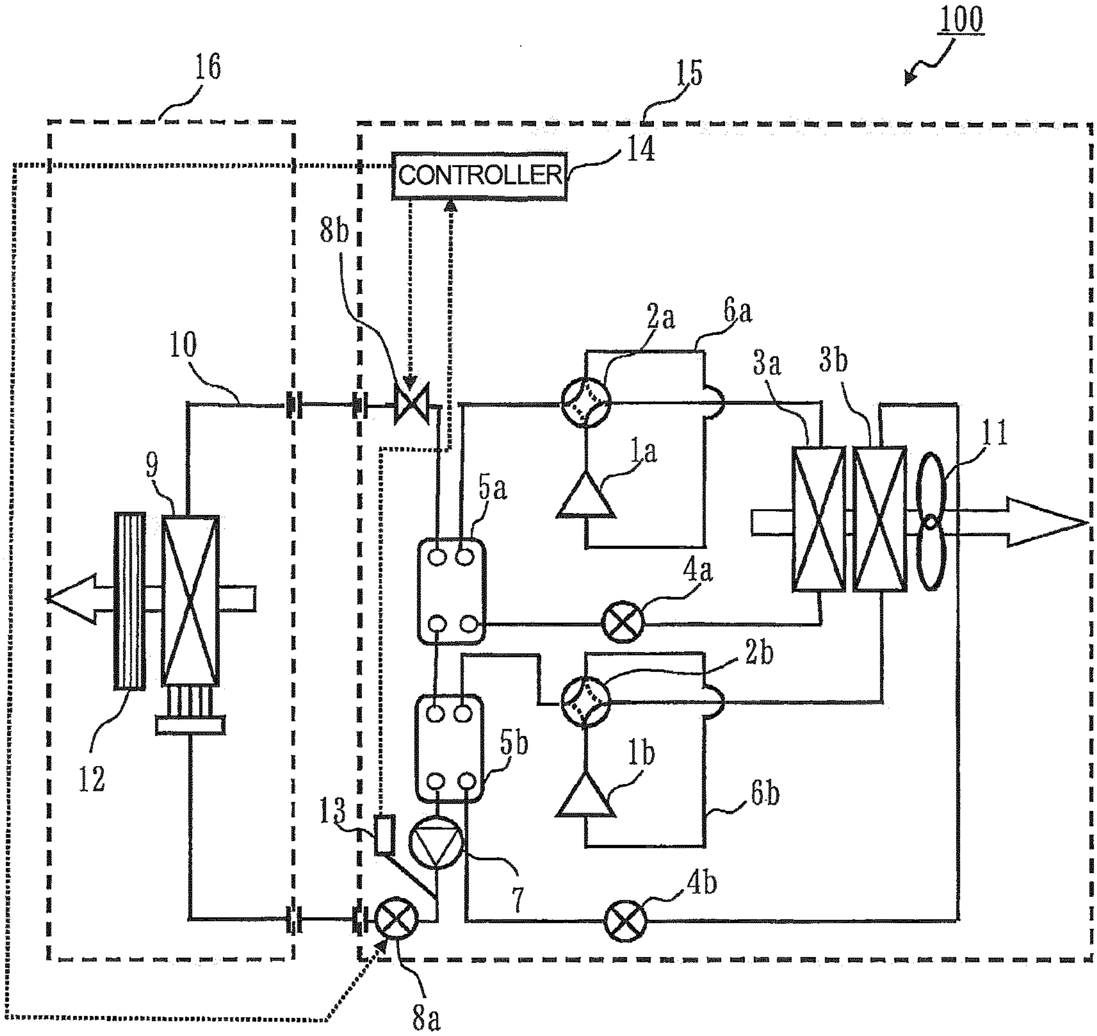
S1: PRESSURE DETECTING STEP
S2: INCREASE DETERMINING STEP
NO
PRESSURE HAS INCREASED?
YES
TRANSMIT DETECTION SIGNAL
S3: SIGNAL TRANSMITTING STEP
CLOSE VALVES 8a AND 8b
S4: VALVE CONTROL STEP
END

F I G. 5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16
15
CONTROLLER
14
8b
10
2a
6a
3a
3b
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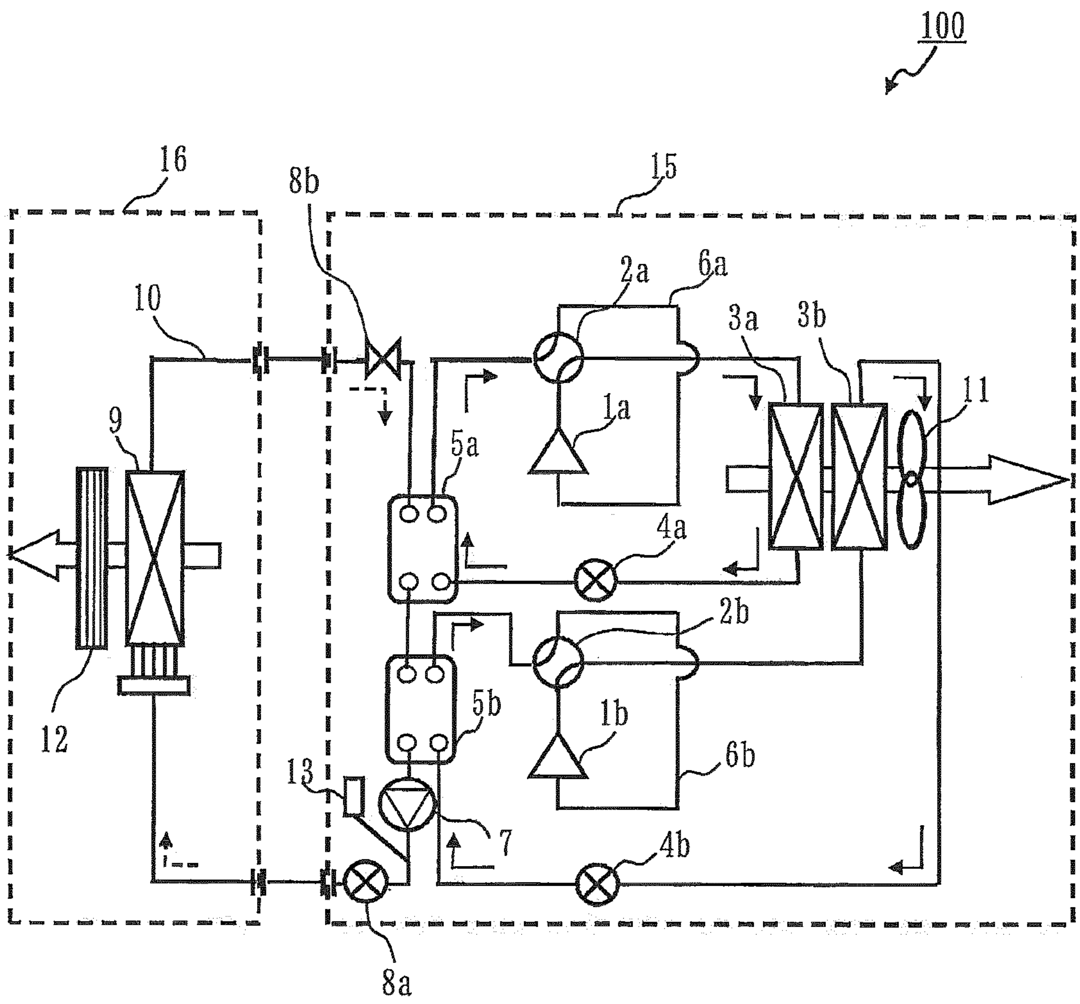
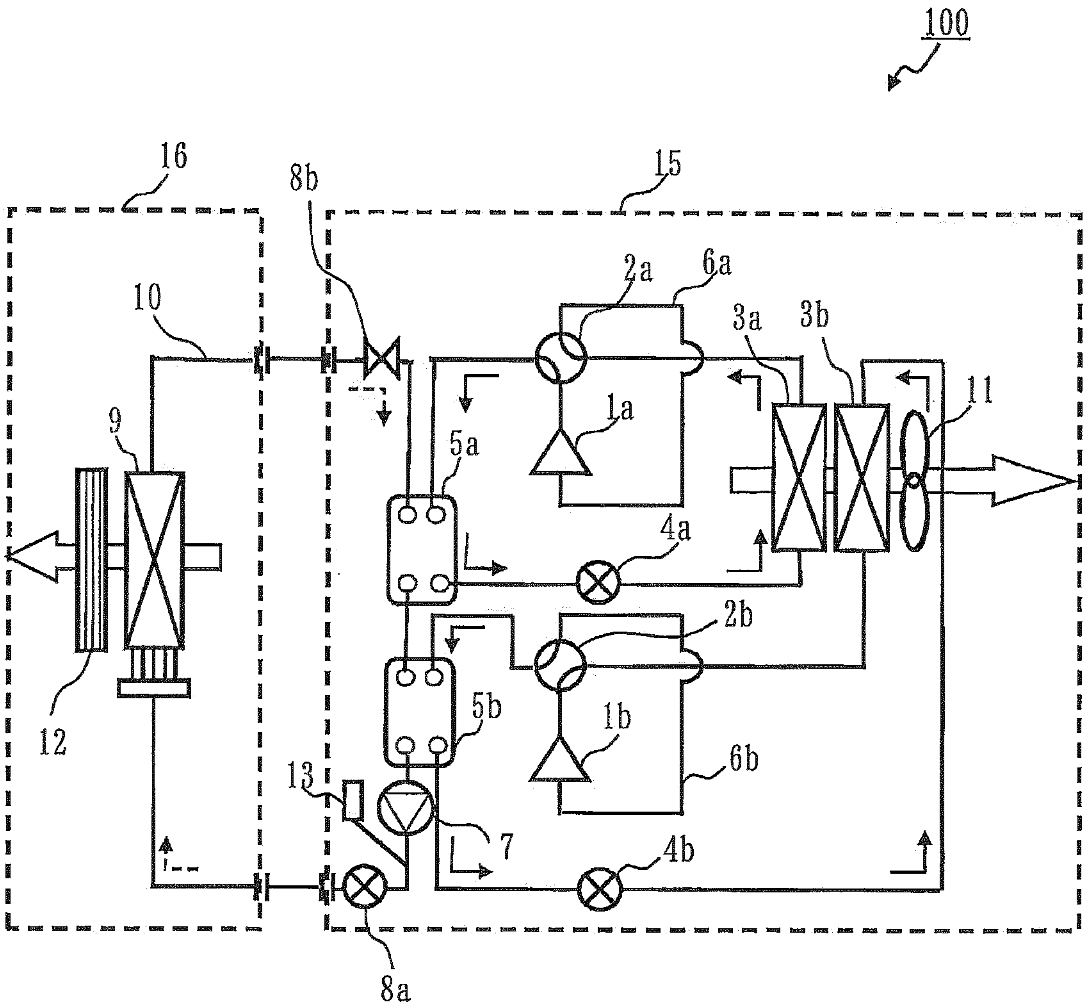
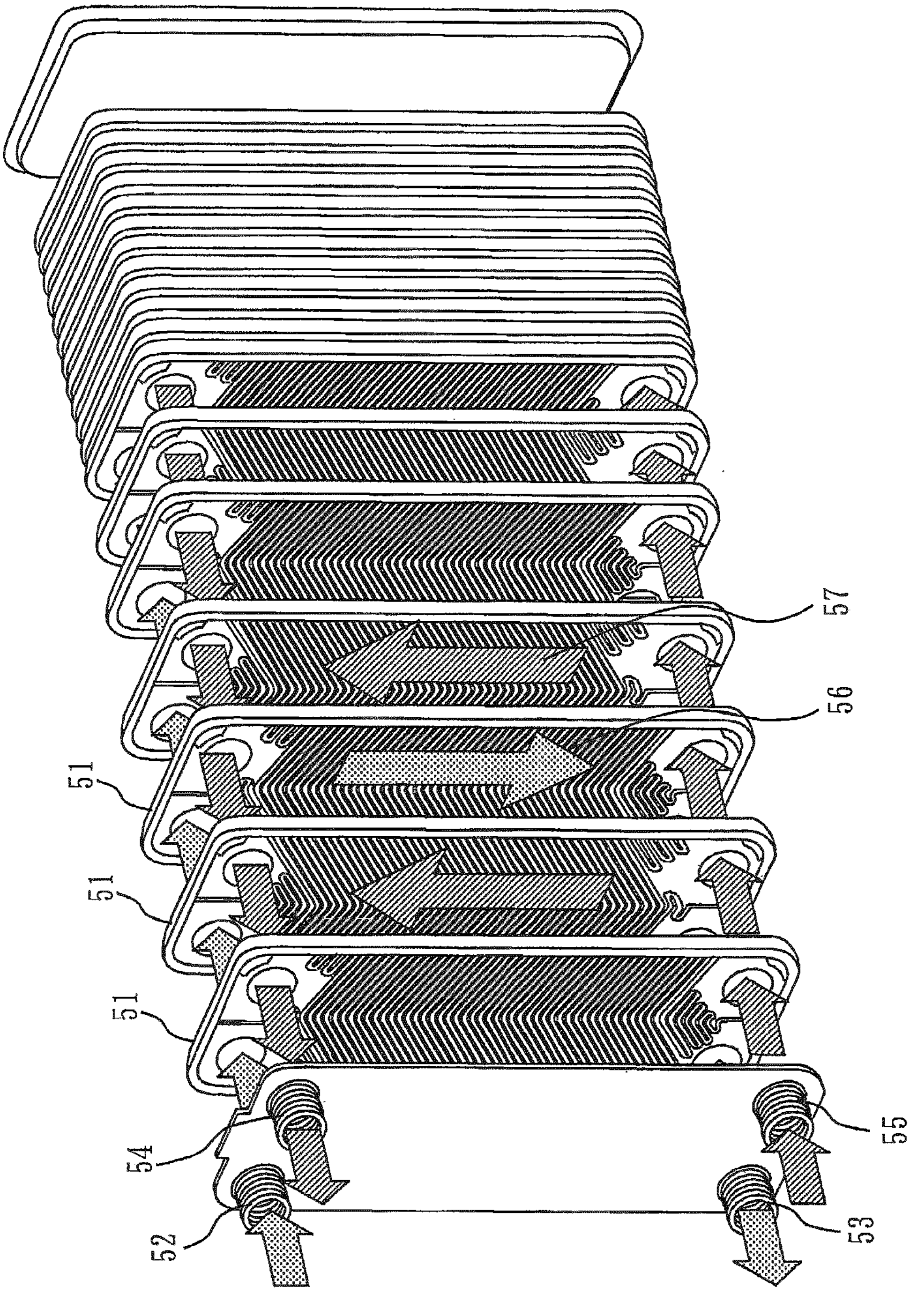
F I G. 6



F I G. 7





F I G. 8

F I G. 9

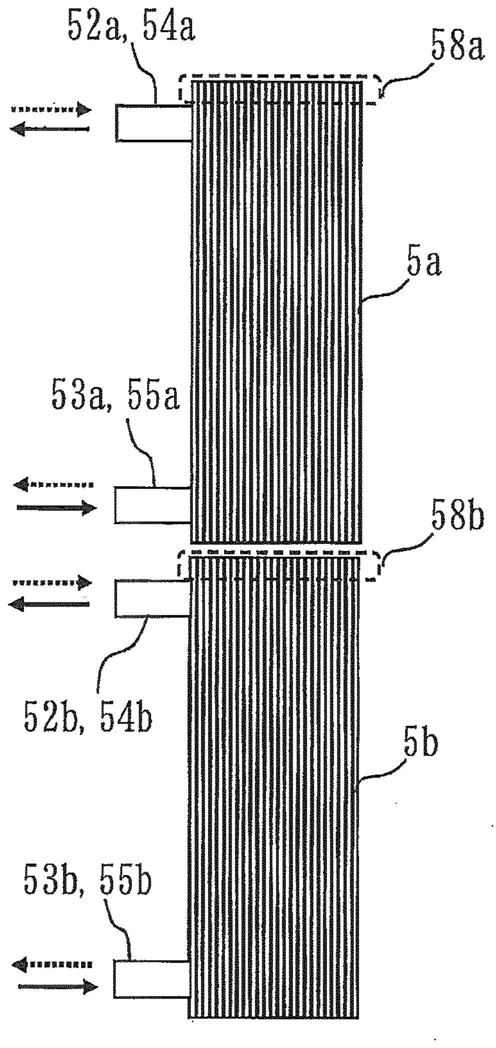
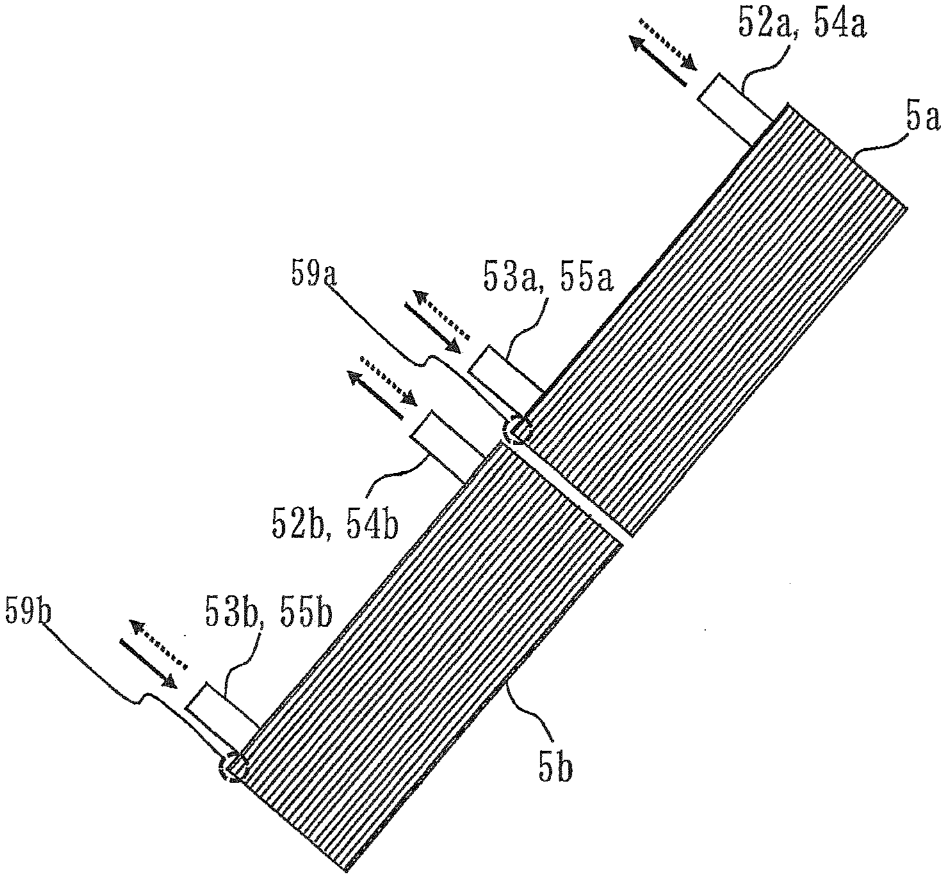
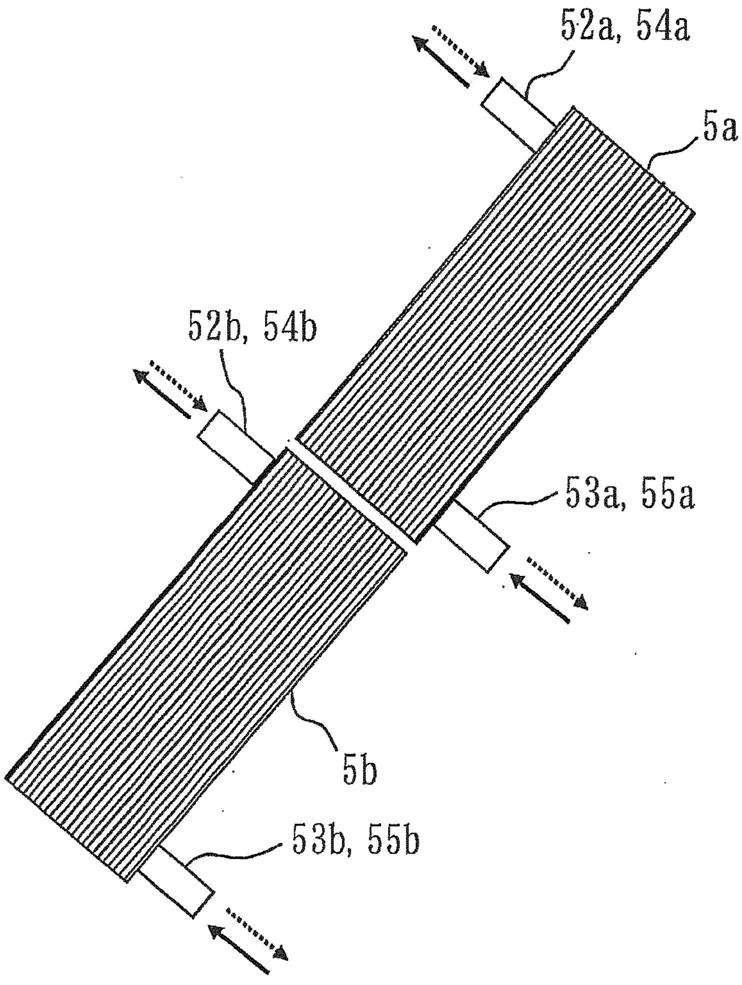


FIG. 10



F I G. 1 1



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/000595

A. CLASSIFICATION OF SUBJECT MATTER
F25B49/02(2006.01)i, *F24F11/02*(2006.01)i, *F25B1/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B49/02, F24F11/02, F25B1/00

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.
X Y	JP 2010-256009 A (Asahi Breweries, Ltd.), 11 November 2010 (11.11.2010), paragraphs [0001] to [0076]; fig. 1 to 5 (Family: none)	1-4,12,13 1-13
Y	JP 2000-230732 A (Zexel Corp.), 22 August 2000 (22.08.2000), paragraphs [0020] to [0046]; fig. 1 to 8 (Family: none)	1-13
Y	JP 2004-53054 A (Chofu Seisakusho Co., Ltd.), 19 February 2004 (19.02.2004), paragraphs [0005] to [0009] (Family: none)	1-13

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

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"&" document member of the same patent family

Date of the actual completion of the international search 27 April, 2012 (27.04.12)	Date of mailing of the international search report 15 May, 2012 (15.05.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/000595

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 2000-2494 A (Mitsubishi Electric Corp.), 07 January 2000 (07.01.2000), paragraphs [0051] to [0056]; fig. 10 (Family: none)	6-11
Y	JP 2000-337783 A (NHK Spring Co., Ltd.), 08 December 2000 (08.12.2000), paragraphs [0008] to [0019]; fig. 1 to 4 (Family: none)	6-11
Y	JP 8-224438 A (Comprimo B.V.), 03 September 1996 (03.09.1996), paragraphs [0039] to [0040] & US 5807410 A & EP 655414 A1 & NL 9302081 A & CN 1108146 A	6-11
Y	JP 2001-355994 A (Toyo Radiator Co., Ltd.), 26 December 2001 (26.12.2001), paragraph [0002]; fig. 6 (Family: none)	6-11
Y	JP 10-132400 A (Mitsubishi Heavy Industries, Ltd.), 22 May 1998 (22.05.1998), paragraphs [0011] to [0014]; fig. 1 to 2 & US 5996356 A & CN 1184240 A & KR 10-1998-0032989 A	9-11

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